Technical Report:

Victorian Options Investigation

BARMAH-MILLEWA FEASIBILITY STUDY

December 2022

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for the **Murray-Darling Basin Authority** under the contract titled '**Barmah-Millewa Feasibility Study**'.

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1 Executive Summary

1.1 Barmah-Millewa Feasibility Study

The Barmah-Millewa Feasibility Study (BMFS) has been initiated in response to an observed reduction in flow capacity in the Barmah-Millewa Reach and increasing risks of impacts on river dependent communities, the environment, and sites of cultural significance.

The study is exploring the merits of a range of options to maintain, and where possible, reinstate the regulated flow capacity through the Barmah-Millewa Reach. The MDBA is coordinating the study on behalf of the joint venture governments.

There are six distinct options being investigated as part of this study. One of these options is to use infrastructure in Victoria to convey water from upstream to downstream of the Barmah-Millewa Reach or to store water to meet peak downstream demands.

The purpose of this report is to document the range of options identified in Victoria and details of those which may be considered for further development as part of any subsequent stages of the project.

1.2 Long-list of Victorian options

There are several potential Victorian options, including the use of storages, bypass works, and creating ecologically-tolerable options for existing inter-valley transfers from the Goulburn Valley.

There have been several investigations previously completed exploring options for the use of Victorian infrastructure. These prior investigations have varied significantly in the depth of assessment, with detailed technical assessments completed for some, and high-level conceptual thinking only completed for others.

A long-list of potential options was collated based on previous studies and engagement with the MDBA and relevant Victorian agencies. A high-level assessment on these options was completed to determine the likely viability of each option.

Four options were identified as being potentially viable and warranting further investigation. A summary of the long-list and the assessment findings is provided below.

No.	Long-listed option	Brief Description	Shortlisted?
1	Victorian Mid-Murray Storages (VMMS) enhancement	Increased utilisation of the mid-Murray storages (excluding Ghow Swamp) to meet downstream demands in the River Murray.	**Yes**
2	Construct a new purpose-built mid-Murray storage	A purpose-built offstream storage built in the mid-Murray reach to store water to meet short-term peak demands in the lower Murray.	No
3	Floodplain storages	Utilisation of floodplain storages (such as Hattah Lakes) as an offstream storage to meet downstream demands.	No
4	Murray-Goulburn interconnector channel	A purpose-built channel from the Murray upstream of the Barmah-Millewa reach outfalling to the Goulburn River near Shepparton for water to then return by the lower Goulburn River to the River Murray (colloquially known as the Bunna Walsh Canal)	No
5	Murray Valley irrigation area outfalls	Upgrade of existing channels and outfalls to enable additional flows to be bypassed into the lower Broken Creek.	**Yes**

6	Barmah Forest natural waterways	Greater utilisation of the natural waterways in the forest to bypass the reach.	No
7	Barmah bypass pumped pipeline	A new pump station and pipeline with an offtake upstream of the Barmah Forest and outlet at the River Murray at Barmah constructed around the periphery of the Barmah Forest.	No
8	Barmah bypass gravity channel	A new gravity channel extending from Lake Mulwala and outfalling into the River Murray near Barmah.	Yes
9	Lake Buffalo to Lake Nillahcootie pipeline	A new pipeline to connect Lake Buffalo and Lake Nillahcootie to enable transfer of River Murray upper tributary flows around the Barmah-Millewa Reach by using the Broken River and Goulburn River.	No
10	RO14 bypass channel	Enlargement and extension of the Rochester No 14 channel, enabling inter-valley transfer water to be transferred from the Goulburn system to the River Murray.	Yes

1.3 Short-listed Victorian options

Enhanced use of the Victorian Mid-Murray Storages (VMMS)

The option investigation confirmed a significant opportunity to enhance the use of the VMMS for supporting potential delivery shortfall events. These storages provide a unique option for managing delivery shortfalls due to their proximity to the lower Murray where there can be periods of high demand over summer.

The proposed activities to enhance the use of the storages include works to reinstate discharge capacity, enhancing the operational arrangements, salinity management, and further consultation with Traditional Owners.

If enhancement works are undertaken, the storages could deliver around 10 GL over a 10-day period to assist in managing a potential delivery shortfall event. This discharge capacity takes into consideration environmental considerations of the lakes (including Ramsar requirements) and rivers.

The option would require capital investment of around $5.7 million and take two years to implement. The ongoing cost for the option over 50-years is around $2.5 million.

Murray Valley Irrigation Area (MVIA) outfalls

There are seven existing outfalls from the MVIA which can bypass the Barmah-Millewa Reach, four of which discharge flows into the highly regulated reaches of the lower Broken Creek. These outfalls are already used to deliver bypass flows over the summer period.

The option investigation revealed that there is no opportunity to increase the use of the outfalls for supplying bypass flows. The lower Broken Creek (which conveys the bypass water from the MVIA to the River Murray) already supports consistently high deliveries during summer as a result of delivering inter-valley transfer (IVT) commitments to the River Murray and existing bypass flows. The ecological investigations indicated that it would be intolerable to further increase the consistently high summer flows in these reaches.

However, there may be an opportunity for increasing bypass flows if there were an alternate route available to deliver some of the existing IVT commitments, such as the construction of the Rochester 14 channel extension option separately contemplated in this report.

If implemented, this option would increase the bypass capacity by around 100 ML/day, requiring a capital investment of $2.1 million and a 50-year operational cost of around $1.8 million. The option could only be implemented if an alternate route for delivering IVT is constructed, which could take around 5 years.

Barmah bypass gravity channel

The option contemplates the extension of the Murray Valley Irrigation Area channel network to discharge flows directly into the River Murray near the Barmah township.

This option investigation determined it would require the re-construction of around 70km of an existing channel and the construction of a new channel for around 20km to increase overall capacity. This would require almost every asset on the existing channel to be replaced or relocated, including approximately 155 irrigation outlets, 94 D&S services, 72 regulators, and 111 bridges or other structures.

Constructing such an option would have an impact on irrigators and local landholders. Constructing the option would involve works in sensitive ecological environments including the construction of a significant siphon under the lower Broken Creek and a discharge structure on the banks of the River Murray.

If implemented, this option would increase the bypass capacity by around 1,000 ML/day, requiring a capital investment of more than $600 million, and a 50-year operational cost of more than $350 million. The option would be expected to take around 5 – 8 years to implement.

Rochester 14 bypass channel

This option contemplates concentrating deliveries of Goulburn commitments to the River Murray during summer by extending the Rochester channel network to discharge directly into the River Murray.

The option investigation revealed that there is reliably more than 500 ML/day of available capacity in the Campaspe Siphon during summer, which is upstream of the RO 14 channel. Accordingly, it was assumed that the RO 14 channel would be re-constructed to allow an additional 500 ML/day to be delivered.

The works to deliver 500 ML/day from the RO 14 channel to the River Murray would require around 28km of channel to be significantly increased in size and the replacement of a 12km pumped pipeline with a new large channel. This would require almost every asset on the existing channel to be replaced or relocated, including approximately 124 irrigation outlets, 129 D&S services, 42 regulators, and 43 bridges or other structures.

Constructing such an option would have an impact on irrigators and local landholders, as well as works in environmentally sensitive areas to construct the discharge structure to the River Murray.

Further, the pumped pipeline at the downstream end of the RO 14 has been constructed in the past decade. Replacing this relatively new asset with a larger channel would require strong justification and effective communication to manage.

Constructing such a bypass channel to deliver existing Goulburn IVT commitments to the River Murray would provide an opportunity to improve the variability of flows delivered in natural watercourses which currently supply the IVT, including the lower Goulburn River, lower Broken Creek and Campaspe River.

If implemented, this option would increase the flows able to be delivered to the River Murray during the peak demand season by around 500 ML/day, requiring a capital investment of around $165 million, and a 50-year operational cost of around $50 million. The option would be expected to take around 5 years to implement.

2 Project background

2.1 Purpose

Alluvium Consulting Australia Pty Ltd (Alluvium) has been engaged by the Murray-Darling Basin Authority (MDBA) to undertake the Barmah-Millewa Feasibility Study (BMFS), investigating infrastructure options for mitigating the risks arising from declining flow capacity in the Barmah-Millewa Reach of the River Murray.

This Technical Report explores the options to enhance water delivery and storage using Victorian infrastructure and forms one of the key deliverables of the project.

2.2 Project background

Barmah-Millewa Reach

The Barmah-Millewa Reach is a naturally occurring narrow section of the River Murray where it flows through the Barmah-Millewa Forest, between the towns of Tocumwal (NSW) and Barmah (Victoria) (**Figure 1**).

The width of the Murray main channel in the Barmah-Millewa Reach naturally declines from 120m at Tocumwal to 40m below Picnic Point. As a consequence of this narrowing and a decrease in depth, this section of the river has the lowest flow capacity of any stretch of the River Murray downstream of Hume Dam[1].

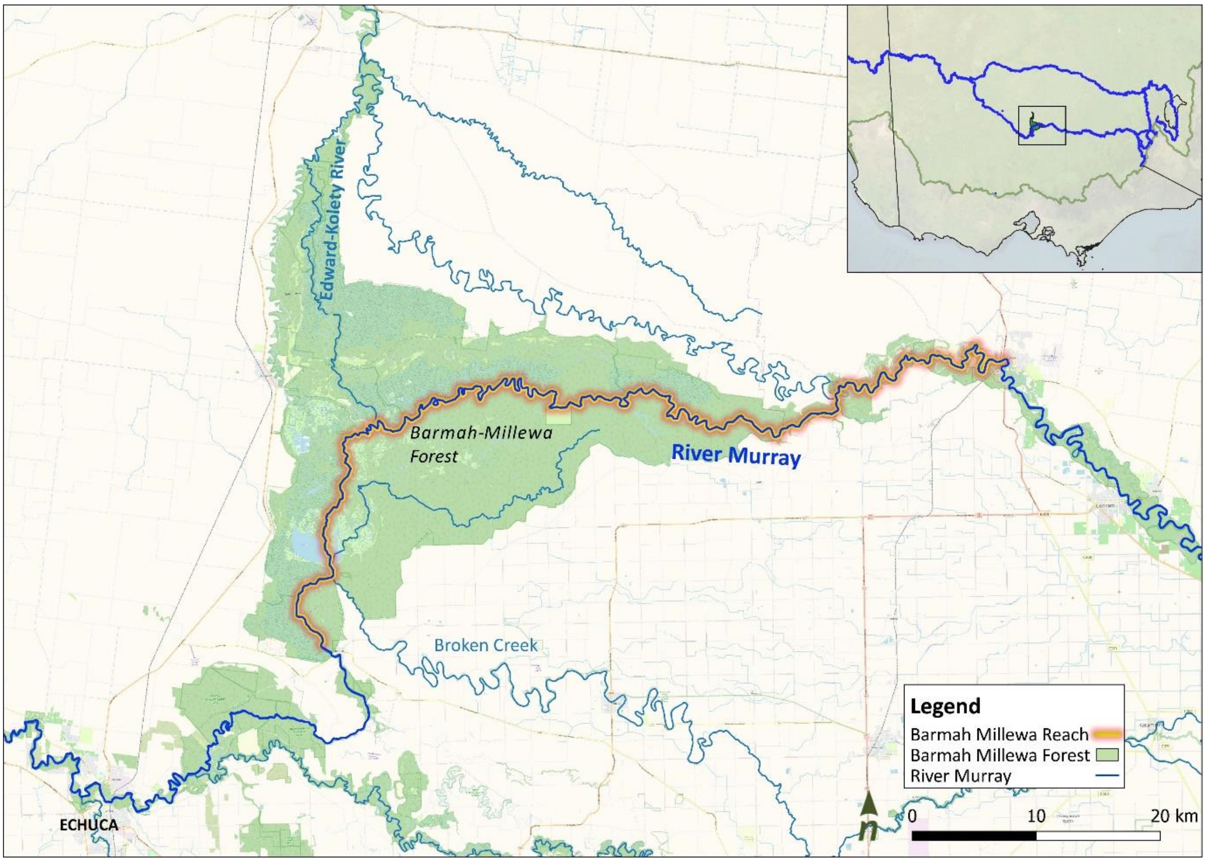

Figure 1. *Location of the Barmah-Millewa Reach of the River Murray*

[1] https://www.mdba.gov.au/water-management/water-markets-trade/barmah-choke

Declining flow capacity in the reach

To prevent unseasonal flooding in the Barmah-Millewa Forest, the river is operated over summer to a maximum height of 2.6m at Picnic Point. This allows flows to be managed within the riverbank.

Over the past 30 years, the flow capacity through the reach has reduced from approximately 11,300 ML/day to 9,200 ML/day (as measured downstream of Yarrawonga weir). This means around 20% less water can flow through the reach in summer[2].

Sand accumulation in the Barmah-Millewa Reach

Independent experts in fluvial geomorphology, stream management and river research have been working to determine the cause of the decline in flow capacity of the reach. The studies have found that a combination of factors such as historic land clearing, gold mining, desnagging, and river regulation means there is now a very large quantity of sand accumulating in the reach: over 4 metres deep in some places. It is estimated that there is more than 20 million cubic metres between Picnic Point and Yarrawonga Weir[3], this equates to around 13 Melbourne Cricket Grounds full of sand. The sand is accumulating in this already narrow section of the river and impacting the amount of water that can flow through. This build-up of sand on the riverbed is expected to:

- cause a further decline in the flow capacity of the River Murray in the Barmah-Millewa Reach with up to a 25-35% reduction in channel capacity in the next 30 years[4].
- the declining flow capacity is increasing the risk of shortfall events, with adverse impacts on water users[5].
- increase the risk of unseasonal flooding and negative impacts on cultural sites as well as environmental and recreational values.
- increase the risk of accelerated bank erosion with the river reach.
- increase the risk of an avulsion and the River Murray changing its course.

Barmah-Millewa Feasibility Study

In recognition of the increasing risks of River Murray shortfalls and damaging Barmah-Millewa Forest flooding from reduced capacity in the reach, the MDBA is undertaking the Barmah-Millewa Feasibility Study (BMFS). The project is examining the feasibility of a range of infrastructure options to mitigate delivery shortfall and unseasonal forest flooding.

There are six options being explored are:

- Option 1 - Potential river works within the Barmah-Millewa Reach: river works to stabilise banks, preventing further losses into the Barmah-Millewa Forest.
- Option 2 - Sediment management: selectively removing the sand from key locations.
- Option 3 - Tar-Ru (Lake Victoria) Drivers Project: proposed implementation of a risk-based framework for making decisions on the timings and source of water transfers to Tar-Ru (Lake Victoria).
- Option 4 - Optimisation of the existing MIL system: optimisation of the Murray Irrigation Limited channel system to deliver water to bypass the Barmah-Millewa Reach.
- Option 5 - Options for delivery through Victorian infrastructure: using existing and new infrastructure in Victoria to bypass the Barmah-Millewa Reach or mitigate the risk of delivery shortfall.
- Option 6 - Use of the Snowy Hydro to transfer Murray Release to the Murrumbidgee: transferring River Murray releases from the Snowy Releases to the Murrumbidgee for delivery to water users downstream of the Barmah-Millewa Reach.

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[2] HARC (2022) *Historical flows in the southern connected Murray Darling Basin, pg. 9*

[3] Grove James R (2021) *A fluvial geomorphic investigation into channel capacity changes at the Barmah choke using multiple lines of evidence.* pg 21

[4] Ian Rutherfurd, Thom Gower, James Grove, Christine Lauchlan Arrowsmith, Geoff Vietz, Alex Sims, Ben Dyer (2020), *Choking the River Murray: explaining the declining flow capacity through the Barmah-Millewa Forest*, 10th Australian Stream Management Conference 2021

[5] Independent Panel for the Murray-Darling Basin Authority (2020), *Managing Delivery Risks in the River Murray System*

There are a range of studies and reports being prepared as part of the Barmah-Millewa Feasibility Study (**Figure 2**).

Technical reports are being prepared to investigate each of the option in detail. This document is the technical report for Option 5 – Victorian options.

An 'Options Summary Report' has been prepared to provide an introduction to each of the six options and provides a summary of what they involve, how they could contribute to managing risk, what studies have been completed to date, and what future stages would involve[6].

A 'Suite of Options' Report' has been prepared, to assess how each of the six options may contribute to managing risks, and how a combination of complementary options (or 'suites of options') may be needed to achieve the best outcomes[7].

A 'Feasibility Study Report' has also been prepared to collate and present the findings of the study[8].

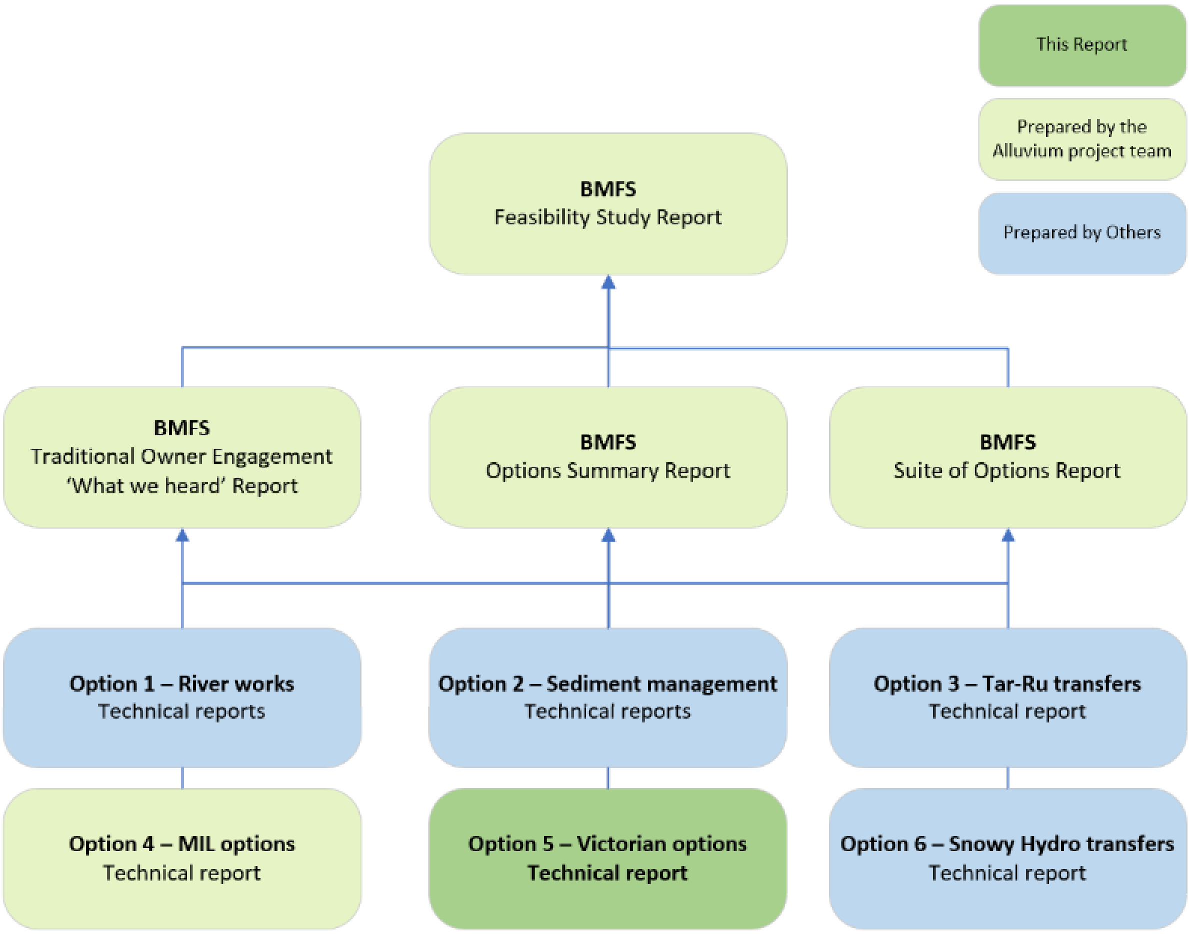

Figure 2. *The various reports being prepared to support the Barmah-Millewa Feasibility Study*

[6] Alluvium (2022), *Barmah-Millewa Feasibility Study: Options Summary Report*
[7] Alluvium (2022), *Barmah-Millewa Feasibility Study: Suite of Options Report*
[8] Alluvium (2022), *Barmah-Millewa Feasibility Study: Feasibility Study Report*

2.3 Victorian options

There are a range of potential infrastructure works located in Victoria that could either convey water from upstream to downstream of the Barmah-Millewa Reach or be used to store water to meet peak downstream demands. The objective of this option is to identify works located in Victoria that could support the project objectives.

For the purposes of this report, the potential Victorian options have been categorised as follows:

- **Storage options**, involving existing or new storages downstream of the Barmah-Millewa Reach to assist with managing delivery shortfall risks.
- **Bypass options**, involving the transfer of water from above to below the Barmah-Millewa Reach by using existing or new infrastructure to assist with managing capacity and delivery shortfall risks.
- **Goulburn system options**, which would supplement water required to be passed through the Barmah-Millewa Reach by providing alternative and ecologically sustainable options for supplying Goulburn water to the Murray.

Some of the Victorian interventions have been considered in previous studies at a feasibility or pre-feasibility level of investigation. Other interventions are new proposals with very limited prior investigation.

This report seeks to build on previous work undertaken to investigate these Victorian options. It identifies, scopes, and assesses the feasibility of the potential options.

The output from this report is a short-list of potentially viable options utilising Victorian infrastructure, including a preliminary assessment of what each option would entail, the potential equivalent bypass flow that the option could provide, and the key considerations and limitations.

The report is intended to inform the feasibility study and potential suites of options. It is intended to be used by decision makers to determine whether any of these options should be further explored as part of subsequent option development stages.

3 Approach & methodology

There are three key steps which have been used in the development of this Technical Report.

No.	Step description	Action
1	Develop the method for assessing the options (this section of the report)	• Set out the project objectives. • Set out how the long-list will be assessed. • Set out how the shortlist will be assessed.
2	Develop and assess a long-list of options (Section 4)	• Collate a long-list of potential options. • Review data and existing technical information. • High-level assessment of the long-list options. • Confirm a shortlist of options for further assessment.
3	Detail and assess the short-listed options (Sections 5 to 8)	• Detailed description of each shortlisted option. • Scoping of each shortlisted option, including preliminary engineering and ecological assessments. • Preliminary cost estimate for each option. • Key findings and considerations for each of the shortlisted options. • Recommendations for next steps if further investigations were to proceed.

3.1 Collate and assess a long-list of potential options

There are several potential Victorian options, including the use of storages, bypass works, and creating ecologically tolerable options for inter-valley transfers from the Goulburn.

There have been several investigations previously completed exploring options for using Victorian infrastructure. These prior investigations have varied significantly in the depth of assessment, with detailed technical assessments completed for some, and high-level conceptual thinking only completed for others.

The long-list of potential options is intended to be exhaustive and includes several options which have been previously deemed to be unfeasible for implementation. All options will be presented for completeness.

The long-list assessment focuses on identifying any key considerations and limitations which would warrant an option to be considered unviable and not warrant further investigation. The method for assessment involved:

- **Project objectives:** the project objectives set out the benefits which are sought by implementing this project. To be considered for further investigation, the options must contribute to at least one of the project objectives.
- **General assessment criteria:** these are general criteria by which the options are compared. The criteria are adapted from the framework used by the MDBA in the technical assessment for other options being considered as part of the BMFS and have been adapted to align with the project objectives. All options are assessed against these criteria, and this is used for the shortlisting process.

The assessment of long-list options is intended to be high-level only in nature. The assessment relies on previous investigations (where available), consultation with key stakeholders, and a practical assessment of the likely outcomes and impacts from option implementation.

This approach acknowledges that several of the options have been previously investigated and dismissed or that there are key considerations for options which would mean that they are clearly unviable and do not warrant further investigation. The approach adopted provides for a 'rapid screening' exercise.

The purpose of this assessment approach is to confirm a shortlist of potentially viable options where the effort for detailed investigations and assessments should be completed.

Project objectives

The objectives of the project are set out by the Terms of Reference for this feasibility study, approved by the Ministerial Council at the June 2020 meeting. The outcomes sought have been used to guide the feasibility study, to ensure that any option considered will directly address the problem statement. The project objectives are listed in **Table 1** below.

Note that these project objectives apply across the Barmah-Millewa Feasibility Study as a whole. Some of the objectives cannot be achieved by Victorian options (such as facilitating further environmental water deliveries into the Edward-Kolety – Wakool system). To be considered for further investigation, the options must contribute to at least one of the project objectives.

Table 1. Project objectives

Project objectives	Outcome sought
Maintain or reinstate delivery capacity	Maintain or enhance the ability to meet peak demand downstream of the Barmah-Millewa Reach (managing delivery shortfalls).
	Maintain or enhance the ability to deliver water downstream of the Barmah-Millewa Reach throughout the year (managing system shortfalls).
	Provide an improved level of confidence to downstream consumptive and environmental users in terms of reliability of water deliveries and environmental watering actions.
	Provide greater protection against undesirable flow regimes through the Barmah-Millewa region, including undesirable inundation of the forest.
	Provide improved ability to deliver environmental watering actions along the River Murray.
Reduce environmental impacts associated with sedimentation	Reduce the localised environmental impacts associated with the ongoing sedimentation of the river reach.
Reduce localised bank failure	Reduce the risks of bank failure in the Barmah-Millewa Forest, protecting the significant environmental and cultural values of the forest floodplain.
Facilitate Edward-Kolety – Wakool system environmental water actions	Further facilitate the delivery of environmental water into sites within the Edward-Kolety – Wakool system.
Improved resilience for future conditions	Benefits generated by the project should be resilient to a range of climatic and water availability conditions.
	Benefits generated by the project should be resilient to a range of potential future demand and management scenarios, including with and without constraints relaxation.

General assessment criteria

The general criteria used in the assessment of options are outlined in **Table 2**.

These general assessment criteria have been developed to support the high-level assessment of the long-list options and to support the rapid identification of options suitable for further investigation. Accordingly, the categories and definitions include a number of qualitative or semi-quantitative assessments. It is expected that more quantitative metrics will be undertaken for the detailed assessment of the shortlist options.

Table 2. General assessment criteria and definitions

Criteria	Category	Definition
Effectiveness in reducing shortfall risks	Operational shortfall	Effectiveness of the option in mitigating short duration peak demand delivery shortfalls downstream of the Barmah-Millewa Reach
	System shortfall	Effectiveness of the option in providing a continuous supply of water downstream of the Barmah-Millewa Reach during the summer months
Technically feasible to implement	Technically feasible	Ease of implementation and the degree of complexity of the required design, approvals, land acquisition and construction activities and industry experience in delivering the type of works.
	Reliability and flexibility	The degree of certainty that the supply capacity will be available when required and the ability of the works to respond to changes in the demand levels. Resilience to future climate change impacts, demand, and management scenarios.
Does not negatively impact on values	Environmental	Consideration of the environmental impacts of the option both at a site footprint level and broader downstream impacts. Changes to the hydrological regime must be ecologically tolerable. Where possible, ecological benefits should be sought. The environmental impacts from implementing an option (as a result of construction and operation changes in the landscape) should be within acceptable tolerances (i.e., the project should be able to obtain necessary environmental and planning approvals on the basis that environmental impacts and mitigations are appropriate).
	Social	Consideration of the social impacts of the project and the likelihood of landholder, broader stakeholder, and community support and acceptance. The social impacts from implementing an option (as a result of construction and operation in the landscape) should be within acceptable tolerances (i.e., sufficient community support should be expected to allow the implementation of the option).
	Cultural	Potential impacts and cultural values and alignment with government policy on cultural matters. The cultural heritage impacts from implementing an option (as a result of construction and operation in the landscape) should be within acceptable tolerances (i.e., the project should be able to obtain cultural heritage approvals on the basis that the cultural heritage impacts and mitigations are appropriate).
	Economic	Potential flow on impacts for regional economies should be within acceptable tolerances (i.e. sufficient regional community support should be expected as a result of the economic impacts and outcomes from implementation of the option).
Provides value for money	Regulatory requirements	Options which are relatively easier to implement (including lead times) are preferred. This may consider matters such as statutory approvals, land acquisition, governance, and approval processes.
	Capital investment	Value-for-money in implementing and operating options should be acceptable to the funders of capital and operational costs.
	O&M costs	

The purpose of assessing the long-list is to determine options which are potentially viable and warrant further investigation. As such, the general assessment scoring framework has adopted a simple increment system as shown in **Table 3** below, with three rating categories ranging from negative impacts to positive impact.

Table 3. General assessment scoring framework

Rating	Colour coding
Positive	
Some issues	
Negative	
To Be Determined	

Negative impacts are defined as matters which are likely to be unacceptable and would result in the option being unviable. Any options which have a negative scoring against any of the general assessment criteria are considered unfeasible and do not proceed to the shortlist.

Some issues are defined as matters which likely require further investigation and detailing in any subsequent stages to determine if they would result in the option being unfeasible to implement.

To be determined are considerations where it is not appropriate for an assessment to be made without further information being provided or the viewpoints from appropriate stakeholders are known.

Each option is assessed against each of the general assessment criteria and informed by the best available information. This information has been sourced from previously documented investigations, consultation with agency stakeholders who have prior involvement in the development of options, and a practical assessment of the likely outcomes. Justifications are provided against each criterion.

Shortlisting of options

Each option is considered against the objectives and general assessment criteria.

If an option has a negative for any of the general assessment criteria it is considered unviable and does not proceed to the shortlist.

An option is recommended to proceed to a shortlist for detailed assessment if it contributes to the project objectives and does not have any negative considerations which would lead the option to be considered unviable.

3.2 Detailed assessment of the short-listed options

The shortlisted options are assessed in more detail, to better quantify the scope of investigations and works required, the bypass flow equivalent, and the extent to which the option may be feasible to implement.

The BMFS requires a detailed conceptual understanding of the various options which are available, such that comparisons can be made between the options and combinations (or 'suites') of different options.

To inform the comparable assessment of these options, a more detailed assessment of the short-listed options is completed, including:

- preliminary scoping and engineering assessments.
- preliminary ecological assessments.
- preparation of cost estimates suitable for the feasibility-stage assessment.

The preliminary engineering assessments focus on understanding the current utilisation of infrastructure, the quantum and type of upgrade works that may be necessary to support the BMFS objectives, and any significant obstructions to increasing the flow capacity. These preliminary investigations are feasibility level only and allow for a high-level comparison to be made between options. If any option were to proceed to further investigation, additional engineering works would likely involve an options investigation report (i.e., investigate multiple potential alignments or work arrangements for the select option, and select a preferred), field investigations, and multiple stages of engineering design for the preferred option.

The preliminary ecological investigations focus on understanding the current flow regimes within natural waterways, the environmental flow recommendations, the key ecological matters to be protected, and the primary threats that are present. These preliminary investigations consider whether changing the flow regime would have an adverse outcome for the waterways and whether these are tolerable. If any option which involves a change to the watering regime on natural watercourses is to proceed to further investigation, additional studies would be required.

Preliminary cost estimates have been prepared for each of the options. At this stage, these cost estimates are high-level and largely desktop, based on rates for previous works (where available) and industry-standard costings. These estimates have been prepared to understand the approximate capital and O&M costs and to allow a high-level comparison between options. If any option were to proceed to further investigation, then the next stages of scope development should include bottom-up cost estimates to be prepared, as appropriate to support any business case development.

This information has been subsequently used to inform an assessment of the Victorian options (as considered in this report) against other options under consideration as part of the broader BMFS. This assessment is available in the Barmah-Millewa Feasibility Study: Suites of Options Report[9].

[9] Alluvium (2022), *Barmah-Millewa Feasibility Study: Technical report: Suites of Options Report*

4 Long-list of options considered

A long-list of all identified potential options was collated based on engagement with agency stakeholders and researching previous investigations. This long-list was exhaustive and included several options which have been previously deemed to be unfeasible for implementation. All options have been included for completeness.

Storage options:

1. **Victorian mid-Murray storage enhancements**: increased utilisation of the mid-Murray storages (excluding Ghow Swamp) to meet downstream demands in the River Murray.
2. **Construct a new purpose-built mid-Murray storage**: a purpose-built offstream storage built in the mid-Murray reach to store water to meet short-term peak demands in the lower Murray.
3. **Floodplain storages**: utilisation of floodplain storages (such as Hattah Lakes) as an offstream storage to meet downstream demands.

Bypass options:

4. **Murray Goulburn interconnector channel**: a purpose-built channel from the Murray upstream of the Barmah-Millewa reach outfalling to the Goulburn River near Shepparton for water to then return by the lower Goulburn River to the River Murray. This option is colloquially known as the Bunna Walsh Canal (a reference to a former politician who supported a canal joining the Murray and Goulburn systems).
5. **Murray Valley irrigation area outfalls**: upgrade of existing channels and outfalls to enable additional flows to be bypassed into the lower Broken Creek.
6. **Barmah Forest natural waterways:** (i.e., Kynmer Creek, or similar) - this option would explore options for the greater utilisation of the natural waterways in the forest to bypass the reach.
7. **Barmah bypass pumped pipeline**: a new pump station and pipeline with an offtake upstream of the Barmah Forest and outlet at the River Murray at Barmah constructed around the periphery of the Barmah Forest.
8. **Barmah bypass gravity channel**: a new gravity channel extending from Lake Mulwala and outfalling into the River Murray near Barmah.
9. **Lake Buffalo to Lake Nillahcootie pipeline:** a new pipeline to connect Lake Buffalo and Lake Nillahcootie to enable transfer of River Murray upper tributary flows around the Barmah-Millewa Reach by using the Broken River and Goulburn River.

Goulburn system options:

10. **RO14 bypass channel:** enlargement and extension of the Rochester No 14 channel, enabling inter-valley transfer water to be transferred from the Goulburn system to the River Murray.

4.1 Option 1. Victorian mid-Murray storages enhancements

Background

The Victorian Mid-Murray Storages (VMMS) consist of four storages: Lake Boga, Lake Charm, Kangaroo Lake and Ghow Swamp. The VMMS are located in north central Victoria, approximately 100 km downstream of the Barmah-Millewa reach.

The storages are naturally ephemeral lakes and wetlands. With the development of the Torrumbarry Irrigation Area, the four waterways have been equipped with regulating structures and are incorporated into the irrigation system. In the late 2000s, the four storages were defined as the VMMS as part of the Lake Mokoan decommissioning project. The purpose of the VMMS is to support allocations to Victorian Murray entitlements. Figure 3 shows the storages and key assets for enhancement.

The enhancement project would investigate works and operational changes needed to use the storages more actively for managing demands and shortfall risks in the lower Murray. This involves accessing the active storage volumes in Lake Boga, Kangaroo Lake, and Lake Charm. Changes to the use of Ghow Swamp is not considered for the purpose of this feasibility study, recognising that there are ongoing discussions with Traditional Owners about how to best manage the cultural site.

The combined storage capacity of Lake Boga, Kangaroo Lake and Lake Charm is approximately 30,000 ML. The lakes have a combined design discharge capacity in the order of 1,500 ML/day. However, the discharge capacity is understood to currently be substantially lower than the design capacity.

The use of the VMMS to store water and supply the River Murray is constrained by the current limitations on discharge capacities, timing competition to fill the lakes, competing internal irrigation demands, and the need to manage social and recreational uses. Kangaroo Lake is also part of the Ramsar-listed Kerang Lakes and its character description specifies the depth range over which it can operate.

Project concept

The project concept involves enhancing the current use of the storages to supply peak demand in the River Murray. This concept may involve:

- Re-instating discharge capacity.
- Changing the current operating practices of the storages.
- Constructing infrastructure to increase the maximum discharge flow rates possible.

Scope of works

The proposed scope for this option:

- Works to reinstate the discharge capacity at Lake Boga.
- Works to enhance the capacity of the discharge channel at Lake Boga
- Development of operating models and coordinated operating arrangements that integrates environmental, flood protection, recreational, salinity, cultural heritage and irrigation considerations and enables more effective decision-making regarding the capture of flows into the VMMS storages, the conveyance of flows between the storages, and the release of flows.

The infrastructure is already in place to support delivery volumes which would assist with this project's objectives. Accordingly, depending on the discharge flow rates desired, the expected costs are relatively very low to low ($1M to $10M).

A $1 - $10M capital investment achieving up to 300ML/day supply equivalent for 100 day's provides an approximate value for money of $3 - 35k per ML/day/100-day supply period.

Shortlisting Consideration

There is potential to enhance the use of the VMMS to support the project objectives. Based on the information available, there are no considerations which are flagging substantial issues that could not clearly be overcome. This option **is recommended** to proceed to the shortlist and be investigated in further detail.

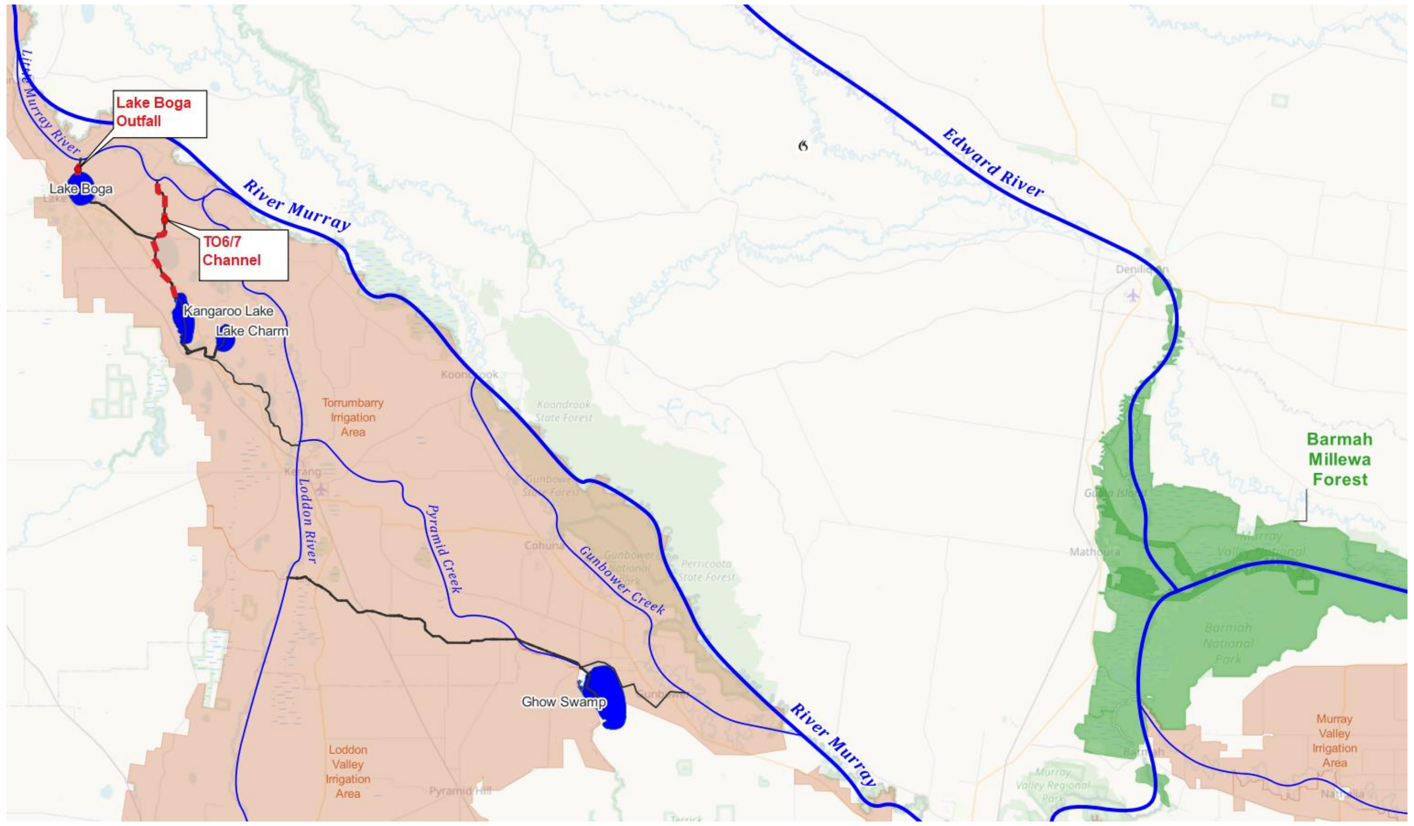

Figure 3. *Victorian mid-Murray storages enhancements – 4 storages shown with TO6/7 channel and Lake Boga outfall*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Relatively large discharge capacity (up to 1,500ML/day) provides ability to support peak demands
	System shortfall		• Subject to capacity use and discharge rates, the operation could contribute the equivalent of 30 GL i.e. 300ML/d over 100 days (less any losses) as part of a suite of options to address system shortfalls over the summer/autumn irrigation season.
Technical	Technically feasible		• Requires changes to the current operating arrangements • Engineering works required are well understood
	Reliability and flexibility		• Reliability depends on ability to harvest flows • Irrigation demands could impact on ability to transfer harvested water
Impact on values	Environmental		• Depending on the scope of works to be undertaken, there could be activities in environmentally sensitive areas. The option would use natural waterways to supply water to and discharge from these storages. The ecologically tolerable flows will need to be identified for these waterways
	Social		• Consideration will need to be provided to social and recreational uses • Potential upgrades to discharge channels may require works to be undertaken on private property to accommodate an increase in discharge capacity
	Cultural	TBD	• No changes will be explored at Ghow Swamp • Engagement with Traditional Owners will be needed to ensure that any enhanced uses of the storages are appropriately scoped and implemented
	Economic		• No changes proposed to priority of irrigation demand in Torrumbarry conveyance system
Costs	Regulatory requirements		• Depending on the scope of works to be undertaken, there could be environmental, planning and cultural heritage approvals required.
	Capital investment		• Expected to be the lowest capital investment of all long-listed Victorian options • Relatively high value-for-money for supply equivalence
	O&M costs		• It is expected that ongoing management costs would be in tolerable limits. • Relatively low operating costs as system is largely gravity driven.

4.2 Option 2. Off stream mid-Murray storage

Background

This option is for the construction and operation of a new off stream storage on the River Murray floodplain, downstream of the Barmah-Millewa reach. The storage would be independent of existing irrigation district supply infrastructure and therefore not encumbered by the need to prioritise irrigation district demand. The storage would be located in Victoria along the mid-Murray reaches with indicative (un-investigated) locations provided for reference only (refer **Figure 4**).

This option is conceptual only in nature. It is understood that no detailed investigations have been undertaken to explore such an option.

Project concept

The option would involve the construction of new infrastructure required to provide offtake, storage, and return supply to the River Murray. The off-stream storage would then be used to harvest and store River Murray flows for release during periods of peak demand shortfall.

The option would be expected to rapidly respond to peak demand shortfalls, however, would provide limited improvements to mitigate system shortfalls as it would be limited by the storage capacity.

The volume and discharge flow capacity of the storage would be sized as appropriate to assist with maintaining and restoring the flow capacity through the Barmah-Millewa reach.

Scope of works

The scale of new infrastructure required would be significant.

The conceptual works scope for this option is:

- Construction of a 10 GL storage capacity earthen reservoir, 4m below ground and with 4 m embankments. The internal reservoir area of such a storage would be 270 ha.
- A 500 ML/day pumped inlet structure from the River Murray.
- A 2,000 ML/day outlet structure discharge to the River Murray.

It is envisaged that the storage would be filled in winter/spring. If flows were available, the storage could be re-filled during the summer to meet additional peak demand events.

A high-level cost estimate has been approximated by scaling from like projects and unit rates. It is expected that the capital cost required to support such an option would be in excess of $100M.

A $100M+ capital investment achieving up to 100 ML/day supply equivalent for 100 day's provides an approximate value for money of $1,000k per ML/day/100-day supply period.

Shortlisting consideration

This option **is not recommended** to proceed to the shortlist as:

- The capital investment required ($100M+) would be significant.
- The value for money would be significantly lesser than other options which may be able to provide an equivalent effectiveness in reducing shortfall risks.
- The storage reservoir area is expected to be more than 250 ha and would likely require substantial land acquisition.
- The use of the land may not be supported by the local community.
- Regulatory approvals may not be practical to secure given the sensitivity of the landscape.

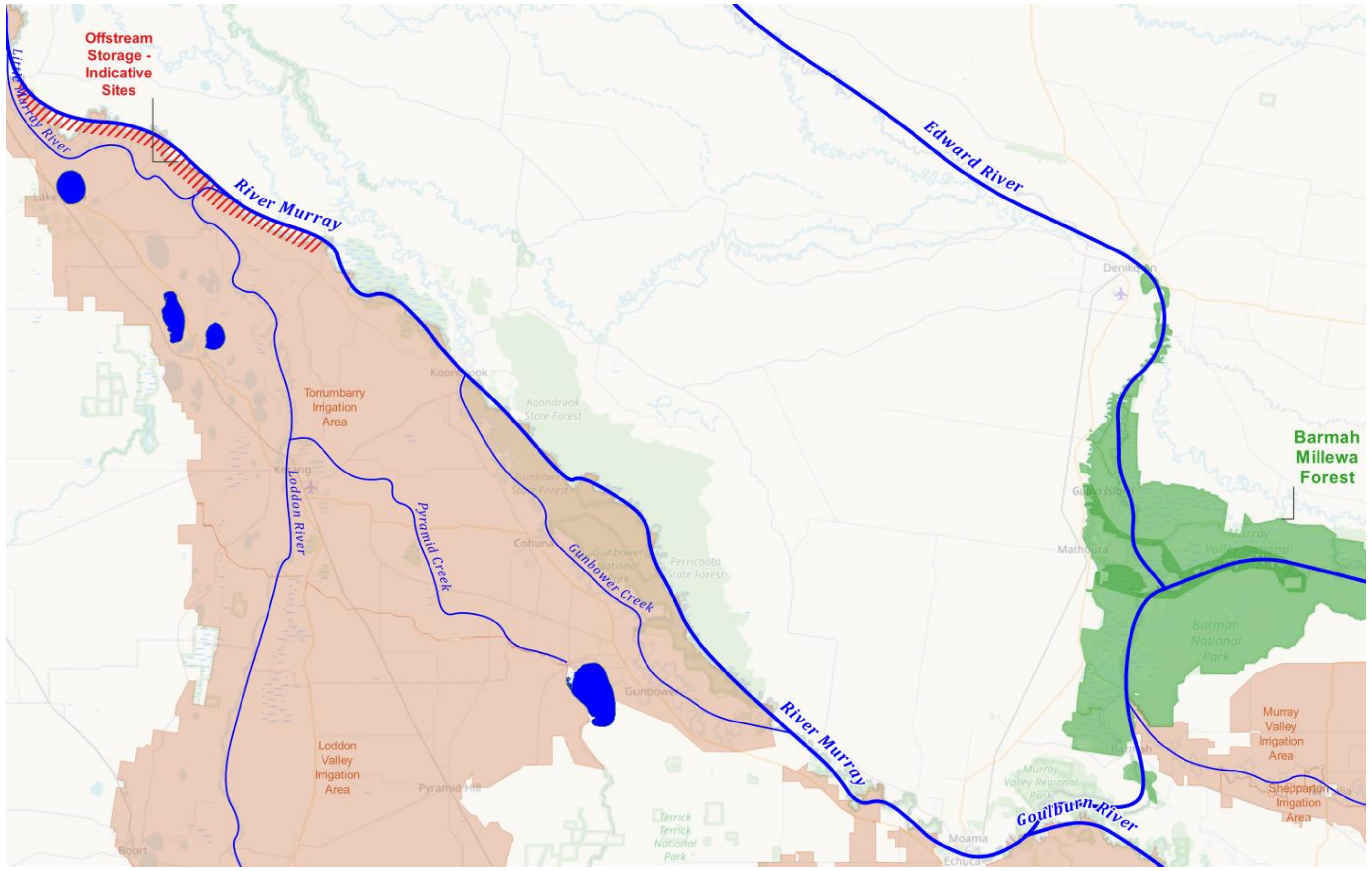

Figure 4. *Victorian off-stream mid-Murray storage, indicatively shown*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• The off-stream storage would be located in the mid-Murray reach with a relatively large discharge capacity to support peak demand
	System shortfall		• Storage capacity of 10,000ML would not contribute substantially to mitigating system shortfalls. However, the operation could contribute up to 100ML/d over 100 days (less any losses) as part of a suite of options to address system shortfalls over the summer/autumn irrigation season
Technical	Technically feasible		• There is a heightened technical risk associated with siting of the storage on the floodplain
	Reliability and flexibility		• Reliability depends on ability to harvest flows • Once the storage capacity is exhausted, it will be difficult to refill in peak demand season
Impact on values	Environmental		• Works would be located within areas already cleared for agriculture. None the less there would be issues of environmental sensitivity • Only partly mitigates the need to run high flows through the Barmah-Millewa reach.
	Social		• Will likely require substantial acquisition of private land • Use of the land to create a new water storage may not be supported by the local community or neighbouring property owners
	Cultural	TBD	• Works footprint would likely be located on floodplain country. The potential to harm cultural heritage would need to be explored.
	Economic		• Unlikely to have significant impacts on the local economy.
Costs	Regulatory requirements		• Construction work involve significant activity on floodplain adjacent to the river. While areas may be located with existing disturbance, there is a high risk to the practicality of securing the required statutory approvals.
	Capital investment		• Very high amounts of capital investment ($100M+) would be required • Very poor value-for-money for supply equivalence
	O&M costs		• Ongoing operational costs are expected to be relatively acceptable

4.3 Option 3. Floodplain storages

Background
Several floodplain managed inundation projects have been or are in the process of being implemented across the Victorian Murray.

These projects involve the construction of regulating structures, containment banks, and in some cases pump stations, to divert and hold environmental water on the floodplain.

Environmental watering actions are delivered to support the ecological objectives for each site. The frequency and timing of water deliveries are informed by the ecological needs of the wetlands and floodplain. Water is typically aimed to be delivered during winter/spring. Some sites allow some return flows to the River Murray, usually for reuse as environmental water at downstream locations.

Project concept
This option considers the use of the infrastructure at these sites to deliver water to the floodplains. Flows would then be returned to the River Murray when required to mitigate potential shortfall risks.

As an example, this option considers the use of Hattah Lakes, a freshwater wetland and lake system located on the floodplain of the mid-Murray (refer **Figure 5**). The Hattah Lakes system is located 69 km downstream from the Euston weir. It comprises approximately 20 ephemeral, semipermanent, and permanent lakes and a large area of floodplain which naturally receive water from the River Murray via floodplain distributary channels during high flow events.

Twelve of the lakes are listed as internationally important wetland systems under the Ramsar Convention on Wetlands of International significance. In 2013, the Living Murray program (TLM) commissioned a large pumpstation (1,000 ML per day) and environmental works to enable the managed inundation of a portion of the Hattah Lakes and floodplain. The Victorian Murray Floodplain Restoration Project (VMFRP) proposes further works to inundate two additional sections of the floodplain. The lakes are directly supplied from the existing pump station and have connections to the River Murray. The lakes are ephemeral and their use as storages would risk changing their character and both wetland and riparian vegetation.

Scope of works
This concept proposes to leverage existing infrastructure which has been constructed for the purposes of delivering environmental water. As such, there are no capital costs associated with this option.

Annual costs for operation and maintenance would include pumping costs and operation of infrastructure.

Shortlisting consideration
This option **is not recommended** to proceed to the shortlist as:

- The infrastructure has been or will be constructed at these specific locations as they support watering of highly ecologically and culturally significant landscapes. The preferred watering regimes for these wetlands and floodplains are typically in late winter to spring, with events typically aimed to be concluded prior to the hotter summer months. To be suitable for the purposes of this project, water would have to be stored in the floodplain environments into the hottest periods to be able to help mitigate potential operational shortfalls during peak demand. Having water held in these highly significant environments into the summer period would typically constitute unseasonal watering with associated risks such as blackwater events and water quality of return flows.
- Whilst some sites do have return paths for flows to re-enter the River Murray, these return flows are reasonably minor compared to the inflow volumes. There are significant losses associated with watering floodplains.
- The floodplain environmental watering scenarios which would provide sufficient water levels to allow return flows are only infrequently ecologically tolerable – and as such, this would not be an option able to be reliably used.

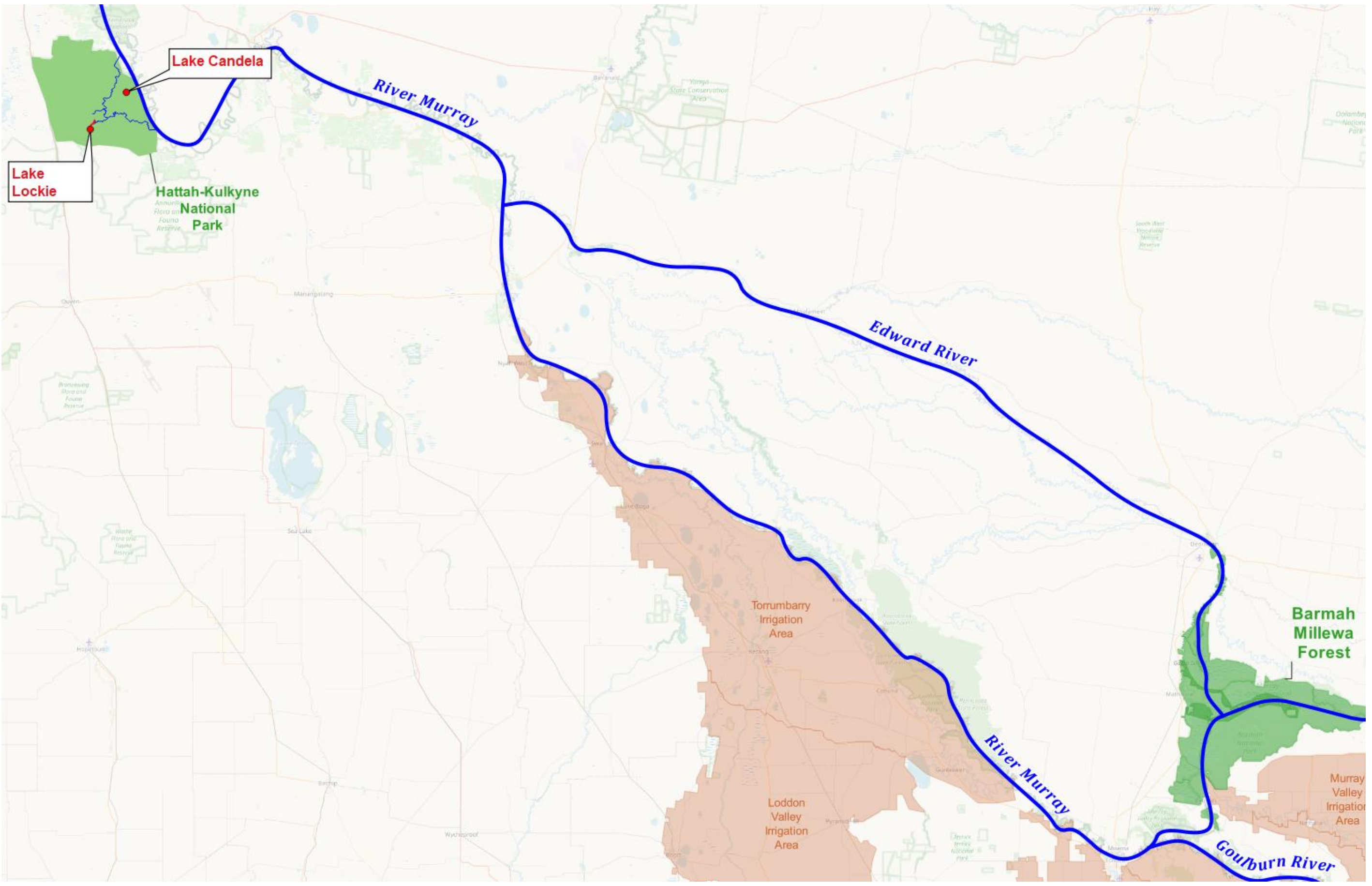

Figure 5. *Victorian floodplain storage in Hattah Lakes system*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Floodplain storage is located close to the source of peak demands • Limited capacity to release water to the River Murray due to reliance on natural waterways
	System shortfall		• Storage capacity would not contribute substantially to mitigating system shortfalls
Technical	Technically feasible		• Utilises existing infrastructure (only at Hattah Lakes)
	Reliability and flexibility		• Watering scenarios which provide sufficient water levels to provide return flows are required infrequently (less regular than 1 year in 5)
Impact on values	Environmental		• Use of the floodplains for storing water during hotter months will be incompatible with environmental objectives for the Ramsar site • Prolonged storage of water on the floodplains would likely exceed the durations targeted to suit the environmental objectives
	Social		• Use of the lakes for storing water for prolonged periods may impact on recreational values
	Cultural	TBD	• The floodplain sites are of high cultural value and their use for storage may impact on these values
	Economic		• High conveyance and storage losses
Costs	Regulatory requirements		• Changes to the intended use of the infrastructure and hydrological regime at the floodplain sites would trigger statutory approvals in National Park
	Capital investment		• No capital investment proposed
	O&M costs		• Ongoing costs associated with pumping operations

4.4 Option 4. Murray Goulburn interconnector channel

Background

In 2007, the Victorian government commissioned a feasibility study into the Murray Goulburn Interconnector (also known colloquially as the ‘Bunna Walsh Canal’, a reference to a former politician who supported the proposal). The study was undertaken within the context of the millennium drought with the imperative to enhance the Victorian Water Grid to secure water supplies for the State. The study concluded that the project was unlikely to be economically feasible and the project did not proceed.

Project concept

The Murray Goulburn interconnector channel is a nominal 2,000 ML/day channel from the River Murray at Lake Mulwala to the Shepparton Irrigation Area in the Goulburn River Catchment (refer Figure 6). The original objective of the interconnector channel was to enable the trade of water from the Murray system to the Goulburn system, providing an enhanced supply of water to the Goulburn sections of the Goulburn Murray Irrigation District. The interconnector would also enable the transfer of 400 ML/day of water around the Barmah-Millewa reach via an outfall to the Broken Creek. The previous studies were prepared on the concept that the interconnector channel could:

- Transfer up to 1,600 ML/day to the Goulburn system.
- Transfer up to 400 ML/day to the Broken Creek, which would then return to the River Murray.

Scope of works

Based on the 2007 Feasibility Outcomes Report, the interconnector requires a 55 km earthen channel from Lake Mulwala and the Murray system to the East Goulburn Main, the main distribution channel in the Shepparton Irrigation Area. The channel alignment would traverse primarily developed agricultural land between the Murray system and Shepparton Irrigation Area. It would be a gravity-based system taking advantage of the natural fall in slope across these areas.

Several options were considered for the bypass component of the project. These options included routing water from the interconnector into the lower Broken Creek. The feasibility study did not nominate a preferred option for the bypass route.

The estimated capital cost for this option was $345M in 2007. This capital cost translates to $500M+ in 2022 values based on CPI.

A $500M+ capital investment achieving up to 400ML/day supply equivalent for 100 day’s provides an approximate value for money of $1,250k per ML/day/100-day supply period, plus the required works for the equivalent volume of Goulburn water to be supplied to the Murray using ecologically tolerable means.

Shortlisting consideration

This option **is not recommended** to proceed to the shortlist as:

- To be used for the purposes of this project, water transferred using the interconnector would be returned to the River Murray through the Broken Creek, as well as any supplementary inter-valley trade water provided from the Goulburn in return. Advice from the relevant catchment management authority is that these natural waterways are already exceeding their ecologically tolerable flows over the target period, and as such, any increase would be ecologically intolerable.
- Obtaining the statutory approvals required to implement the option may be precluded or very difficult due to the potential for environmental harm as a result of the change in hydrology within natural receiving waterways.
- The capital investment required ($500M+) would be significant and likely preclusive.

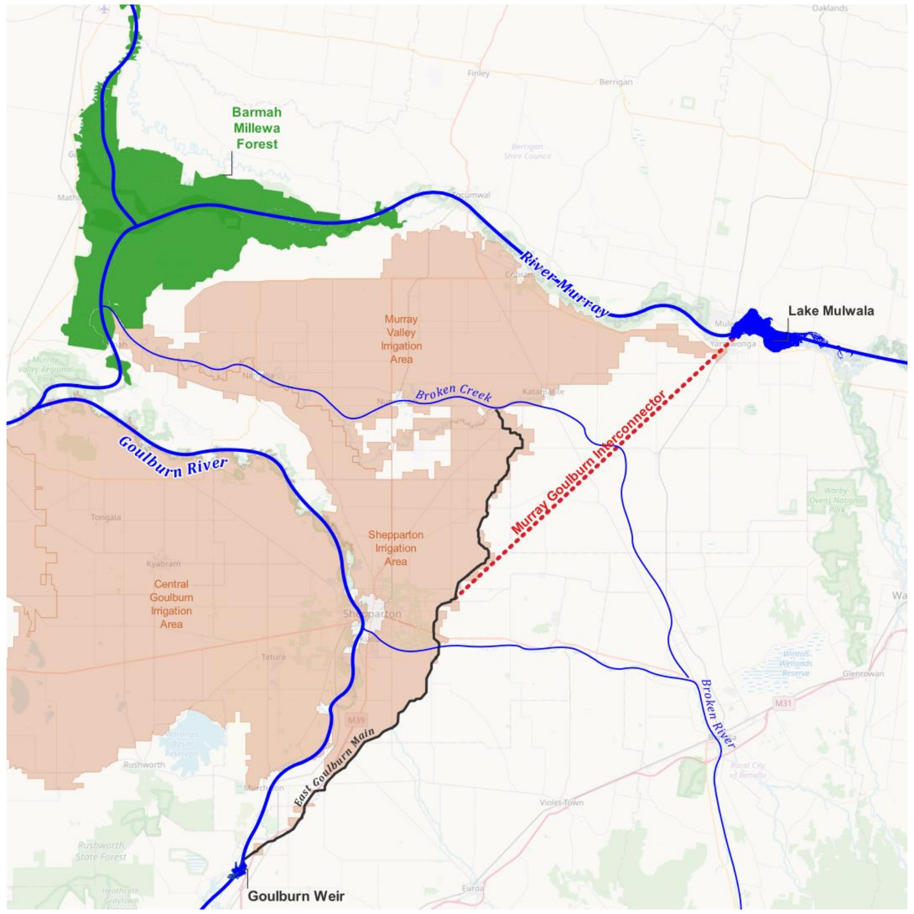

Figure 6. *Murray Goulburn interconnector channel*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Long travel time to areas of peak demand
	System shortfall		• Potential to provide an ongoing supply for extended periods would be limited by ecological constraints in the receiving waterways
Technical	Technically feasible		• Utilises well understood infrastructure solutions
	Reliability and flexibility		• Reliable technology with flexibility to vary flow rates
Impact on values	Environmental		• Sustained use of the receiving natural waterways during summer will almost certainly be ecologically intolerable
	Social		• Significant land and easement acquisition required to support construction of the new infrastructure • Sustained use of receiving natural waterways during summer may be unacceptable to riparian landholders.
	Cultural	TBD	• The potential for cultural heritage harm from construction activities and changes in hydrological regimes would need to be explored
	Economic		• Will compete with delivery of Goulburn IVT water
Costs	Regulatory requirements		• Extensive approval program required for the works. • Statutory approvals may not be provided on the basis of the potential for environmental harm in natural waterways as a result of the hydrological changes.
	Capital investment		• Prohibitively high capital cost ($500M+) • Prohibitively poor value-for-money for supply equivalence.
	O&M costs		• Ongoing costs for gravity fed channel likely to be relatively low

4.5 Option 5. Murray Valley irrigation area outfalls

Background

The channel system of the Murray Valley Irrigation Area (MVIA) diverts water from the River Murray at Lake Mulwala via the Yarrawonga Main Channel (YMC) to supply irrigators within the district. A few the channels in the MVIA connect to the lower Broken Creek via outfall structures. The lower Broken Creek flows into the River Murray just below the Barmah-Millewa reach. As a result, the MVIA channels can be used to bypass the Barmah-Millewa reach by conveying water from the River Murray through the channel system and outfalling the water to the lower Broken Creek (refer **Figure 7**).

In recent years MVIA channel outfalls have been used to pass between 15,000 to 35,000 ML/year of environmental and operational water around the reach supplied from the River Murray. However, the use of the MVIA channels is constrained by the channel and outfall flow capacity and the ecological tolerances of Broken Creek.

Project concept

There are seven existing outfalls in the MVIA that are regularly used to divert water around the reach with a combined nominal capacity of approximately 180 ML/day. Four of these outfalls are located downstream of the confluence of the Nine Mile Creek and the Broken Creek. This reach of the creek is regulated, with weirs facilitating the extraction of irrigation water. The ecologically desirable flows in this section are up to 350 ML/day over summer. This flow is currently met through a combination of outfall volumes from the MVIA, the delivery of environmental water, and inter-valley transfers.

This option explores the potential to increase the capacity of the MVIA to outfall water supplied from the River Murray to Broken Creek. The outfall capacity needs to account for the flow recommendations in the upper reaches (80ML/day), inter-valley transfer deliveries supplied from the Goulburn system, localised inflows, and the confirmation of 350ML/day as sustainable in the lower Broken River.

For the purposes of exploring the concept and noting the above, it is assumed that the outfall capacity could increase to 280 ML/day (e.g. an increase of 100 ML/day above current capacity). This is potentially optimistic and likely to be limited by environmental flow recommendations and the volumes of inter-valley transfers.

Scope of works

This option requires:

- Confirmation of the expected future flow volumes in the lower Broken Creek over the summer period to identify if there is any potential to increase the amount of bypass water.
- Scoping works for the four outfalls that discharge into the lower reaches of lower Broken Creek to achieve the additional 100 ML/day capacity.

It is expected that the capital cost to support an additional 100 ML/day would be around $5M.

A $5M capital investment achieving 100 ML/day additional supply for 100 day's provides an approximate value for money of $50k per ML/day/100-day supply period.

Shortlisting consideration

This option **is recommended** to proceed to the shortlist and be investigated in further detail.

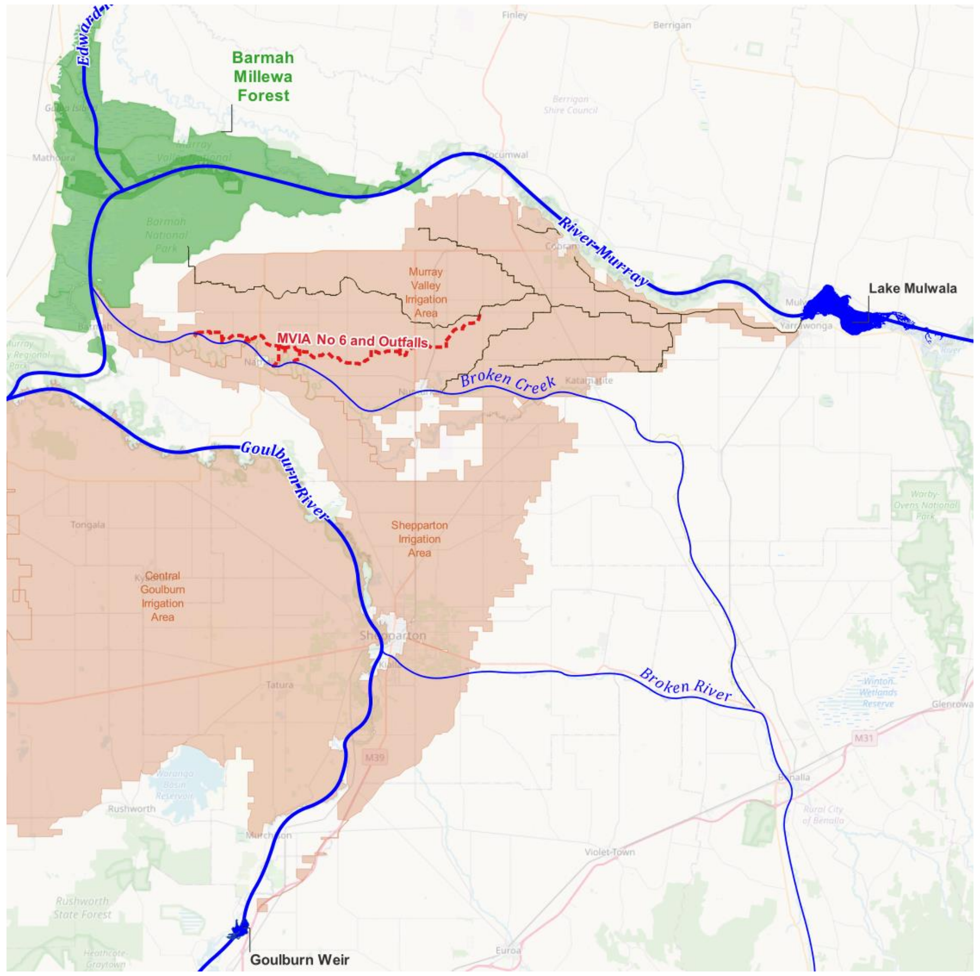

Figure 7. *Murray Valley Irrigation Area outfalls*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Long travel time to areas of peak demand
	System shortfall		• Potential to provide an additional 100 ML/day of ongoing supply capacity. • Opportunity to increase capacity further by extending a new channel section past the Broken Creek to link up with the River Murray directly
Technical	Technically feasible		• Utilises well understood infrastructure with low-risk technology
	Reliability and flexibility		• Available on call, subject to internal MVIA irrigation demands
Impact on values	Environmental		• CMA advise lower Broken Creek requires flows of up to 350 ML/day during summer to mitigate risks in lower Broken Creek • Ecological tolerances for the Broken Creek would govern the potential available capacity throughout the year • IVT may be reduced and supplied via alternative ecologically tolerable routes
	Social		• Land acquisition required to widen the channel infrastructure
	Cultural	TBD	• Cultural heritage assessments will need to be appropriately considered, including new infrastructure works, as well as the potential for changes in the waterways associated with the deliveries (including erosion)
	Economic		• Review of available capacity will need to consider IVT volumes
Costs	Regulatory requirements		• Works within largely disturbed footprints
	Capital investment		• Relatively high value-for-money supply equivalence.
	O&M costs		• Ongoing costs for use of the MVIA channel system relatively cost-effective

4.6 Option 6. Barmah Forest natural waterways

Background

There are a number of natural floodplain waterways flow through the Barmah Forest bypassing the narrowest sections of the reach and returning at Barmah Lake.

The 2011 SKM options report identified Kynmer Creek, a distributary waterway upstream of the Gulf Creek, as a potential bypass flow path. Kynmer Creek diverts from the Murray at the upstream end of the Forest, travels around the southern side of the Forest flows into the Tullah Creek, discharging into Barmah Lakes. The total length of waterway is 65km (refer **Figure 8**).

Project concept

The objective of this option would be to utilise Kynmer Creek to supply an additional 200 ML/day of bypass capacity.

This route would require infrastructure works at the river offtake into the creek and modify flow obstructions (e.g., track crossings) along the course of the creek.

This option would be subject to environmental drawbacks as it traverses the forest and incurs losses. Accordingly, it would only be available for use from September to November only, depending on environmental considerations at these times.

Scope of works

The conceptual scope for this option would involve:

- Construction of a three-bay box culvert regulator and containment banks at the offtake from the River Murray to Kynmer Creek to enable high river flows to be diverted into the Creek and conveyed to Barmah Lakes.
- Ancillary works on Kynmer Creek to remove flow obstructions in the Creek and protect private property from flooding.

The estimated capital cost for delivery of the works is $10M.

Shortlisting consideration

This option is **not recommended** to proceed to the shortlist as:

- It would not be ecologically tolerable to provide the flow rates to a level required to meaningfully contribute to managing shortfall risks during the summer months.
- The reliability and availability of providing flows would be limited by the ecological tolerance of the receiving waterway.
- Securing the necessary statutory approvals to construct and operate the works could be preclusive noting the Ramsar site and potential for environmental harm.

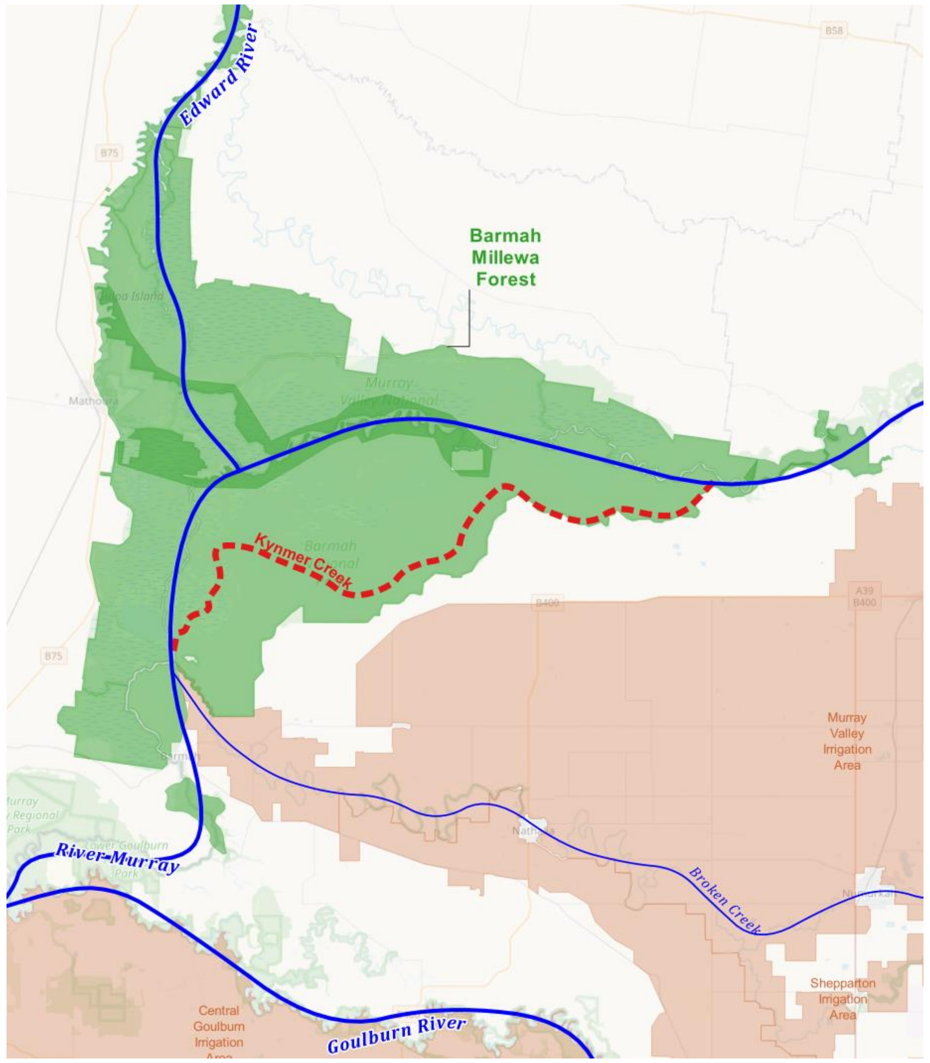

Figure 8. *Barmah Forest natural waterways*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Long travel time to areas of peak demand
	System shortfall		• Potential to provide an ongoing supply of 200 ML/day for extended periods, but limited by environmental concerns regarding the use of the creek system within the Barmah-Millewa Forest to convey flows
Technical	Technically feasible		• Utilises well understood infrastructure
	Reliability and flexibility		• Availability subject to ecological tolerance of receiving waterways
Impact on values	Environmental		• Sustained use of Kynmer Creek during summer likely to be environmentally detrimental to forest and wetland vegetation.
	Social		• Social concern arising from potential environmental degradation if the creek was used outside of ecological tolerances
	Cultural	TBD	• The potential for cultural heritage impacts as a result of increased flows would need to be further considered
	Economic		• Conveyance losses would need to be further considered
Costs	Regulatory requirements		• Works within the Barmah-Millewa Ramsar site likely require extensive approvals
	Capital investment		• Relatively low capital cost
	O&M costs		• Low ongoing O&M costs

4.7 Option 7. Barmah bypass pumped pipeline

Background
This option involves the construction of a new pressurised pipeline with an alignment around the southern perimeter of the Barmah Forest from upstream to downstream of the Barmah-Millewa reach (refer **Figure 9**). The pipeline requires pumping to lift water out of the River Murray and to overcome the pipeline friction head given the elevation difference across the reach is only approximately 15 metres.

This option is conceptual only in nature. It is understood that no detailed investigations have been undertaken to explore such an option.

Project concept
This option requires the construction of a dedicated pressurised pipeline around the southern perimeter of the Barmah Forest.

A key factor in determining the sizing and feasibility for this option is the availability of power for the pump station. A 2,000 ML/day pipeline is expected to require a load of more than 20 MW (depending on pipe sizing). The nearest zone substation to the site is at Cobram East, 40 km from the site. A 20+ MW pump station would be approximately equivalent to 50% of the peak load at the Cobram East zone substation.

A more realistic option would be a 500 ML/day pump station. It is estimated that a pump station/pipeline of this size would draw a load of approximately 2MW assuming twin DN1800 pipes and the availability of 15m of static head reflecting the difference in elevation between the intake and discharge points.

Based on conceptual assessment of the pipeline requirements it was determined that a practical capacity of the pump station and pipeline would be 500 ML/day.

Scope of works
An indicative pipeline alignment was identified from the River Murray conceptually at the Ulupna Bridge Road and discharging back into the river at Murray Rd in the town of Barmah. A pipeline with a capacity of 500 ML/day would conceptually require:

- an approximately 2 MW pump station on the River Murray at Ulupna Bridge Road, including electrical power supply and upgrades to the distribution/transmission system in the area.
- an approximately 30km twin DN1800 buried pipeline.
- a crossing of the pipeline underneath Broken Creek.
- a discharge structure at the termination of the pipeline into the River Murray at Barmah.

The conceptual pipeline alignment would follow existing public roads to minimise the regulatory approval requirements. The estimated cost for delivery of the pipeline works is $500M+.

A $500M+ capital investment achieving up to 500 ML/day supply equivalent for 100 day's provides an approximate value for money of $1,000k per ML/day/100-day supply period.

Shortlisting consideration

This option is **not recommended** to proceed to the shortlist as:

- construction and operation of the option would require prohibitively high levels of investment.
- the land acquisition and compensation to support the works would be extensive.
- very low value-for-money proposition compared to other options.
- there is a high potential for environmental and cultural heritage sensitivities to require active management during construction, and statutory approvals may not be possible to secure.

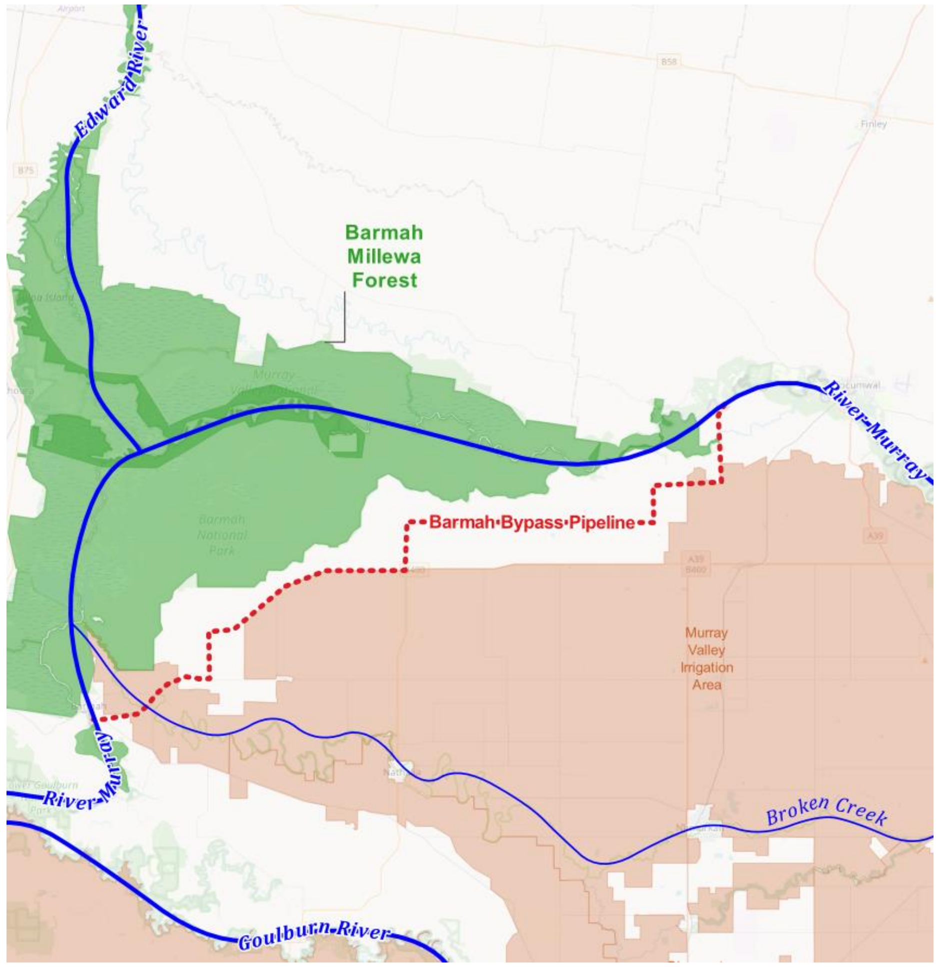

Figure 9. *Barmah bypass pumped pipeline*

Criteria	Category	Rating	Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Bypass capacity of 500 ML per day is a moderate flow contribution • Long travel time to areas of peak demand
	System shortfall		• Potential to provide an ongoing bypass capacity of 500 ML per day
Technical	Technically feasible		• Requires a very large twin pipeline, pumpstation and outfall structure, which would be challenging to construct. By means of comparison, the North-South pipeline is 70 km in length has a capacity of 300 ML/day and the Victorian desalination pipeline is 84 km in length and has a capacity of 320 ML/day.
	Reliability and flexibility		• Very reliable and flexible technology available to supply between zero and 500 ML/day on call.
Impact on values	Environmental		• Large pumpstation and discharge structure and the River Murray may have some environmental impacts
	Social		• Land acquisition and easements required to install the infrastructure
	Cultural	TBD	• The potential for cultural heritage impacts as a result of construction works would need to be explored.
	Economic		• Positive regional economic impact during construction due to the very large nature of the project
Costs	Regulatory requirements		• Inlet and discharge structures and the River Murray likely to require extensive environmental and planning approvals
	Capital investment		• Very high capital cost ($500M+) • Prohibitively poor value-for-money, compared to other options
	O&M costs		• Prohibitively high ongoing costs

4.8 Option 8. Barmah bypass gravity channel

Background
This option seeks to leverage the natural fall of the land across the Barmah-Millewa reach to gravitate water around the reach while avoiding the Barmah Forest National Park (refer Figure 10).

The option would mirror the alignment of the main channel system within the Murray Valley Irrigation Area (MVIA), with the option to utilise existing MVIA infrastructure or channel alignments to the extent possible.

This option is conceptual only in nature. It is understood that no detailed investigations have been undertaken to explore such an option.

Project Concept
To supply up to 2,000 ML/day of bypass capacity from Lake Mulwala to Barmah utilising gravitational flow to minimise the ongoing operation costs.

Scope of works
An indicative channel alignment was identified conceptually from Lake Mulwala and discharging back into the River Murray to the South of the Barmah-Millewa Forest.

This option would conceptually involve the construction of:

- an 18 km enlargement of the existing Yarrawonga Main Channel with an incremental capacity of 2,000 ML/day from Yarrawonga Weir to the No 2 main channel. This would likely also require rebuilding of the offtake structure.
- a 75 km enlargement of the existing No 2 and No 5 main channel with an incremental capacity of 2,000 ML/day from Yarrawonga Weir to the No 2 main channel. This would require acquisition of channel easements across multiple irrigation properties. Given the very densely settled nature of the agricultural land in the area there would be significant land acquisition required.
- 15 km of new 2,000 ML/day channel from the No 5 main channel discharging to the River Murray at Barmah, including a syphon under Broken Creek and a large discharge structure on the River Murray.

The conceptual channel alignment would follow the existing MVIA channel alignment with new infrastructure constructed across largely private owned land. The estimated cost for delivery of the channel works is $500M+.

A $500M+ capital investment achieving up to 2,000 ML/day supply equivalent for 100 day's provides an approximate value for money of $250k per ML/day/100-day supply period.

There are several potential capacity and alignment options to achieve the concept of constructing a new channel from the MVIA to the River Murray. These sub-options would be explored as part of any further assessment. There is a potential opportunity to explore a combination of this concept along with increasing the outfall capacity into the lower Broken Creek (option 5). This would involve enlarging the channels and outfalls leading from the MV6 channels to the lower Broken Creek, with a new channel section then constructed from the Broken Creek to the River Murray at Barmah. This concept would be explored further as part of more detailed investigations.

Shortlisting consideration
This option **is recommended** to proceed to the shortlist and be investigated in further detail.

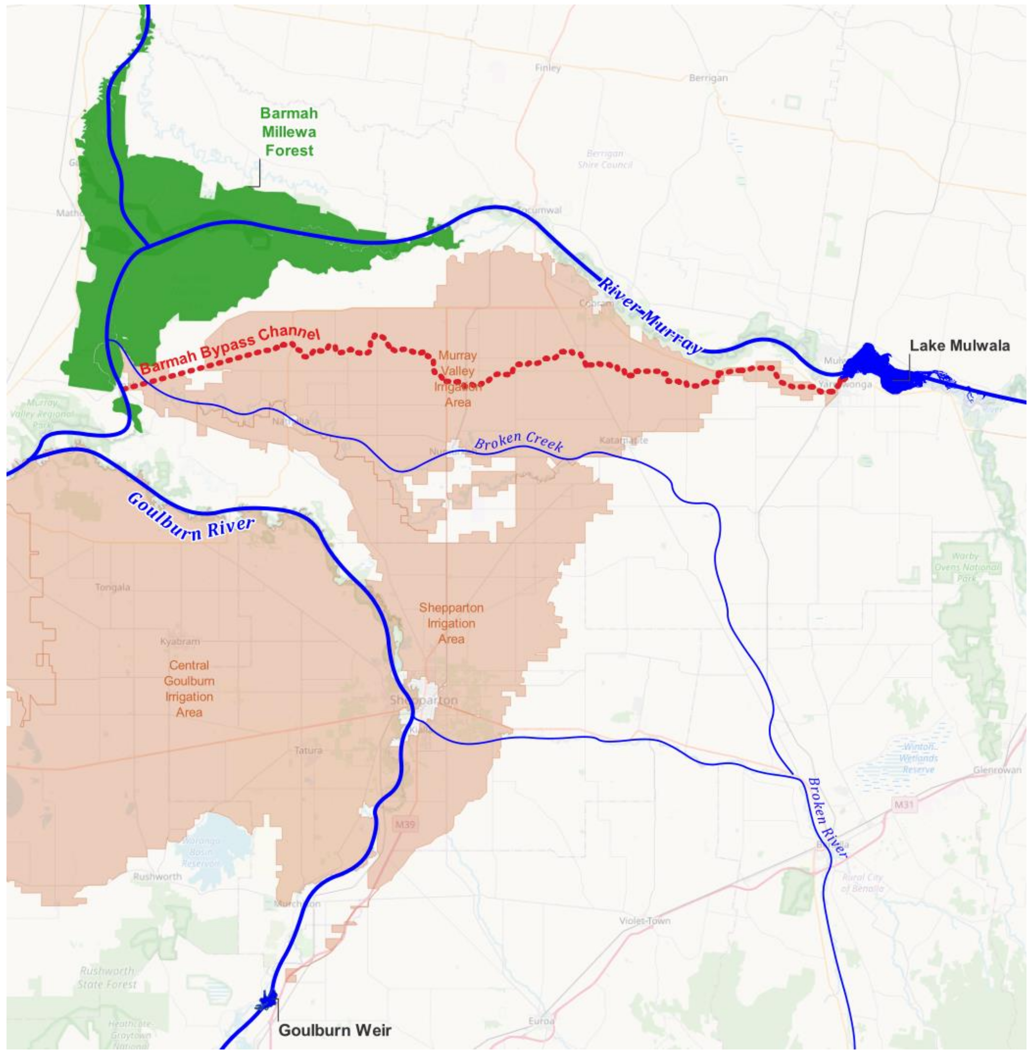

Figure 10. *Barmah bypass gravity channel*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Bypass capacity of up to 2,000 ML/day is a significant flow contribution • Long travel time to areas of peak demand
	System shortfall		• Potential to provide an ongoing bypass capacity of up to 2,000 ML/day
Technical	Technically feasible		• Proof of concept and confirmation of technical feasibility would require engineering assessments to be completed.
	Reliability and flexibility		• Very reliable and flexible technology available to supply between zero and up to 2,000 ML/day on call.
Impact on values	Environmental		• Syphon under Broken Creek and discharge point on the River Murray would have environmental impacts that would need to be explored
	Social		• Large number of easements required likely to be socially disruptive
	Cultural	TBD	• The potential for cultural heritage impacts as a result of construction works would need to be explored.
	Economic		• Positive regional economic impact during construction due to the very large nature of the project
Costs	Regulatory requirements		• Broken Creek syphon and River Murray likely to require extensive environmental approval
	Capital investment		• Very high capital cost • Relatively moderate value-for-money supply equivalence.
	O&M costs		• Low to medium ongoing costs

4.9 Option 9. Lake Buffalo to Lake Nillahcootie pipeline

Background

Lake Buffalo is a 24 GL storage located on the Buffalo River, a tributary of the Ovens River, in turn a tributary of the River Murray upstream of the Barmah-Millewa Reach.

Expanding the capacity of the storage and connecting the dam to Lake Nillahcootie in the Broken River catchment via a pipeline to supply the Goulburn system has previously been considered at a conceptual level (refer **Figure 11**). The objective of the proposal is understood to be based on improving water security and reliability. The works would be used to provide a Barmah-Millewa Reach bypass route.

Project Concept

The option would involve the raising of Lake Buffalo and the construction of a buried pipeline between Lake Buffalo and Lake Nillahcootie. Flows would then be returned to the River Murray from the Broken River either via the Broken Creek at Casey's Weir or the lower Goulburn River.

For the purposes of this feasibility study, the objective of this project would be to utilise the capacity within the proposed pipeline as a Barmah bypass route. It is assumed that up to 500 ML/day would be directed to the River Murray downstream of the Barmah-Millewa reach, noting that there would be significant conflicts with the Broken River environmental flow recommendations, the Broken System bulk entitlement, and limited existing capacity in the upper Broken Creek.

Scope of works

This option would conceptually involve the construction of:

- works to increase the capacity of Lake Buffalo.
- an approximately 62km pipeline (nominally 500 ML/day) to be installed between Lake Buffalo and Lake Nillahcootie
- a substantial sized pump station, to overcome the high ground between the two sites.

The estimated cost for delivery of the pipeline works is more than $500M, plus the cost to increase the capacity of Lake Buffalo.

A $500M+ capital investment achieving up to 500 ML/day supply equivalent for 100 day's provides an approximate value for money of $1,000k per ML/day/100-day supply period, plus the costs associated with increasing the storage capacity of Lake Buffalo, and the costs associated with transferring water from the Goulburn to the River Murray. These additional costs are very significant.

Shortlisting consideration

This option is **not recommended** to proceed to the shortlist as:

- it would not be possible to provide increased flows through the Broken River or the lower Goulburn River during the peak demand season.
- the reliability for using the system would be substantially restricted by the ecological tolerances of the natural waterways during peak demand season.
- the works would require extensive construction activities within environmentally and culturally sensitive landscapes including National Parks. Obtaining statutory approvals to undertake the works may not be possible due to the potential harm during construction and/or through operation with the change to the hydrological regime.
- construction and operation of the option would require prohibitively high levels of investment.

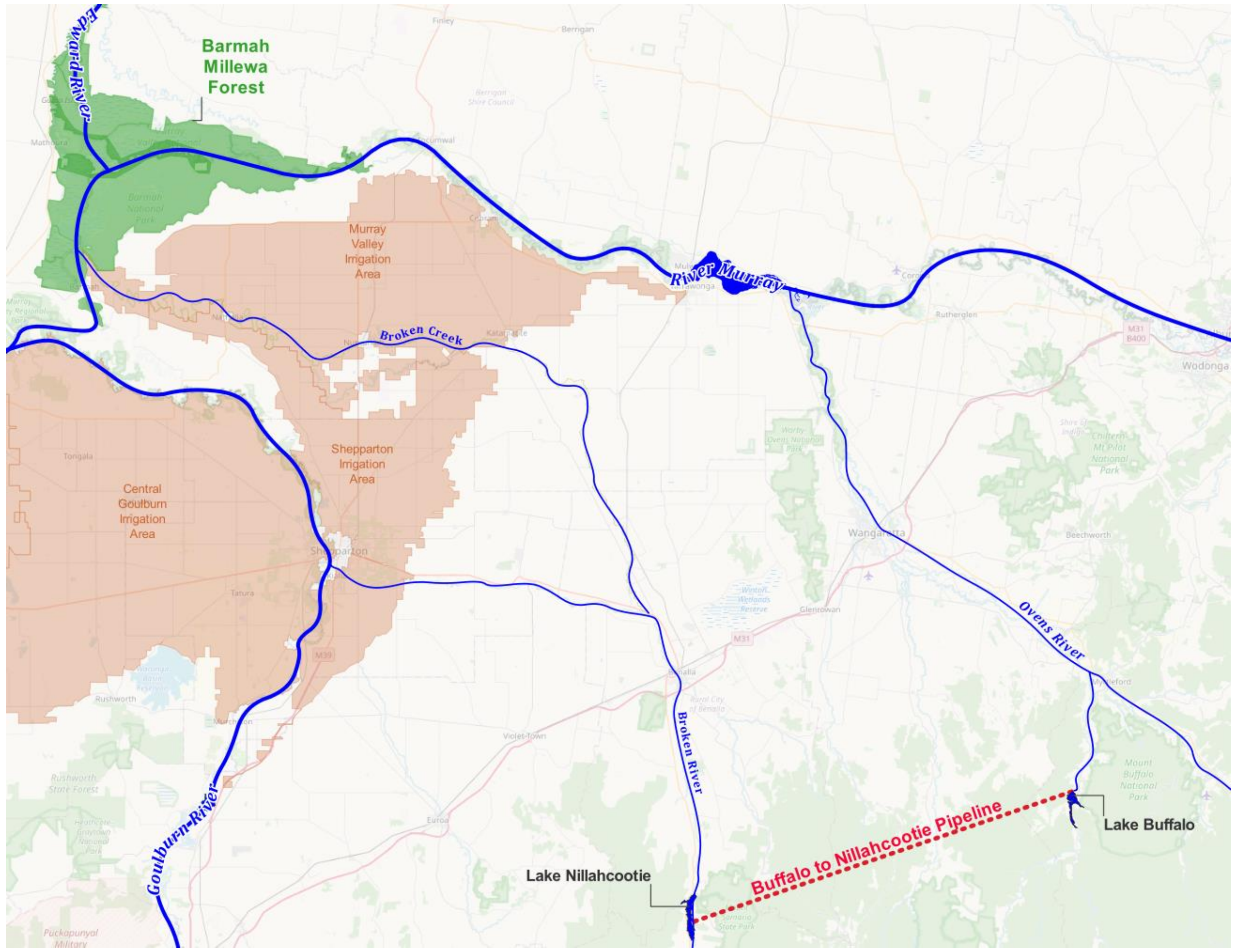

Figure 11. *Lake Buffalo to Lake Nillahcootie pipeline*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Long travel time to areas of peak demand
	System shortfall		• Ecological tolerances in the Broken River and lower Goulburn may restrict the ability to constancy supply bypass water over the summer periods
Technical	Technically feasible		• Utilises well understood infrastructure technology.
	Reliability and flexibility		• Highly constrained by ecological tolerances in the Broken Creek and lower Goulburn
Impact on values	Environmental		• Requires construction through national parks
	Social		• Large number of easements required likely to be socially disruptive
	Cultural	TBD	• The potential for cultural heritage impacts as a result of construction works would need to be explored.
	Economic		• Positive regional economic impact during construction due to the very large nature of the project
Costs	Regulatory requirements		• Extensive requirements to construct through national park
	Capital investment		• Prohibitively high capital cost ($500M+) • Prohibitively poor value-for-money, compared to other options
	O&M costs		• Very high ongoing costs ongoing costs

4.10 Option 10. RO 14 bypass channel

Background

The RO 14 channel is a medium sized irrigation channel within Goulburn-Murray Water's Rochester Irrigation Area. RO 14 flows from the Waranga Western Channel (WWC) for 39.5 km towards the River Murray. The WWC offtakes from the Goulburn River and Goulburn Weir (refer Figure 12).

This option is conceptual only in nature. It is understood that no detailed investigations have been previously undertaken.

Project Concept

Each year there is water held in the Goulburn system that is ‘owed’ to the Murray system because of legacy commitments, historic exchange rate trades, lower Broken Creek entitlements, and allocation trade. These volumes vary year-to-year depending on allocation and uptake of trade opportunities, from at least 100 GL in most years to more than 300 GL in some years. This water is delivered from the Goulburn system to the Murray primarily via natural waterways (i.e., Goulburn River). These waterways have ecological tolerances which constrain the rates of delivery, particularly over summer, as flows in the waterways would have naturally been at their lowest over this season.

There is an opportunity to increase the peak delivery capacity from the Goulburn system with the construction of a large channel between the WWC and the River Murray, such as along the alignment of the RO 14 channel. This would allow more concentrated delivery of the Goulburn commitments to the Murray to be made during the peak demand period, which could offset the volume needing to be supplied to the lower Murray from Hume Dam via the Barmah-Millewa Reach during these periods. This option could also increase the operational flexibility for river operators on the Goulburn and reduce the pressure on the ecological condition of the lower Goulburn River, lower Broken Creek, and Campaspe Rivers.

The capacity of such an option is likely to be limited by available capacity within the WWC. For the purposes of this high-level assessment, it has been assumed that the infrastructure would be sized to supply 500 ML/day to the River Murray.

Whilst the option presented involves the RO 14 channel, there are alternate means of potentially achieving this concept, such as extending other channels (e.g., the EG 12) or the use of existing drains (e.g., the Lockington and Bamawm drains). These alternate concepts may also be explored as part of any further investigations.

Scope of works

The works involved would conceptually comprise:

- Re-building approximately 28 km of the RO 14 channel to support an outfall capacity of 500ML/day.
- Replacement of the existing pipeline to suit the increased capacity.
- Construction of a new outfall structure to the River Murray.

The estimated cost for delivery of the works is approximately $100M.

A $100M capital investment achieving up to 500 ML/day supply equivalent for 100 day’s provides an approximate value for money of $200k per ML/day/100-day supply period.

Shortlisting consideration

There is potential to provide alternate arrangements for providing inter-valley transfers from the Goulburn to the Murray without using natural carriers, either through the RO 14 channel extension or similar alternate concepts. This option **is recommended** to proceed to the shortlist and be investigated in further detail.

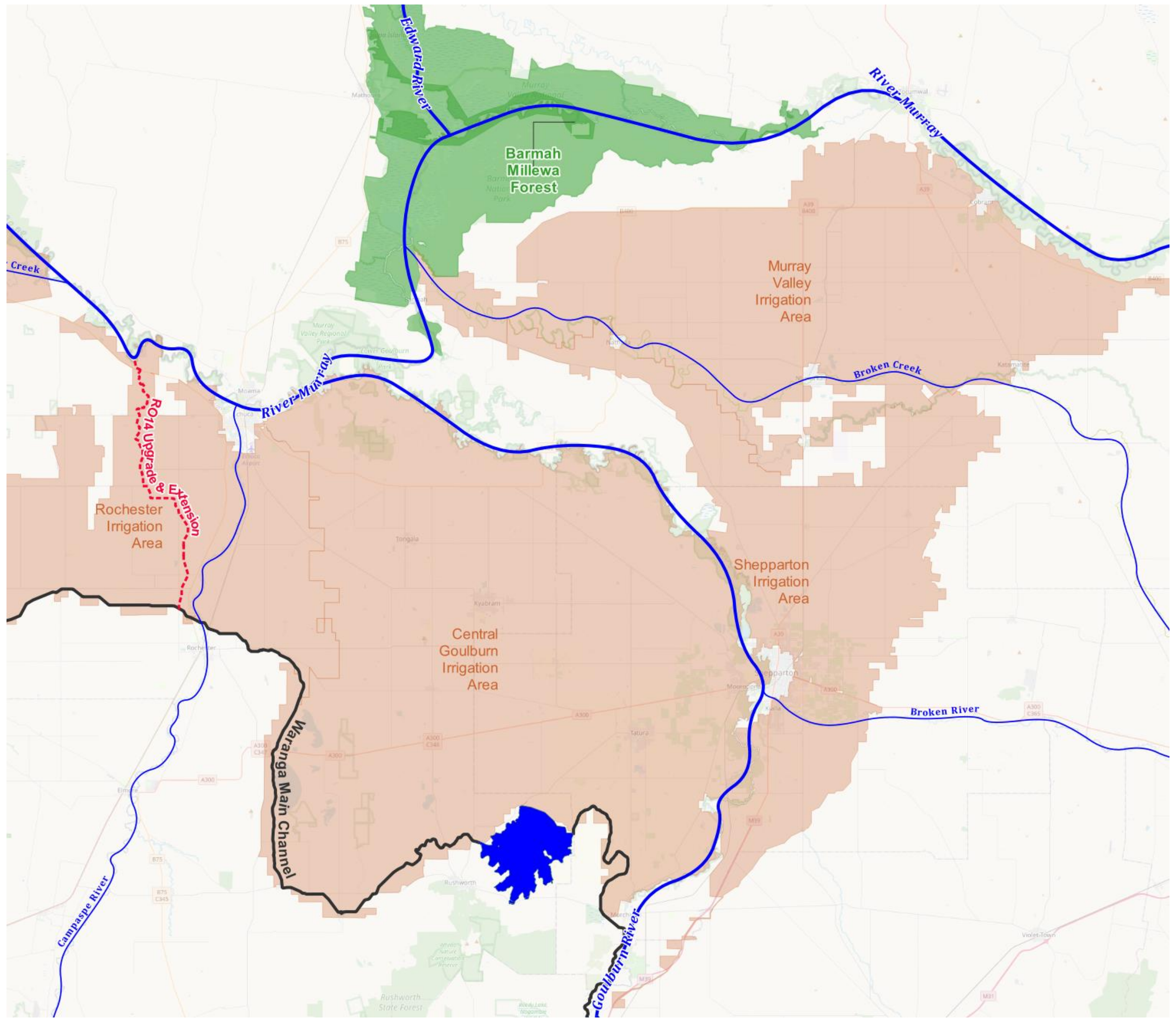

Figure 12. *RO14 bypass channel*

Criteria	Category		Justification
Effectiveness in reducing shortfall risks	Operational shortfall		• Long travel time to areas of peak demand
	System shortfall		• Available over irrigation season to provide constant flow of up to 500 ML/day (reduced by volumes required for supplying irrigation demand)
Technical	Technically feasible		• Utilises well understood infrastructure technology
	Reliability and flexibility		• Flexible to vary flow rates over the irrigation season
Impact on values	Environmental		• Requires new outfall to River Murray. The option would need to be assessed in terms of ecologically tolerable flows in the Mid Goulburn River between Lake Eildon and Goulburn Weir.
	Social		• This option would re-instate infrastructure in a similar location to recently decommissioned channel. The rationale for this would need to be clearly explained to the local community.
	Cultural	TBD	• The potential for cultural heritage impacts as a result of construction works would need to be explored.
	Economic		• Positive regional economic impact during construction
Costs	Regulatory requirements		• The alignment of the RO 14 channel has been previously disturbed
	Capital investment		• Relatively moderate to high capital cost
	O&M costs		• Low ongoing costs

4.11 Summary of assessment

Table 4 provides a summary of the assessment for the long-list of options against the general criteria. The approach adopted for selecting shortlisted options involves eliminating any option that rank negatively against any general criteria. On this basis, the following options are shortlisted for further assessment:

- **Option 1.** Victorian Mid-Murray Storages Enhancements
- **Option 5.** Murray Valley Irrigation Area Outfalls
- **Option 8.** Barmah Bypass Gravity Channel
- **Option 10.** RO14 Bypass Channel

The following Sections 5 to 8 of this report investigate each of the shortlisted options in more detail to better quantify the scope of investigations and works required and the extent to which the options are reasonably expected to contribute to the BMFS objectives.

Table 4. Summary of options ranking against general criteria

Criteria	Category	1. Victorian mid-Murray storages	2. Off-stream mid-Murray storage	3. Floodplain storage	4. Murray-Goulburn Interconnector	5. Murray Valley Irrigation Area outfalls	6. Barmah Forest natural waterways	7. Barmah bypass pipeline	8. Barmah bypass channel	9. Lake Buffalo to Lake Nillahcootie	10. RO14 bypass channel
Effectiveness in reducing shortfall risks	Operational shortfall	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow
	System shortfall	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Red	Green
Technical	Technically feasible.	Green	Yellow	Green	Green	Green	Green	Yellow	Yellow	Yellow	Green
	Reliability and flexibility	Yellow	Yellow	Red	Green	Green	Red	Green	Green	Red	Green
Impact on values	Environmental	Yellow	Yellow	Red	Red	Green	Red	Yellow	Yellow	Red	Yellow
	Social	Yellow	Red	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Green
	Cultural	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	Economic	Green	Green	Red	Yellow	Yellow	Yellow	Green	Green	Green	Green
Costs	Regulatory requirements	Yellow	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Red	Yellow
	Capital investment	Green	Red	Green	Red	Yellow	Green	Red	Yellow	Red	Yellow
	O&M costs	Yellow	Yellow	Yellow	Yellow	Green	Green	Red	Yellow	Red	Green
Value-for-money equivalence ($k/ML/day-100 days)		$3 – 35k (High VFM)	$1,000k (Very poor VFM)	N/A	$1,250k (Very poor VFM)	$50k (High VFM)	N/A	$1,000k (Very poor VFM)	$250k (Moderate)	> $1,000k + other works (Very poor VFM)	$200k (Moderate)
Shortlist		✓	✗	✗	✗	✓	✗	✗	✓	✗	✓
Primary rationale for shortlisting decision		Effective in reducing shortfall risks with low capital cost	Very poor value-for-money. Substantial land acquisition.	Ecologically not tolerable. High losses.	Very poor value-for-money. Ecologically not tolerable in receiving waterways.	Effective in reducing shortfall risks. Opportunity to expand on concept.	Ecologically not tolerable. High losses.	Prohibitive capital and operational costs. Very poor value-for-money.	Effective in reducing shortfall risk and high capacity volume.	Ecologically not tolerable. Very poor value-for-money.	Effective in reducing shortfall risks with moderate capital cost

5 Shortlisted option investigation: Victorian mid-Murray storages

5.1 Detailed description of the option

Overview

The Victorian Mid-Murray Storages (VMMS) consist of four storages: Lake Boga, Lake Charm, Kangaroo Lake and Ghow Swamp. The VMMS are located within the Torrumbarry Irrigation Area (TIA) in north central Victoria, approximately 100 km downstream of the Barmah-Millewa Reach (see **Figure 13**). The storages are naturally ephemeral lakes and wetlands. With the development of the TIA, the four lakes were equipped with regulating structures and incorporated into the irrigation system, with Lake Boga returning to the system as part of the formation of the VMMS.

In the late 2000s, the Victorian Government re-purposed the four storages as the VMMS as part of the Lake Mokoan decommissioning project. The primary purpose of the VMMS is to captures, store, and release water to the benefit of the Victorian Murray System users, including supplementing downstream bulk water demands. Water harvested into the VMMS can be returned to the River Murray to supplement flows to meet Victorian River Murray commitments or minimise releases from the upper Murray storages[10].

Water released from the VMMS to the Murray can be supplied from Lake Boga, Kangaroo Lake, and Lake Charm. Ghow Swamp is primarily used for supplying TIA irrigation demands, buffering supplies to the irrigation district from the Murray system headworks[11].

Due to its location in the mid-Murray, the VMMS can respond quickly to potential shortfall events in the lower Murray. This ability is of particular importance to River Murray operators during periods when Menindee Lakes are unavailable as a shared resource under MDBA control. If the VMMS are available, River Murray operators can manage releases from Lake Hume more efficiently, and in the case of a potential delivery shortfall event, VMMS releases can be utilised to at least in part offset the shortfall. The extent to which the VMMS can be used to offset shortfalls is determined by the storage volume as well as achievable discharge rate.

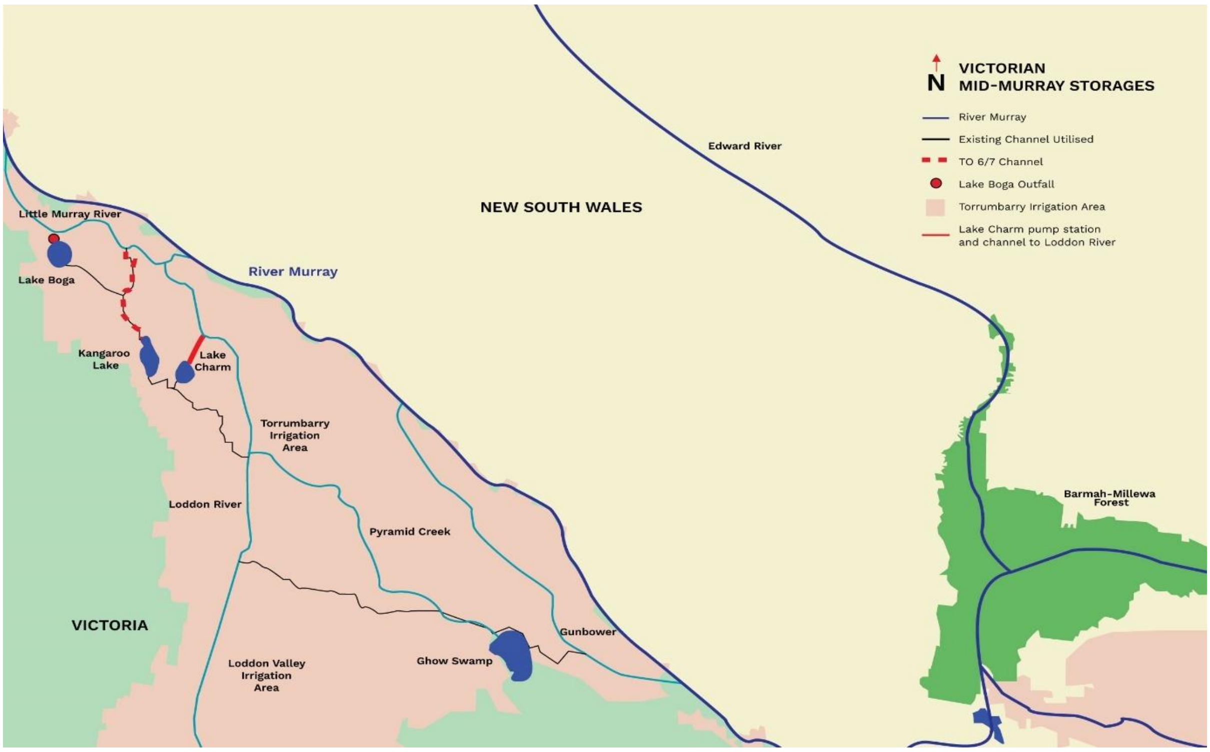

Figure 13. *Location of the Victorian Mid-Murray Storages relative to the Barmah-Millewa Reach*

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[10] https://www.g-mwater.com.au/water-resources/catchments/storages/murray/lakeboga
[11] GMW (2022), *Victorian Mid-Murray Storages 2022/2023 Annual Operating Plan, June 2022.*

Current operating arrangements

Water is currently harvested into the VMMS when River Murray flows are unregulated or are receiving significant unregulated flow from the Broken system via the Goulburn River.

Alternately, the storages can be filled by transferring regulated water from upstream storages. This may occur if harvesting opportunities are limited and there is potential for high summer demand. Transferring regulated water to the VMMS has not commonly been needed in the recent historical period. However, with a reducing capacity in the Barmah-Millewa Reach, demand changes in the lower Murray, and the potential for less frequent access to Menindee Lakes, the regularity of regulated transfers to the VMMS may change in future.

Water is delivered from the River Murray to the VMMS via the National Channel, the main channel into the TIA. Water diverted for the VMMS is either harvested in Ghow Swamp or supplied downstream via the Contour Channel. Harvesting in Ghow Swamp can occur at rates of up to 3,000 ML/day when there are short-lived winter surplus flow events on the River Murray and the storage level in Ghow Swamp is low. Ghow Swamp is generally drawn down over the irrigation season and filled during the winter.

Water is typically supplied from Ghow Swamp to Lake Charm, Kangaroo Lake, and Lake Boga via Box Creek and Pyramid Creek (1,000 ML/day capacity). This transfer generally occurs at the start of the irrigation season when irrigation demands are low and there is spare capacity in the carrier channels. Water can be transferred from the Macorna (TO 2) Channel; however, this is not the standard route, as it is limited by the capacity of the channel outfall to the Loddon River (150 – 200 ML/day).

Water stored in Lake Charm, Kangaroo Lake and Lake Boga can be released back to the River Murray at short notice. Stored water is released back into the River Murray via the following routes:

- **Lake Charm:** water is pumped from the storage into an outfall channel which discharges into the Loddon River, upstream of Fish Point Weir, and subsequently flows into the River Murray.
- **Kangaroo Lake:** water is released by gravity into the TO 7 irrigation channel, which can then either be discharged into the Little Murray River via the TO 6/7 channel or be routed into Lake Boga via the TO 7 channel. The Little Murray River then flows into the River Murray.
- **Lake Boga:** water is released by gravity into an outfall channel, which discharges into the Little Murray River, upstream of the Little Murray Weir, which then flows into the River Murray.

Figure 14 provides a schematic of the VMMS system and primary flow paths. The primary channels, natural carriers and watercourses required for the operation of the VMMS are coloured in blue and the storages are coloured in green.

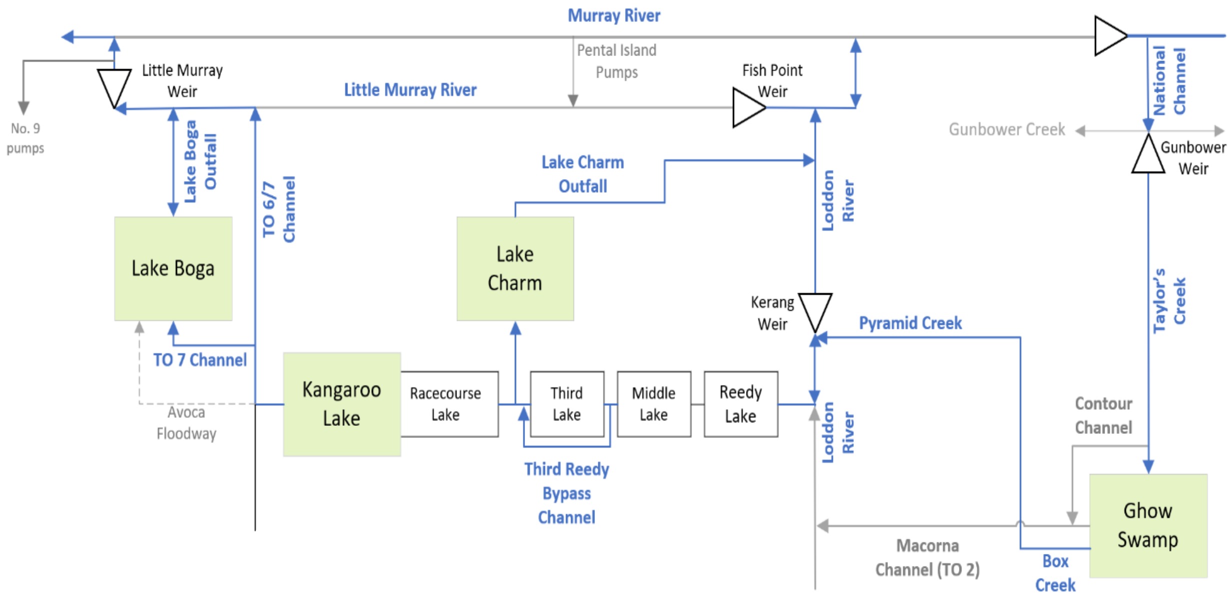

Figure 14. *A system schematic of the Victorian Mid-Murray Storages*

Limitations and opportunities

The combined available active storage capacity of Lake Boga, Kangaroo Lake and Lake Charm is approximately 30,000 ML. The combined maximum design discharge capacity to the River Murray is more than 2,000 ML/day, and the normal operational discharge rate combined for the lakes is around 950 – 1,250 ML/day (**Table 5**).

Table 5. Active storage capacity and maximum design discharge for the Victorian mid-Murray storages[12]

VMMS waterbody	Active storage volume (ML)	Maximum design discharge (ML/day)	Normal operational discharge (ML/day)
Lake Boga	20,907 ML	0 – 1,000[1]	200 – 500[2]
Kangaroo Lake	7,840 ML	1,000 (flood releases) 650 (operational)[3]	Up to 610[3]
Lake Charm	3,590 ML	150 (pumps)	150
Ghow Swamp[4]	-	-	
TOTAL	**Approx. 30,000 ML**		**950 – 1,250 ML/day**

[1]: the low gradient of the Lake Boga channel is assumed to limit the outfall capacity and the design discharge rate may be over-stated.
[2]: the discharge rate from Lake Boga will reduce during an event as the available head in the storage lowers
[3]: the discharge rate from Kangaroo Lake will reduce during an event as the available head in the storage lowers.
[4]: the normal operational discharge rate provided is the design capacity of the TO 6/7 channel, downstream of the SH82 regulator. The availability of this capacity would be limited by demand from local irrigators (which would be prioritised).
[5]: the enhanced use of Ghow Swamp and its active storage capacity is not being considered as part of this feasibility study, in recognition that there is ongoing engagement with Traditional Owners about how to best manage the cultural site.

While the VMMS already contributes to the objectives of the BMFS, maximising the use of the storages is currently limited. There is an opportunity to enhance the use of the storages if these limitations can be appropriately managed and addressed. These key limitations and opportunities include:

- **Reduced discharge capacity:** the discharge capacity currently achievable from Lake Boga, Kangaroo Lake and Lake Charm are lower than the normal operational rates. This can be addressed through targeted investigations and construction activities, as contemplated in this report.
- **Operational management practices:** currently the VMMS storages are infrequently used to supply lower Murray demands. If the storages were to be used more often for this purpose, operational models and coordinated operating arrangements would need to be developed which would integrate environmental, flood protection, recreational, salinity, cultural heritage, and irrigation considerations. This would enable a more effective decision-making framework regarding the capture of flows into the storages, the conveyance of flows between the storages, and the release of flows.
- **Salinity management:** under historic practices, salinity levels in Lake Charm averaged around 5,000 EC. To minimise salinity increases in the River Murray, the Lake Charm outfall is subject to the Lake Charm Disposal Pumps Operational Procedures. These procedures limit releases to periods of high flow on the River Murray. Both Lake Charm and Lake Boga are currently operated under interim operating rules to manage salinity impacts on the River Murray.
- **Social use conflicts:** while the primary purpose of the storages is to capture, store, and release water for Victorian entitlement holders, the lakes are of important recreational and social value to the community. The use of the VMMS would typically require the lakes to be drawn down relatively quickly to respond to a potential shortfall event, likely during summer. Affected social activities could include fishing, regattas, swimming events (Lake Boga), and water skiing (Lake Charm and Kangaroo Lake). The

[12] *Op. Cit.*

enhanced use of the storages to supply River Murray shortfalls would need to consider these social values and how communication is managed with the local community and lake users.

- Cultural heritage: there are significant cultural sites and values at the storages. Currently, the Victorian government is actively engaging with Traditional Owners about how to best manage cultural sites, including Ghow Swamp. Any operational changes in discharging and re-filling the storages will require consultation with Traditional Owners. No change to the operation of Ghow Swamp is proposed as a result of this option.
- Constraints on re-filling: if the VMMS were used to support a potential delivery shortfall event, high volumes would be released over a short period of time. This would draw down the storages and reduce the head available for future gravity releases until such time that the storages were re-filled. As such, at the conclusion of the event, there would be limited opportunity to contribute to managing another potential shortfall until the storages could be re-filled. The re-filling is most likely to occur over the winter and spring periods, during which time water used to re-fill the system would be competing with other demands on the River Murray. This would need to be considered in operational event planning and with River Murray operators to ensure it does not contribute to an increase in potential for a system shortfall event during these periods. Re-filling would be expected to occur over an extended period, noting that the No. 7 channel capacity into Lake Boga is limited to 200 ML/day.
- TIA channel demands: channel capacity constraints within the TIA need to be considered when harvesting to the VMMS. GMW prioritises channel capacity for delivery shareholders, meaning that harvesting to the VMMS only occurs when spare capacity exists.

Enhancing the operation of the VMMS storages

To allow for the enhanced operation of the VMMS for the purposes of supporting the BMFS objectives, it is recommended that the following works would need to be undertaken:

- Works to reinstate discharge capacity: the discharge capacity for the storages would be increased through targeted investigations and infrastructure works. This scope of these potential investigations and infrastructure works is detailed in Section 5.2 of this report.
- Enhanced operational arrangements: the management of the VMMS is currently described by an Annual Operating Plan for the storages. Enhancing the use of the VMMS will require operational models and coordinated operating arrangements to be developed to better support GMW operators in their operational management of the lakes. There may be also a requirement for additional GMW resourcing to undertake the management of the storage system, including ongoing consultation with the key stakeholders.
- Salinity management: the interim release rules for Lake Charm are proposed each year to increase VMMS operational flexibility. The finalisation of these interim rules should be progressed and, once agreed to by Basin states, the rules would be subject to longer-term monitoring of salinity in Lake Charm under ongoing VMMS operation.
- Cultural heritage: ongoing consultation with Traditional Owners on the management of the storages, including Ghow Swamp, should include consideration for any changes to the operation of Lake Boga, Kangaroo Lake, and Lake Charm.
- Social and environmental investigations: there are a wide-range of social and environmental values which may be affected by changing the operating regime for the storages. These matters should be investigated in consultation with key stakeholder groups and any appropriate mitigation measures identified. This would include engagement with the community and recreational groups.

5.2 Engineering & works considerations

Lake Boga outfall works

Lake Boga discharges to the Murray through an outfall channel to the Little Murray River. There is a three-bay regulator (SH73) at the head of the outfall channel, which flows for 1.5km before discharging to the Little Murray River, approximately 6km upstream of the Little Murray Weir.

The rate of gravity release from Lake Boga is dependent on the head difference between the Little Murray River and Lake Boga. In 2015, the primary weir on the Little Murray River was lowered to enable gravity outfall from Lake Boga. Since these works were undertaken, the maximum release rate from Lake Boga is yet to be confirmed. The maximum design release rate is 1,000 ML/day; however, observations from GMW are that the low gradient of the outfall channel may be limiting this capacity and previous estimates may be over-stated.

The normal operating discharge rate is in the range of 200 – 500 ML/day. During a discharge event from Lake Boga, the flow rate would be expected to rapidly decline as the available head reduces. Preliminary 1D modelling suggest that an average flow of:

- 500 ML/day could be sustained for 13 days.
- 320 ML/day could be sustained for 30 days.
- 250 ML/day could be sustained for 42 days.

The discharge structure is infrequently used. In recent years, difficulties have been observed in discharging flows from Lake Boga. In 2018, Lake Boga was at 68.5m (approximately 70% full) and this was observed to be close to the minimum level at which water could flow from Lake Boga to Little Murray River. In 2019 and 2020, the minimum level was observed to be around 68.4m AHD. The maximum flow recorded in each event was around 100 – 450 ML/day, with an average of around 50 – 150 ML/day.

Higher flows were recorded across a two-week period in summer 2021 when the lake height was 68.9 – 68.6m; however, the flow rates recorded were not stable, and thus these readings are not considered reliable. In all recent operations, GMW have observed the discharge flows to be restricted due to cumbungi restricting flow in the outfall channel, as well as a sandbar that is believed to have formed in front of the channel offtake[13].

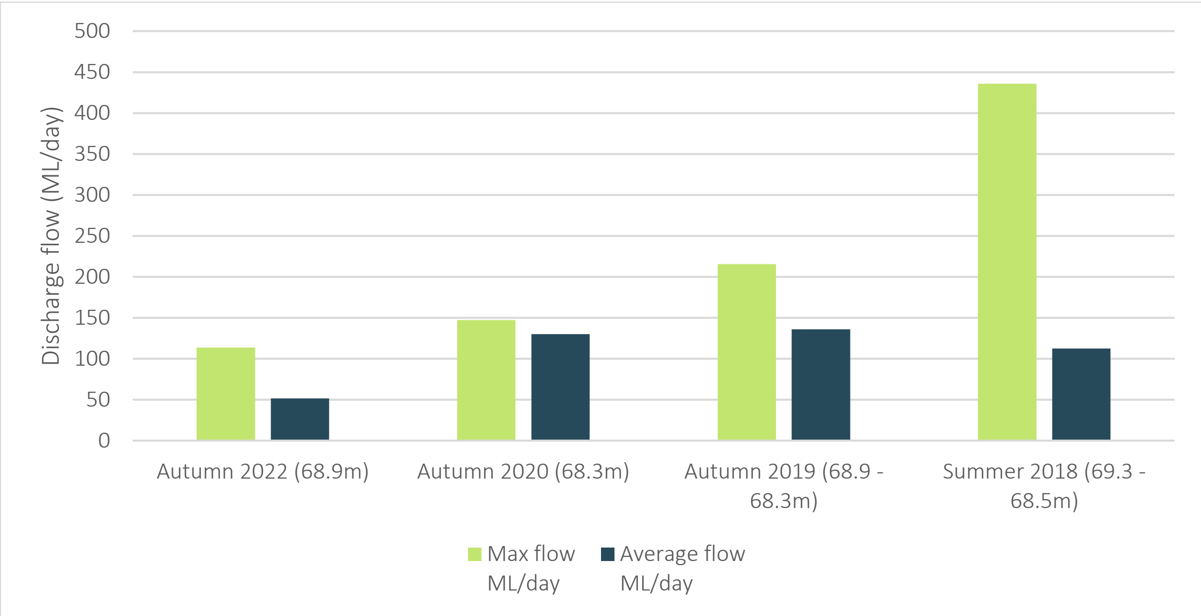

Figure 15. *Discharge flow volumes recorded at the Lake Boga outfall regulator from 2018 - 2020*

[13] *Op. Cit.*

The cumbungi in the Lake Boga outfall channel is likely a result of the channel being consistently wetted by flows backing up into the channel from the Little Murray River and potential leakage from the gates at Lake Boga.

The proposed scope of work to improve the discharge capacity from Lake Boga includes:

- engineering investigations including targeted site inspections and review of system characteristics to confirm the scope of works required (indicatively provided below).
- construction of a regulating structure on the Lake Boga outfall, immediately upstream of where it discharges into the Little Murray River. The structure would include flap valves to prevent backflow from the Little Murray River into the outfall channel. To allow for flows of up to 1,000 ML/day, the structure would indicatively require a 5-barrel culvert and a drop structure. The structure should be appropriately sized to allow flood operators to take advantage of the Little Murray Weir lowering with respect to routing floods through Avoca Floodplain and Lake Boga.
- the Lake Boga outfall channel should be de-silted and re-profiled for its entire length (1.5km).
- the Lake Boga outfall regulator should be inspected for leaks and any remedial works should be undertaken on the gates as required.
- investigations should be undertaken to confirm the presence of a sandbar upstream of the Lake Boga outfall regulator which may be limiting flows. These investigations should involve targeted bathymetric surveys, followed by detailed design of the works required. The scale of works are not able to be practically quantified until such investigation is complete.

These works targeted to improve the discharge capacity from Lake Boga are shown in Figure 16 below.

Figure 16. *Proposed scope of works to reinstate the discharge capacity from Lake Boga*

At this time, it is unclear the extent to which the discharge flow capacity from Lake Boga can be improved by undertaking these works. For the purposes of this feasibility study, it is assumed that the flow rate from the 1D modelling of 500 ML/day (supplied for up to 13 days) could be achieved by undertaking the works.

Further investigations are required and, following works completion, the improved discharge capacity should be verified. If additional discharge capacity above and beyond that which can be achieved under gravity were to be proposed, new works would be required, such as the construction of a new low-lift pump station on the shoreline of Lake Boga. Such additional works have not been considered as part of this feasibility study.

Lake Boga salinity considerations

The salinity level at Lake Boga has been maintained at around 1,500 EC in the recent record.

The release of water from Lake Boga will contribute salinity in the River Murray. As such, releases from Lake Boga would be managed using the Lake Charm proposed operating rules. It is expected that the enhanced use of the storage for harvesting and delivering water to the River Murray would reduce salinity levels in the lake, thus this should be manageable as part of any proposed enhance use of the storages.

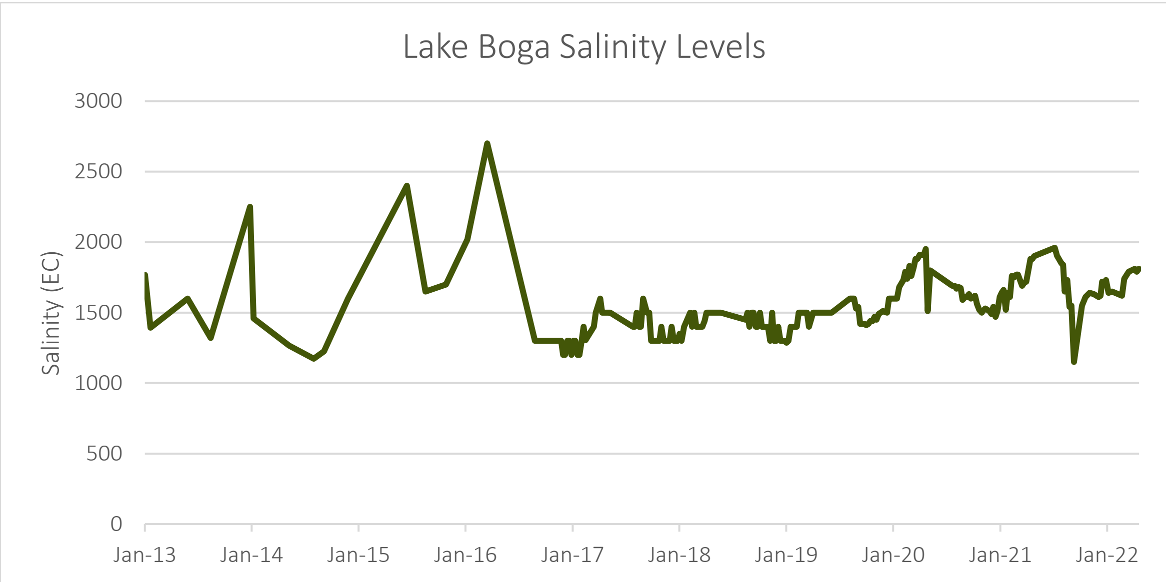

Figure 17. *Lake Boga salinity levels in the recent record*

Lake Boga photographs

Photographs showing the existing structures and site conditions are shown in **Figure 18**.

Lake Boga offtake regulator (SH73)

Lake Boga outfall channel (CH015124)

Immediately U/S of the Lake Boga offtake regulator

Lake Boga

Figure 18. *Site photographs at the Lake Boga outfall regulator and channel*

Kangaroo Lake – TO 6/7 channel works

Kangaroo Lake can deliver flows to the River Murray either through supplying via the TO 6/7 channel or through filling Lake Boga via the TO 7 channel (see **Figure 19**). For the purposes of this study, the discharge flow rate of interest is for flows that can be provided through the TO 6/7 channel, which discharges into the Little Murray River approximately 22.5km upstream from the Little Murray Weir.

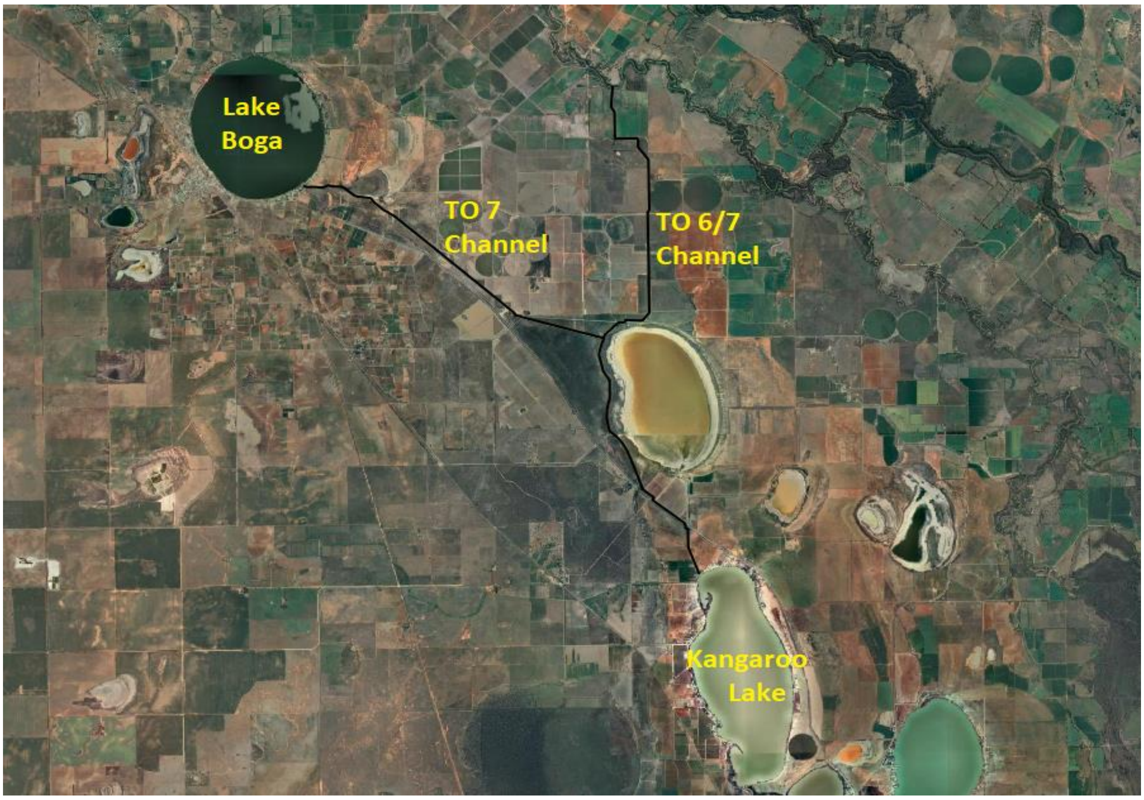

Figure 19. *Kangaroo Lake discharge routes which can supply through to the River Murray*

Kangaroo Lake has an operational discharge capacity of 650 ML/day and the TO 6/7 channel has a design capacity of 610 ML/day. Following completion of the Swan Hill Modernisation Project and the lowering of the Little Murray Weir, irrigation supply on the TO 6/7 has significantly reduced. In recent years, the TO 9 pump station has mostly been supplied by flows on the Little Murray Weir through Fish Point Weir (rather than from the TO 6/7 channel). This reduction on the TO 6/7 channel means that there is reliably 450 – 550 ML/day of capacity available over summer, which could be used for releases from Kangaroo Lake to the River Murray.

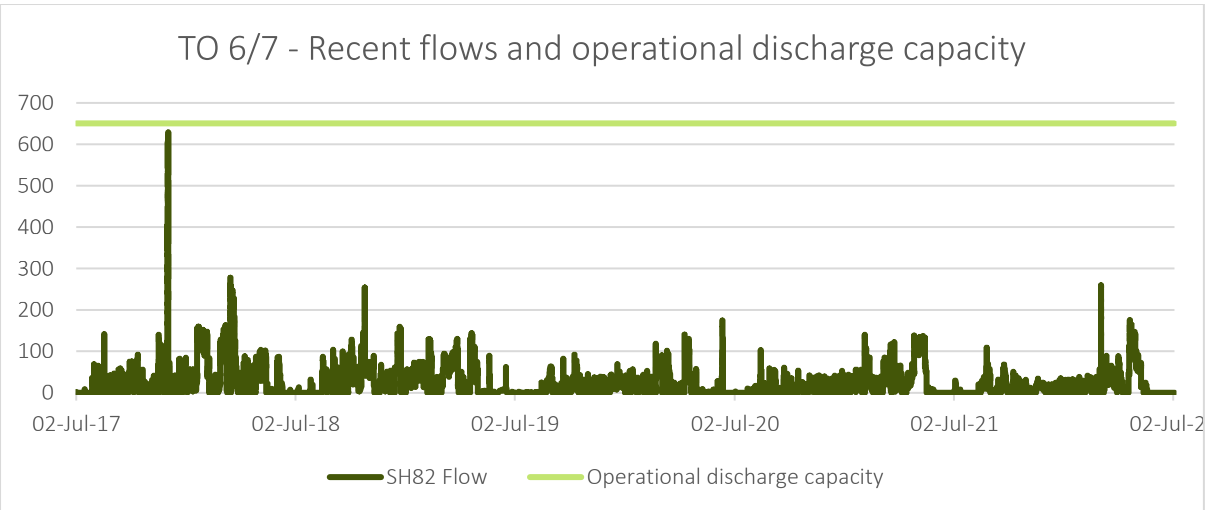

Figure 20. *Recent flows and operational discharge capacity on the TO 6/7 channel*

If Kangaroo Lake discharges were to occur more frequently in future, GMW advise that the TO 6/7 channel would require some re-profiling to support delivery of these higher flows. For the purposes of approximating a scope of work, it is expected that this may involve targeted re-profiling the TO 6/7 channel between the offtake regulator (SH82) and the Little Murray River, a total channel distance of approximately 6.7km, assuming targeted work in a 1.0km reach.

Lake Charm outfall channel works

Lake Charm can deliver flows to the River Murray through an existing pump station and outfall channel. The channel discharges through the Hogg Road Culvert into the Loddon River, which joins the Little Murray River upstream of Fish Point Weir (see **Figure 21**).

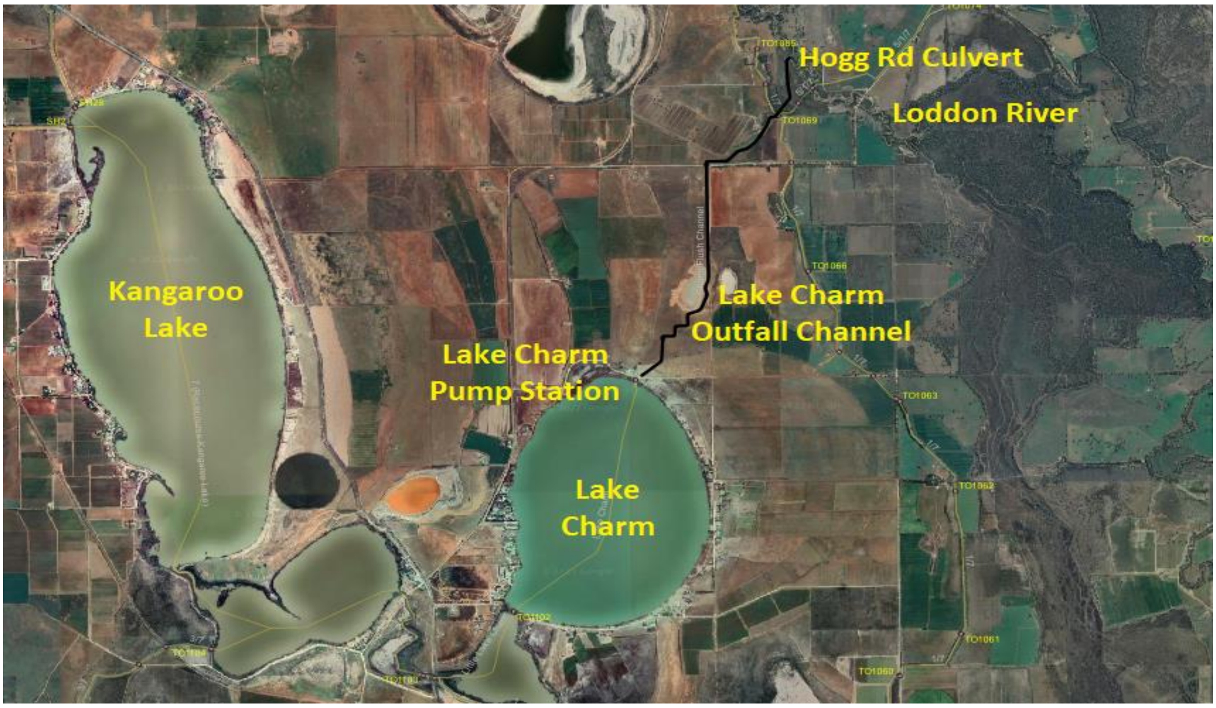

Figure 21. *Lake Charm discharge route to the Loddon River and associated infrastructure*

The pump station and channel have existing design capacity to deliver 150 ML/day. GMW advise that, if the use of Lake Charm were to be enhanced for the purposes of supplying Victorian Murray demands, the Hogg Road culvert would require inspection and potential upgrade. This work would involve re-constructing a 150 ML/day culvert and drop structure into the Loddon River. Photographs showing the existing channel and culvert are shown in **Figure 22**.

Lake Charm outfall channel, U/S of Hogg Rd culvert

Culvert on Hogg Rd discharging to the Loddon River

Existing culvert requiring remedial works

Discharge location to the Loddon River

Figure 22. *Site photographs of the Lake Charm outfall channel and culvert*

Lake Charm salinity considerations

The use of Lake Charm for the purposes of the VMMS is currently limited due to the operational costs of pumping and the salinity rules.

Under historic practices, salinity levels in Lake Charm averaged around 5,000 EC. To minimise salinity increases in the River Murray, the Lake Charm outfall is subject to the Lake Charm Disposal Pumps Operational Procedures, which limit releases to periods of high River Murray flows.

Since the VMMS operating plan has been in place, the salinity levels in Lake Charm have decreased to less than 2,000 EC. In their annual operating plans, GMW currently propose interim operating rules for discharges from Lake Charm, which consider a lower requirement for dilution flows. It is expected that the enhanced use of the storage for harvesting and delivering water to the River Murray would further reduce salinity levels in the lake through more frequent operation. This is based on previous experiences with similar storages.

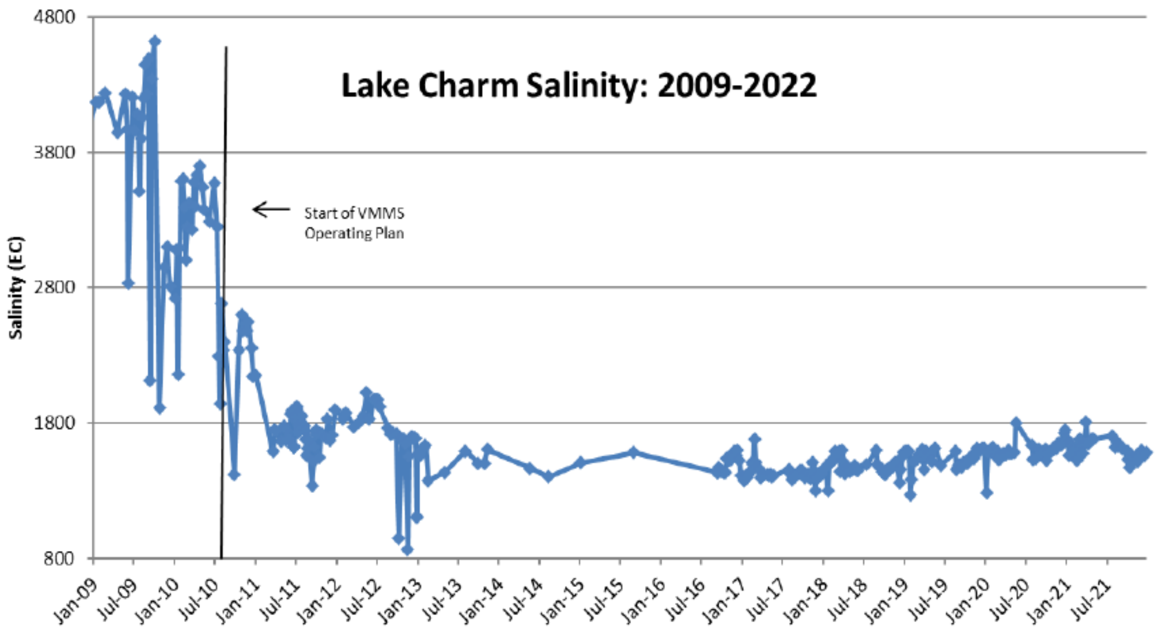

Figure 23. *Lake Charm salinity levels in the recent record*

Summary of proposed investigations and works

The infrastructure necessary for the VMMS to contribute to the objectives of the BMFS is already in place, with enhancement works proposed to include:

- engineering investigations, targeted site inspections, and detailed review of system characteristics to confirm the scope of works required.
- construction of a regulating structure on the Lake Boga outfall (5-barrel culvert to support 1,000 ML/day capacity and non-return flaps).
- de-silting and re-profiling of the Lake Boga outfall channel (1.5km).
- survey, design, and removal of sandbar near the Lake Boga outfall regulator.
- targeted re-profiling of the TO 6/7 channel to support higher flow deliveries (1.0km).
- construction of a new discharge culvert on the Lake Charm outfall channel (150 ML/day).

Discharge rate and volume

Assuming that the VMMS are used to supply high volumes over a short period (10 days) to assist with a potential delivery shortfall event, following the enhancement works, it is expected that:

- Lake Boga may contribute around 500 ML/day (a total of 5 GL), subject to confirming how much the discharge flow rate is improved by undertaking the works.
- Kangaroo Lake may contribute around 500 ML/day (a total of 5 GL), subject to the available capacity in the TO 6/7 channel.
- Lake Charm may contribute around 150 ML/day (a total of 1.5 GL), subject to the interim operating rules for managing salinity.

This equates to a total flow of around 1,150 ML/day sustained over a 10-day period.

5.3 Ecological considerations

This option engages a number of natural waterbodies and watercourses, including:

- Kangaroo Lake
- Lake Charm
- Lake Boga
- Pyramid Creek
- Loddon River
- Little Murray River

The lakes hold social, environmental, and cultural significance with Ramsar status to both Kangaroo Lake and Lake Charm. The Ramsar status means both Kangaroo Lake and Lake Charm have additional criteria to consider in terms of ecological tolerance in their use as storages.

Specific to the ecological assessment of this storage option is the drawdown rate of each of the lakes, to ensure the water level does not drop at an unsustainable rate. The depth and variability requirements are designed to ensure that the mosaic of vegetation types within the lakes are sustained. While there is no direct specification, a key component of the variation is the rate of water level fall as water is released from the storage. This is mainly due to the need to give aquatic and amphibious plants time to become established before the sediments dry. Major changes to the rate of draw-down could affect the vegetation community with cascading influences on the invertebrate, fish, and waterbird communities.

Lake Charm

In its natural state, Lake Charm is a terminal lake filling and lowering in response to flow changes in the Loddon River, Sheepwash Creek and Kerang Wetlands. Since the commencement of irrigation regulation there has been minimal flushing of Lake Charm due to water levels being held high to support gravity supply, resulting in salt accumulation.

Rising salinity threatened the viability of diverters irrigating from Lake Charm and in the mid-1990s the Lake Charm Flushing Station and Drain were constructed to draw down the lake and discharge flow into the Loddon River and River Murray when sufficient flow was available for dilution that would mitigate EC impacts. The Millennium Drought provided no opportunities to operate the station, with the largest flushing event occurring in the 2010/11 drought-breaking flood.

Lake Charm is also part of the Ramsar listed suite of Kerang Wetlands which are important for the diversity of wetland types, their support of diverse vegetation and threatened species. The Ramsar character description identifies Limits of Acceptable Change (LAC) to sustain the character of each lake.

For Lake Charm there are three LAC that need to be considered under this option:

- Permanently inundated
- Water level to not be > 74.1 m AHD or < 72.9 m AHD for more than two years in a row.
- Salinity should not be greater than 4000 EC when more than 75% full [14]

The above limits are the revised LAC from 2016. A previous limit to Lake Charm was 'to not exceed the 1000mm range of water levels two years in a row'. We have retained use of this LAC to assess the acceptable change in water level due to delivery of bulk water in a shortfall event.

While rate of fall is known to be important, there is little specific information on the requisite rates of draw-down due to variations among sites and vegetation types. We analysed historical operation data to identify the rates of drawdown for Lake Charm on the basis that historical management practices have sustained the lake in their current condition and are therefore likely to sustain condition if continued. The 10th and 90th percentile

[14] Butcher, R. and Hale, J. (2016*) Addendum to Ecological Character Description for the Kerang Wetlands Ramsar Site. DELWP, East Melbourne*

daily draw-down rates for Lake Charm were 0.3cm and 5cm respectively. The 90th percentile values correspond to 259 ML/day.

The provision of additional water for storage in Lake Charm and operational decisions to remain within the specified height limits will ensure that the permanent and freshwater characteristics are sustained. The current outlet capacity for the Lake is limited by the pump to 150 ML/day which is well below the 90th percentile and so water could be released at the outlet's full capacity.

The proposal has also been developed around a 10-day release of water from the Lake. Lake Charm operated at outlet capacity of 150 ML/day would release its entire storage volume of **1,500 ML in 10 days**. This volume of release is approximately 500mm change in water level and is within the previous Ramsar LAC of 1000mm range in fluctuation in water level two years in a row.

The delivery volume of 1,500 ML is within the active storage volume of 3,590 ML.

Kangaroo Lake

Kangaroo Lake is part of the Ramsar-listed suite of Kerang Wetlands which are important for the diversity of wetland types, and their support of diverse vegetation and threatened species. Kangaroo Lake is one of three permanent freshwater lake with little emergent vegetation used as a storage. As one of the permanent lakes within the Kerang Lakes Ramsar site, the lake represents an important refuge during drought conditions when most natural wetlands in the region would dry. Across the Ramsar site in dry years, an average of 20,000 waterbirds have been recorded with a maximum of 55,900. Kangaroo Lake also supports regional vegetation diversity due to the presence of riverine chenopod woodland which is dominated by black box with a shrubby understorey with species such as tangled lignum, nitre goosefoot (Chenopodium nitraria), and various saltbushes (e.g. Atriplex spp.).

The Ramsar character description identifies Limits of Acceptable Change (LAC) to sustain the character of each lake.

For Kangaroo Lake the same three LAC need to be considered under this option:

- Permanently inundated
- Water level to not be > 74.1 m AHD or < 72.9 m AHD for more than two years in a row.
- Salinity should not be greater than 4000 EC when more than 75% full [15]

The above limits are the revised LAC from 2016. A previous limit to Kangaroo Lake was 'to not exceed the 600mm range of water levels two years in a row'. We have retained use of this LAC to assess the acceptable change in water level due to delivery of bulk water in a shortfall event.

While the rate of fall is known to be important, there is little specific information on the requisite rates of draw-down due to variations among sites and vegetation types. We analysed historical operation data to identify the rates of drawdown for Kangaroo Lake on the basis that historical management practices have sustained the lake in their current condition and are therefore likely to sustain condition if continued. We identified the 10th (0.3cm) and 90th (3cm) percentile draw-down rates for Kangaroo Lake. The 90th percentile values correspond to 363 ML/day. The current outlet capacity for the Lake is 500 ML/day and so protecting the Lake would require a reduction in outflows below the design capacity to keep the rate of fall tolerable. This is an estimate and it is possible that greater releases could be tolerable, but further work would be required to identify vulnerable vegetation communities and particular times or conditions under which their vulnerability increases (heat waves, germination).

The proposal has also been developed around a 10-day release of water from the Lake. For Kangaroo Lake operated at 363 ML/day would release a volume of **3,635 ML in 10 days**. This volume of release is approximately 550mm change in water level and is within the previous Ramsar LAC of 600mm range per year in fluctuation in

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[15] Butcher, R. and Hale, J. (2016) *Addendum to Ecological Character Description for the Kerang Wetlands Ramsar Site. DELWP, East Melbourne*

water level two years in a row. Caution would therefore need to be exercised if the option were implemented two years in a row as the flows would approach the identified limit of 1200mm over two years.

The delivery volume of 3,635 ML is within the active storage volume of 7,840 ML.

Lake Boga

Lake Boga is one of the four mid-Murray storages. The Lake's active storage volume is 21 GL and, when full, covers 940 Ha. Lake Boga is a popular recreational and tourism destination with boating and angling popular activities.

The use of Lake Boga as a storage has been associated with an increase in social values. Implementation of the option may impact these social values. Following the method applied to Kangaroo Lake and Lake Charm we examined rates of fall on Lake Boga. The 10th and 90th percentile draw-down rates for Lake Boga were 0.1cm and 4cm respectively. These values correspond to 372 ML/day if no additional water is being added. The current outlet capacity for the Lake is 500 ML/day which represents a 26% increase above the 90th percentile. While vegetation around Lake Boga contributes to its environmental and social values, there is greater scope to increase release rates (from 372 to 500 ML/day) and use this as an opportunity to examine effects on vegetation communities with adaptive management.

The proposal has also been developed around a 10-day release of water from the Lake. Lake Boga operated at outlet capacity of 500 ML/day would release 5,000 ML over 10 days, which would translate to a change in depth of around 550mm. Once again, this may represent a short-term decline in amenity, but timing and weather conditions will also be significant influences.

The delivery volume of 5,000 ML is within the active storage volume of 20,907 ML.

Waterways

The three lakes have inflows delivered via Pyramid Creek and various channels. The lakes then discharge:

- From Lake Charm into the lower Loddon River
- From Kangaroo Lake into the Little Murray River (via channels)
- From Lake Boga into the Little Murray River

These waterbodies are shown in Figure 24 and the assessment of each reach follows.

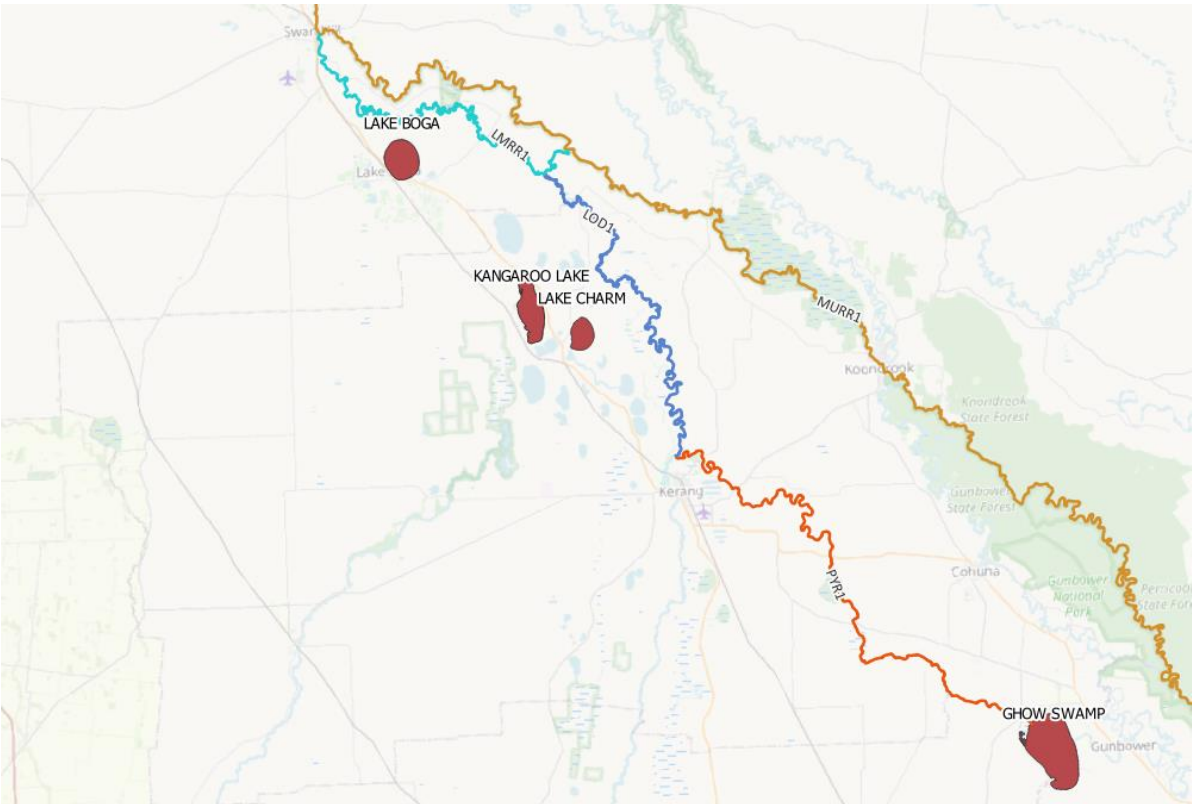

Figure 24. *Study river reaches and waterbodies*

Pyramid Creek - PYRR1

Pyramid Creek forms at the confluence of Bullock Creek and Box Creek. Box Creek flows from Ghow Swamp in the west. Pyramid Creek flows generally northwest for around 60 km, before meeting the Loddon River at Kerang weir pool, just upstream of Kerang Weir and north of the town of Kerang. The Creek flows through a flat alluvial plain.

Inflows are influenced primarily through released water from Ghow Swamp (part of the Mid-Murray Storages), including water diverted from Torrumbarry Weir and harvested unregulated inflows from the south via the Bendigo Creek / Mt Hope Creek system. Unregulated flows also flow to this reach from Bullock and Calivil Creeks[16].

Pyramid Creek was extensively dredged in the 1960s for use as an irrigation supply channel[17]. The hydrology of Pyramid Creek has been further altered with the advent of flood control work, irrigation and drainage works. These works have caused large sediment loads to be delivered downstream, along with salinity problems in the Creek due to highly saline groundwater discharging to the Creek[18]. The Creek is part of a salt interception scheme aimed at reducing salinity downstream[19].

[16] NCCMA (2015b) Loddon River System Environmental Water Management Plan, North Central Catchment Management Authority, https://www.vewh.vic.gov.au/__data/assets/pdf_file/0007/368710/Loddon-River-EWMP.pdf

[17]Jacobs (2015) Loddon River Environmental Flows update for the EWMP, prepared for North Central Catchment Management Authority, https://www.vewh.vic.gov.au/__data/assets/pdf_file/0007/357541/Loddon-River-Environmental-Flows-update-for-the-EWMP_Final.pdf, MDBA (undated) Pyramid Creek Salt Interception Scheme, summary factsheet, https://www.mdba.gov.au/sites/default/files/pubs/MDBA-13722-Pyramid-Creek-WEB-FA.pdf

[18] Jacobs (2014) Pyramid Creek Environmental FLOWS Study, prepared for North Central Catchment Management Authority, https://www.vewh.vic.gov.au/__data/assets/pdf_file/0009/357543/Pyramid_Final_Environmental_Flow_Recommendations_Report.pdf, MDBA (undated)

[19] MDBA (undated)

Pyramid Creek is now an artificially deep and narrow, homogenous, trapezoid channel with steep banks and narrow benches, lacking geomorphological features such as pools and riffles[20]. Dredging and deepening of the channel has disconnected Pyramid Creek from the floodplain, including Hird and Johnson Swamps[18]. Bank erosion is currently an issue along Pyramid Creek. The delivery of sustained high flows (up to 1,000 ML/day) at the start of the irrigation season has the potential to create notching on the riverbanks and increases the likelihood of bank erosion. This risk of notching can be offset by slowly varying water delivery levels to allow time for any bank vegetation to recover and to reduce the rate of notch development on the bank. Such a flow regime would be detailed at a later stage. The channel shape is uniform, with less riparian vegetation and more bank erosion in upstream reaches (upstream of Hird Swamp) [18].

The overarching environmental objective for Pyramid Creek is to enhance the value of the creek as "*a conduit for the dispersal of aquatic fauna such as native fish, platypus and freshwater turtles*"[18]. Within this overarching objective there are three further specific objectives:

- Maintaining and enhancing native **fish movement, colonisation, recruitment, habitat and connectivity;**
- Maintaining and promoting **fringing vegetation on the lower banks of the channel; and**
- Maintaining and enhancing channel conditions to facilitate the dispersal of juvenile platypus and Eastern long-necked turtles.

Pyramid Creek would be used as part of the filling of the lakes in winter and spring. The documented flow recommendations for Pyramid Creek in winter-spring are listed in **Table 6**:

Table 6. Environmental flow recommendations for Pyramid Creek in winter / spring season only[18].

Flow component	Flow objective	Flow recommendations
Low flow	Operate fishways, maintain connectivity and habitat for fish, Platypus and turtles Maintain and promote fringing vegetation along lower banks	90 ML/d in dry climatic season, delivered in mid-June to end August (minimum) 200 ML/d in wet or average climatic regime
High flows	Trigger and facilitate fish movement	900 ML/d, once in September for 10 days in wet or average climatic regime 900 ML/d, over 10 days. Not needed every year in dry climatic regime but no more than two consecutive years without.

Flows down Pyramid Creek over winter-spring are currently below 100 ML/day for 99% of the time. The environmental flow recommendations seek provision of spring freshes/ high flows of 900ML/day for 10 days. The provision of 1,000ML/day for 10 (and potentially up to 14) days would complement and in part fulfill this requirement. This suggests that the proposed additional flows of 1,000 ML/day in winter-spring has potential to improve the condition of Pyramid Creek and meet environmental objectives.

Overall, increasing flows are likely to improve opportunities for fish, platypus, and turtle movement. Increasing flows in winter and spring may improve riparian vegetation, but long duration of inundation (more than 14 days has potential to pose risk that existing vegetation would be replaced by more water dependent flood tolerant or semi-riparian vegetation species. This could be managed through the delivery of a more variable flow regime that comprised both 10-to-14-day peak flows of up to 1,000 ML/day and lower winter base flows.

[20] Jacobs (2014), NCCMA (2015b)

Loddon River - LODR1

This reach of the lower Loddon River from Kerang to the confluence with Little Murray River is approximately 70 km long. The waterway flows generally north, then northwest. Sheepwash Creek diverts from the Loddon just upstream of Kerang Weir, re-joining the river around 20 km downstream. The main tributaries include Pyramid Creek, joining upstream of Kerang Weir, and Barr Creek, joining the Loddon at Benjeroop Wildlife Reserve. Along with Pyramid Creek (discussed above), Barr Creek has been significantly modified through deepening and is highly saline[21]. Flow is regulated through this reach by the Kerang Weir where water can be diverted from the weir pool towards the Kerang Lakes, released to downstream reaches of the Loddon. Fish Point Weir at the end of the reach controls flows into the Little Murray River[21].

The Loddon River downstream of Kerang would have likely been a discontinuous channel historically, with wide, shallow sections full of vegetation and a mosaic of anabranching channels between deeper pools. The main flow path being what is now known as Sheepwash Creek. The volume of water in the lower Loddon River in summer has increased with operation of Kerang weir pool and dredging and use of Pyramid Creek as an irrigation supply channel[22]. In the lower part of the reach, the Little Murray can generate a backwater that extends as far upstream as Banjeroop[22]. This change in hydrology and delivery of large sediment loads from Pyramid Creek has partially filled many pools and created sediment bars[22]. Historically, flows would have inundated the floodplain, however levee banks now isolate the channel from its floodplain. Prior to regulation, flow in the Loddon River would have been the reverse of current regulated flows and seasonally variable, with high flows and regular flooding in winter and spring and low flows to no flow in summer and autumn[23].

This reach is highly sinuous, flowing through an expansive alluvial plain. The channel has relatively uniform morphology with sections up to 20 m wide and 3 m deep. The channel is generally flatter and more uniform than it would have been naturally. Sedimentation in the reach has resulted in formation of mid-channel islands[21].

The Environmental Flow Study for the Loddon System recommended a bank full flow magnitude of 2,000 ML/day, measured at Kerang Weir (Lower Loddon River; Reach 5)[22]. The low gradient of the Loddon in this reach means shear stress generated by bank full flows of this magnitude are unlikely to re-create large pools but may maintain existing pools[22]. This suggests flows of this magnitude would not lead to significant deepening and bed scour. Levee banks and disconnection from the floodplain mean overbank flows are uncommon.

Under this proposal, the Loddon River would receive inflows from Pyramid Creek over winter and spring into the Kerang Weir pool. The water is then diverted from the weir pool to the mid-Murray storages. The weir pool is a highly modified environment and whilst not devoid of environmental value, the effects of slow delivery of additional flows to fill the lakes is unlikely to have any adverse impact on the already degraded state of the channel.

The environmental goal for the Loddon River is to "*Promote a widespread and diverse aquatic fauna community particularly native fish and platypus, by providing high quality breeding and feeding habitat and where possible facilitating movement throughout the Mid-Murray Floodplain System. Rehabilitate riparian River Red Gum vegetation communities along the river, and where possible connect floodplain habitats, through the provision of an appropriate flow regime*". To contribute to this goal, the following flow recommendations are developed for environmental flow reach 5:

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[21] NCCMA (2015b)
[22] Jacobs (2015)

Table 7. Relevant environmental flow recommendations and objectives in Loddon River

Flow component	General flow objective	Flow recommendations
Summer low flow	Maintain sufficient depth throughout the run habitats in the channel to maintain a variety of habitats for fish, macroinvertebrates, Platypus and aquatic vegetation.	60 – 100 ML/d over 6 months from Dec – May
Summer freshes	Facilitate large-bodied native fish to move upstream through the Kerang Weir fishway. Generate sufficient shear stress to flush fine silt from submerged wood and other hard surfaces. Promote wetting and drying of biofilms on submerged wood during the growing season and promote the growth of non-woody emergent vegetation on the low banks of the river.	220 ML/d, 3 events per year (1 event in Dec – Feb, 2 events in Mar – May), 2-3 days at peak

There is a recognised trade-off between delivering summer freshes to promote riparian vegetation and disturbing slackwaters that may support fish recruitment. Jacobs recommend three freshes to support riparian vegetation however, it is acknowledged that this should be reviewed once riparian condition has improved to ensure native fish recruitment is not impacted[24].

The Loddon River would also receive releases from Lake Charm which would be in the order of 150 ML/day in summer for up to 10 days. Flows in December have historically been declining from spring peaks of around 800 ML/day to summer flows between 100 and 200 ML/day. The additional flows would contribute to the provision of a summer fresh in the Loddon River.

The additional flows would not contribute to overbank events and as a consequence wetland and floodplain vegetation would not be affected. The proposal seeks 10 days of higher flows and this will not represent a threat to the banks of the river. Within the context of the delivery of irrigation flows, the additional flows may provide some much-needed flow variability. In summary, there may be some risk to littoral vegetation, however, overall, impacts would be expected to be minor.

Little Murray River – LMRR1

The Little Murray River, previously known as the Marraboor River, is an anabranch of the River Murray. The Little Murray Weir located near Swan Hill was built in the early 1900s providing gravity irrigation into the No. 9 Channel through Swan Hill, Tyntynder Flats and across to the Beverford/Woorinen Area.

In response to rising salinity in the Barr-Pyramid Creeks the Little Murray River was disconnected from the River Murray by construction of the Fish Point Weir. Supply to the weir pool normally occurs via Pyramid Creek to Kerang Wetlands via the 6/7 Channel. However, during times of poor water quality the 6/7 Outfall is closed, and the Pental Island pumps are used to deliver flow into the weir pool. In times of River Murray flooding the Fish Point Weir is opened and additional flows spill through the Little Murray River.

Since completion of the Connections Modernisation program the Little Murray Weir has been lowered, a fish ladder constructed, and the No. 9 Channel reconfigured for a pumped supply. Significant improvements in water quality have allowed Fish Point Weir to operate fully open which allows flows in the River Murray to reconnect to the Little Murray River.

Historically, the Little Murray was an ephemeral anabranch of the River Murray. This characteristic has been lost and there is no intent to restore cease-to-flow events. There are no environmental flow recommendations for

[24] Jacobs (2015)

the Little Murray, but based on the Loddon River, summer low flows and freshes would be desirable. Currently over summer, the median flows at Little Murray River are 183 ML/d.

Under this proposal, the Little Murray would receive up to an additional 150 ML/day from Lake Charm via the Loddon River, 360 ML/day from Kangaroo Lake via channel 6/7 and 500 ML/day from Lake Boga via the Lake Boga outfall. In combination (without considering transmission losses), this would represent an additional 1,010 ML/day into the downstream end of the Little Murray River.

The addition of 1 GL of daily flow for ten days will significantly increase the flows in the Little Murray (i.e. 1,183 ML/d in total).

The bankfull capacity of the Little Murray is estimated around 4,000 ML/day. The additional flows will remain at less than half bank full and in this respect would operate in a manner similar to a summer fresh and would not represent a threat to floodplain or aquatic vegetation.

The velocity and shear stresses in this reach of the Little Murray are expected to be very low and the short release (fresh) is unlikely to initiate any significant erosion.

Summary of ecological considerations

This assessment has revealed that use of Victoria's mid-Murray Storages has some potential for adverse ecological impacts. However, these potential impacts can be managed by operating the system in a manner that supports identified values such as the provision of high winter or spring events for infilling the lakes via Pyramid Creek, the provision of storage releases in summer that reflect summer freshes in the Loddon and Little Murray River and controls on the rate of drawdown in the storages. A summary of the proposed limitations on the use of the waterways and lakes is provided in **Table 8**. These limits or controls are preliminary and suitable for a feasibility assessment, but should be the subject of more detailed assessments, should this option proceed beyond the feasibility stage.

Table 8. Storage volumes, recommended ecological drawdown rates and river flow rates for VMMS

Waterbody	Available storage (ML)	Maximum drawdown rate (ML/day)	10-day Delivery volume (ML)	Limiting factors	Tolerable additional flow rate (ML/day)
Lake Charm	3,590	150	1,500	Existing drawdown (pump rate), Ramsar criteria, water level fluctuation	
Kangaroo Lake	7,840	363	3,635	Historic drawdown rates, Ramsar criteria, water level fluctuation	
Lake Boga	20,907	500	5,000	Impact on social use	
Total	32,337	1,013	10,135		
Pyramid Creek					1,000 (winter conveyance)
Loddon River					150 (as summer fresh)
Little Murray River					1000 (as summer fresh)

5.4 Proposed works and flow capacity

The proposed scope of works to enhance the use of the VMMS includes:

- Works to reinstate discharge capacity:
    - engineering investigations, targeted site inspections, and detailed review of system characteristics to confirm the scope of works required.
    - construction of a regulating structure on the Lake Boga outfall (5-barrel culvert to support 1,000 ML/day capacity and non-return flaps).
    - de-silting and re-profiling of the Lake Boga outfall channel (1.5km).
    - survey, design, and removal of sandbar near the Lake Boga outfall regulator.
    - targeted re-profiling of the TO 6/7 channel to support higher flow deliveries (1.0km).
    - construction of a new discharge culvert on the Lake Charm outfall channel (150 ML/day).
- Enhanced operational arrangements: the management of the VMMS is currently described by an Annual Operating Plan for the storages. Enhancing the use of the VMMS will require operational models and coordinated operating arrangements to be developed to better support GMW operators. These arrangements should include consultation with Victorian entitlement holders regarding the proposed changes (including cost recovery). There may also be a requirement for additional GMW resourcing to undertake the management of the storage system, including ongoing consultation with the key stakeholders.

- Salinity management: the interim release rules for Lake Charm are proposed each year to increase VMMS operational flexibility. The finalisation of these interim rules should be progressed and, once agreed to by Basin states, the rules would be subject to longer-term monitoring of salinity in Lake Charm under ongoing VMMS operation.
- Cultural heritage: ongoing consultation with Traditional Owners on the management of the storages, including Ghow Swamp, should include consideration for any changes to the operation of Lake Boga, Kangaroo Lake, and Lake Charm.

- Social and environmental investigations: there are a wide-range of social and environmental values which may be affected by changing the operating regime for the storages. These matters should be investigated in consultation with key stakeholder groups and any appropriate mitigation measures identified. This would include engagement with the community and recreational groups.

With a combined active storage of 30 GL and a combined discharge capacity of around 1,000 ML/day which could be sustained over a 10-day period, the storages could be used to:

- Assist with managing potential delivery shortfalls: by providing a high flow over a short period, which could be provided to the lower Murray with limited notice. This would require high volumes to be delivered from each of the storages for a short period (10 days). Lake Boga could provide a flow of 500 ML/day (subject to the discharge capacity being improved), Kangaroo Lake could provide a flow of 360 ML/day (subject to ecological limits on drawdown rates and demand on the TO 6/7 channel), and Lake Charm could provide 150 ML/day (subject to the interim operating rules for managing salinity). In total, around 1,000 ML/day could be provided in this period for a total volume of around 10 GL.
- Assist with managing potential system shortfalls: by providing a sustained flow over a longer period. This would assist river operators with managing potential system shortfall events. This could occur over summer, which would reduce the volume of water needing to be released from Lake Hume and take pressure off the Barmah-Millewa Reach. The active storage between Lake Boga, Kangaroo Lake and Lake Charm is 30 GL. Accordingly, if released over a sustained 100-day period, the storages could provide up to an equivalent of 300 ML/day/100-days.

5.5 Cost to implement

The cost estimates for this option were developed using actual construction costs from similar projects as provided by GMW and MIL. To calculate the 2022 present value, inflations rates were sourced using the publicly available Producer Price Indexes published by the Australian Bureau of Statistics[25]. The total costs for the Victorian Mid-Murray storages option are summarised in **Table 9.**

Complexity levels (high, medium, and low) have been applied to estimate program management, survey, design, approval, overhead, operational and maintenance costs. These complexity levels correspond with a percentage to be applied and qualitatively estimates the amount of work required in each of those categories to deliver the works.

Additional asset maintenance and renewal costs have been calculated in present annual value as a % of the capital cost. A 2% per annum allowance has been included. This recognises that the assets are mostly static and long-lived, existing assets are being updated which would reduce maintenance and asset renewal liability, and new or expanded assets are being installed which would increase the maintenance and asset renewal liability. This allowance generally considers the above factors; however, the actual contribution for asset maintenance and renewal costs would need to be further detailed and negotiated as part of any further option development.

The enhanced use of the VMMS would likely require additional operational management of the storages by GMW. An allowance for this increased operational management has also been included.

Budget allowances should be made to support the ongoing consultation with Traditional Owners and to support investigation of social and environmental changes expected as a result of the operating change.

The total O&M cost has been assessed over a 50-year period using a 7.0% discount rate.

Note that Victorian Murray bulk water customers currently pay for delivery services through the Torrumbarry Irrigation Area system to operate the VMMS. If the use is expanded to benefit all lower Murray users, it would be expected that they should meet any additional annual delivery charges through the TIA.

Table 9. Victorian Mid-Murray storages cost estimate

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	Infrastructure costs				2,833,421
1.1	**Lake Boga regulating structure (1,000ML/day)**				**1,300,000**
1.1.1	New culvert and drop structure – construct new (1,000 ML/day capacity)	1	1,300,000	/ ea	1,300,000
1.2	**Lake Boga channel de-silting and re-profiling**				**656,053**
1.2.1	Silt removal 10m3, (0 – 50km)	1.5	85,000	/ km	130,164
1.2.2	Outside bank modelling	1.5	350,000	/ km	525,888
1.3	**Lake Boga outfall sandbar removal**				**290,000**
1.3.1	Bathymetric survey	1	40,000	Lump sum	40,000
1.3.2	Sandbar removal (m3)	1	250,000	Lump sum	250,000
1.4	**TO6/7 channel targeted re-profiling**				**437,368**
1.4.1	Silt removal 10m3, (0 – 50km)	1	85,000	/ km	86,776
1.4.2	Outside bank modelling	1	350,000	/ km	350,592
1.5	**Lake Charm outfall discharge structure**				**150,000**
1.5.1	150ML/day discharge structure	1	150,000	/ ea	150,000

[25] Producer Price Indexes, Australia, March 2022 | Australian Bureau of Statistics (abs.gov.au)

2	**Investigations and operational arrangements**				**300,000**
2.1	**Enhanced operational arrangements – GMW Operators**				**200,000**
2.1.1	Establish enhanced VMMS operating plan	1	200,000	Lump sum	200,000
2.2	**Salinity Management**				**100,000**
2.2.1	Salinity Management planning and operations	1	100,000	/ year	100,000
3	**Program Management, survey, design, approvals and overheads**				**920,862**
3.1	**Program management and overheads**				**425,013**
3.1.1	Program management - Low complexity - 15% of capital costs	1	15.0%	percentage	425,013
3.2	**Survey, design and approvals**				**495,849**
3.2.1	Survey and Design - Medium complexity - 7.5% of capital costs	1	7.5%	percentage	212,507
3.2.2	Regulatory approvals including offsets - Medium complexity - 10% of capital costs	1	10.0%	percentage	283,342
4	**Contingency**				**1,621,713**
4.1	**Contingency**				**1,621,713**
4.1.1	40% of infrastructure, program management, survey, design, approval, and overhead costs	1	40%	percentage	1,621,713
	Total capital cost				**5,675,996**

5	**Operations and Maintenance**				**2,429,206**
5.1	**Operations and maintenance (NPV over 50 years, 7% discount)**				**2,429,206**
5.1.1	Additional maintenance and renewal costs as a result of upgrade works	1	2%	percentage	1,566,660
5.1.2	Additional operational management of the storages	0.25	$250,000	FTE per year	862,547

6 Shortlisted option investigation: Murray Valley Irrigation Area outfalls

6.1 Detailed description of the option

Overview

The channel system of Goulburn Murray Water's (GMW) Murray Valley Irrigation Area (MVIA) in northern Victoria diverts water from the River Murray at Lake Mulwala via the Yarrawonga Main Channel (YMC) to supply irrigators within the district (**Figure 25**). Several channels in the MVIA flow to the Broken Creek via outfall structures. The Broken Creek is a tributary of the Murray that flows into the river immediately downstream of the Barmah-Millewa Reach. This hydrological connection means the MVIA channels can be used to bypass flows around the Barmah-Millewa Reach, within the capacity of channel system.

There are several existing outfalls in the MVIA which are regularly used by the MDBA in collaboration with GMW to divert water around the reach. Four of these outfalls are located downstream of the confluence of the Nine Mile Creek and the Broken Creek, referred to as Lower Broken Creek reaches 3 and 4. This section of the creek is highly regulated, with weirs holding up the river level and facilitating the extraction of irrigation water. The environmental water target over summer in these reaches is up to 350 ML/day[26].

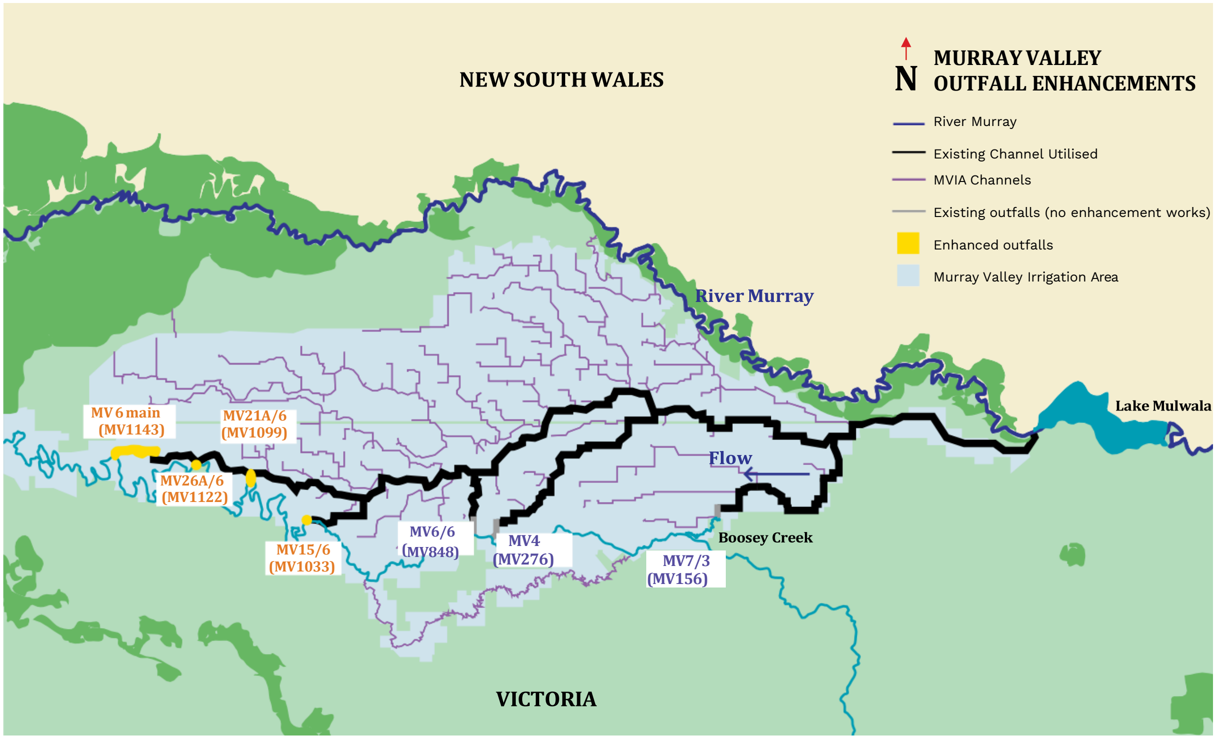

Figure 25. *Location of the existing outfalls from the MVIA into the lower Broken Creek.*

This option explores the potential to increase the capacity of the four existing MVIA outfalls to Reaches 3 and 4 to increase the supply to the River Murray downstream of the Barmah-Millewa Reach.

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[26] Jacobs (2019), *Lower Broken Creek Flows Study – Issues and Flow Recommendations Paper, Prepared for the Goulburn Broken CMA, March 2019.*

Table 10. Existing outfalls which supply discharge to the lower Broken Creek from the MVIA

Outfall	Current capacity	Outfall location
MV 6 main end outfall (MV 1143)	15 ML/day[1]	Lower Broken Creek Reach 4 (Broken Creek: Nathalia Weir to Murray River)
MV 26A/6 outfall (MV 1122)	30 ML/day	
MV 21A/6 outfall (MV 1099)	30 ML/day	Lower Broken Creek Reach 3 (Broken Creek: Nine Mile Creek to Nathalia Weir)
MV 15/6 outfall (MV 1033)	15 ML/day	
MV 6/6 outfall (MV 848)	20 ML/day	Lower Broken Creek Reach 1 (Broken Creek: Boosey Creek to Nine Mile Creek) *No increased flows considered for these outfalls*
MV 4 main outfall (MV 276)	10 ML/day	
MV 7/3 outfall (MV156)	60 ML/day	
TOTAL	180 ML/day	

[1]: this outfall is not currently used by GMW.

Current operating arrangements

The MDBA has arrangements in place with GMW to utilise the MVIA channel system and outfalls to bypass water around the Barmah-Millewa Reach. The channel system is available to convey bypass water during the irrigation season (August to May). In the most recent irrigation season 2021-22, a total of approximately 40,000 ML was bypassed through the channel system, with a flow of 140-150 ML/day delivered consistently throughout the summer months.

Limitations and opportunities

Initial investigations and consultation with the Goulburn Broken CMA (GBCMA) and GMW indicated that the potential to increase the bypass flow capacity from the MVIA into Lower Broken Creek would be limited by the ecological flow tolerances of the creek.

These flow tolerances are currently met by the delivery of intervalley transfers (IVT), River Murray bypasses using the MVIA outfalls (subject of this investigation), and environmental flows. Based on this initial consultation, any opportunity to increase outfall volumes is expected to be limited to around 100 ML/day.

6.2 Engineering & works considerations

MV 6 main outfall (MV1143)

The MV 6 main outfall is a disused outfall regulator and channel at the end of the Murray Valley 6 supply channel. Whilst outfall infrastructure remains in place with an existing capacity of delivering flows up to 15 ML/day, inspection of asset condition and works would be required if the outfall were to be actively used again.

There is potential to increase the capacity of the outfall through infrastructure upgrades.

Outfall infrastructure and arrangement

The MV1143 regulator is located at the end of the MV 6 channel, between the townships of Picola and Nathalia. The regulator outfalls into a channel which runs for approximately 4.3km before discharging into the Lower Broken Creek. There are existing crossings under Tinklers Rd, Murray Rd, Picola South Rd and Lindsays Rd. The channel also has occupational crossings for landholder access. There is a crest weir and pipe structure with headwall at the end of the channel which discharges into the lower Broken Creek.

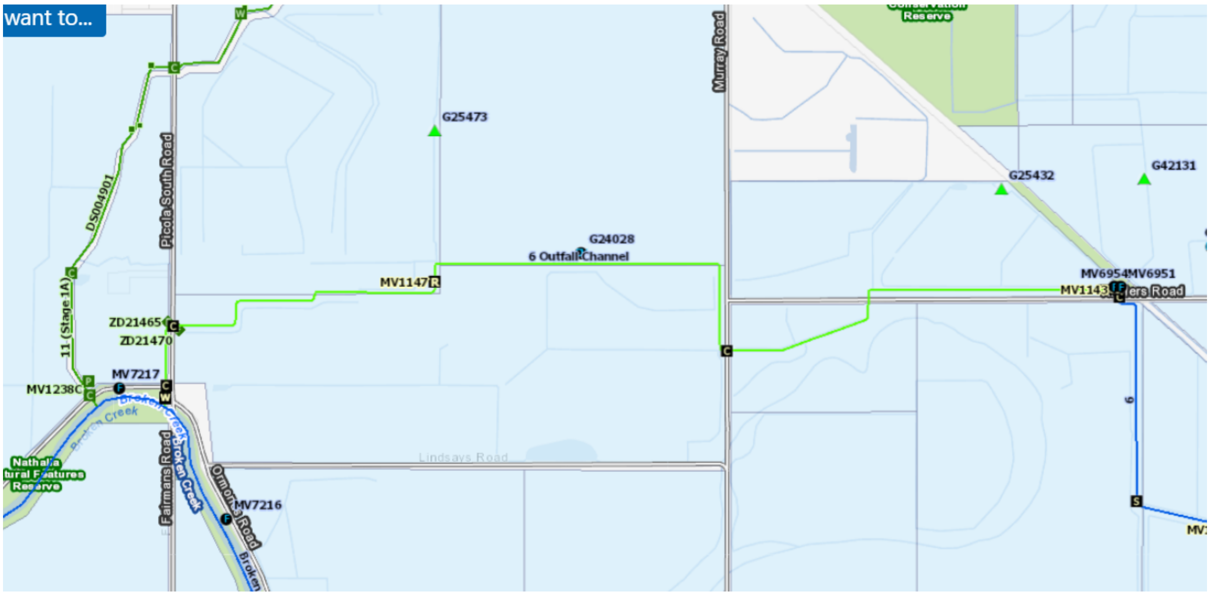

Figure 26. *Location of the MV 6 outfall channel and structures (highlighted in green)*

Flow capacity

The MV 6 channel directly upstream of the MV1143 outfall regulator (CH012220) has a design capacity of 73ML/day. GMW advise that the current capacity of the outfall is 15 ML/day, limited by the outfall infrastructure.

For the purposes of this feasibility study, it is assumed that the outfall infrastructure could be upgraded to deliver a sustainable flow of 50ML/day without needing to upgrade any infrastructure on the upstream channel. This would allow an additional 35ML/day to be delivered.

Infrastructure works

The existing infrastructure has been reviewed at a high-level to determine likely upgrade works required to deliver a flow of 50ML/day. **Table 11** below summarises the existing infrastructure and the proposed works.

Table 11. Infrastructure upgrades required to support additional MV6 outfall capacity

Infrastructure	Proposed works
Regulator - MV 1143	Replace with a new 50 ML/day capacity regulator (1-bay)
Regulator – MV 1147	Remove regulating structure
Channel - CH012226, CH012228, CH012229, CH012230, CH017250	De-silt and re-profile channel as required (4.3km)
Road crossings (x4)	No works. Information provided indicates that the existing road crossings are 1200mm, which would deliver more than 50 ML/day.
Occupational crossings (x1)	Replace with a new occupational crossing to support 50 ML/day
Crest weir and outfall structure	Replace with a new discharge pipe and headwall to support 50 ML/day

Site photographs

MV1143 regulator (upgrade)

MV1147 regulator (remove)

Lindsays Rd crossing (1200mm diameter, retain)

Entrance to lower Broken Creek (upgrade)

Figure 27. *Site photographs of the existing infrastructure for the MV 6 main outfall*

MV 26A/6 outfall (MV 1122, 'Flanners')

The MV 26A/6 outfall is an outfall regulator and open channel supplied from the Murray Valley 6 supply channel. The existing infrastructure supports flows of 30 ML/day. The outfall is actively used by GMW to provide flows into the lower Broken Creek, delivering around 4.5 GL during the 2021-22 water year. There is potential to increase the capacity of the outfall through infrastructure upgrades.

Outfall infrastructure and arrangement

The MV1122 regulator is located off the MV 6 channel near Peter Hawkey Rd, approximately 3km North-West of the Nathalia township. The regulator outfalls into an open channel which runs for approximately 80m before entering a road crossing and then discharging through a spillway into the Lower Broken Creek (MV1122D).

Figure 28. *Location of the MV 26A/6 outfall channel and structures (highlighted in green and purple)*

Flow capacity

The MV 6 channel directly upstream of the MV1122 outfall regulator (CH012233) has a design capacity of 135ML/day. GMW advise that the current capacity of the outfall is 30 ML/day, limited by the outfall infrastructure. This outfall is actively used for supplying the Lower Broken Creek. **Figure 29** confirms the current maximum sustained delivery was 30ML/day from the most recent water year.

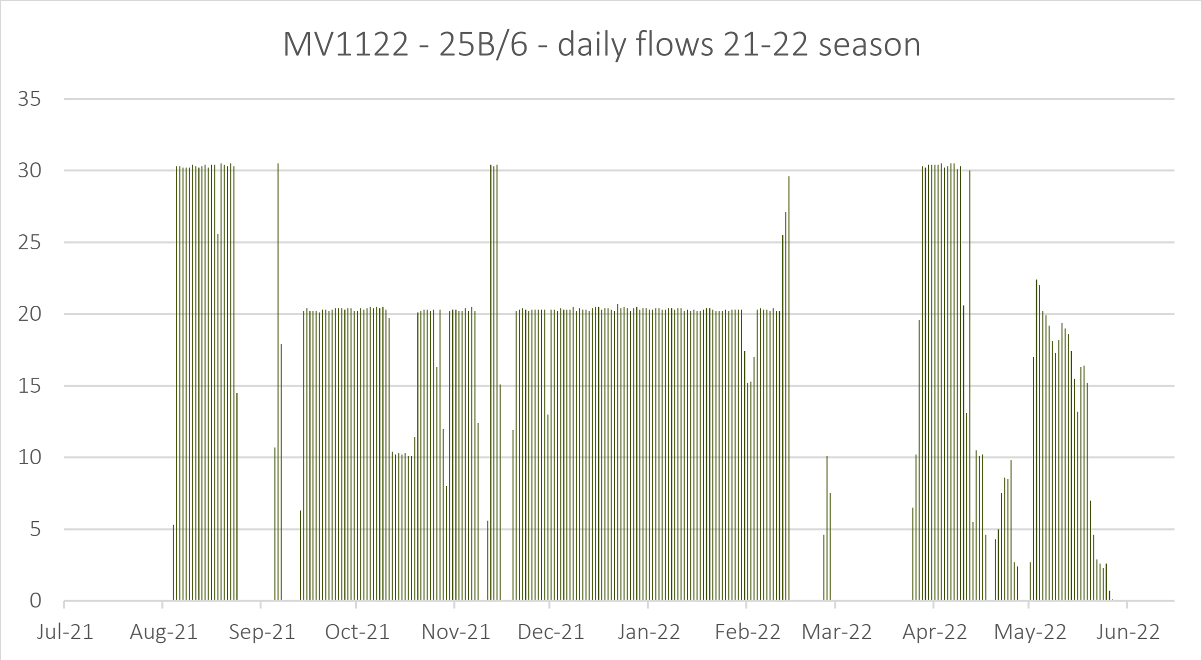

Figure 29. *Daily flow delivered through the MV1122 regulator during the 2021-22 water year*

For the purposes of this feasibility study, it is assumed that the outfall infrastructure could be upgraded to deliver a sustainable flow of 60ML/day without needing to upgrade any infrastructure on the upstream channel. This would allow an additional 30ML/day to be delivered.

Infrastructure works

The existing infrastructure has been reviewed at a high-level to determine likely upgrade works required to deliver a flow of 60ML/day. **Table 12** summarises the existing infrastructure and the proposed works.

Table 12. Infrastructure upgrades required to support additional MV26A/6 outfall capacity

Infrastructure	Proposed works
Regulator - MV 1122	Replace with a new 60 ML/day capacity regulator (2-bays)
Channel – CH017080	De-silt and re-profile channel as required (0.1km)
Road crossing (x1)	No works. The existing structure is a 1200mm diameter pipe. This should be sufficient to support 60 ML/day delivery
Combine regulator (spillway) – MV 1122D	Modify to support 60 ML/day delivery

Site photographs

MV1122 regulator (upgrade)

Existing road crossing (retain)

Spillway to creek (modify)

Spillway to creek (modify)

Figure 30. Site photographs of the existing infrastructure for the MV 26A/6 outfall

MV 21A/6 outfall (MV 1099, 'Jewells')

The MV 21A/6 outfall is an outfall regulator and open channel supplied from the Murray Valley 6 supply channel. The existing infrastructure supports flows of 30 ML/day. The outfall is actively used by GMW to provide flows into the Lower Broken Creek, delivering around 6.3 GL during the 2021-22 water year. There is potential to increase the capacity of the outfall through infrastructure upgrades.

Outfall infrastructure and arrangement

The MV1099 regulator is located off the MV 6 channel near Nathalia-Waaia Rd, approximately 3.5km North-East of the Nathalia township. The regulator outfalls into an open channel which runs for approximately 560m, passing through regulator MV1100, before entering a road crossing and then a small channel before discharging through a pipe and headwall structure into the Lower Broken Creek.

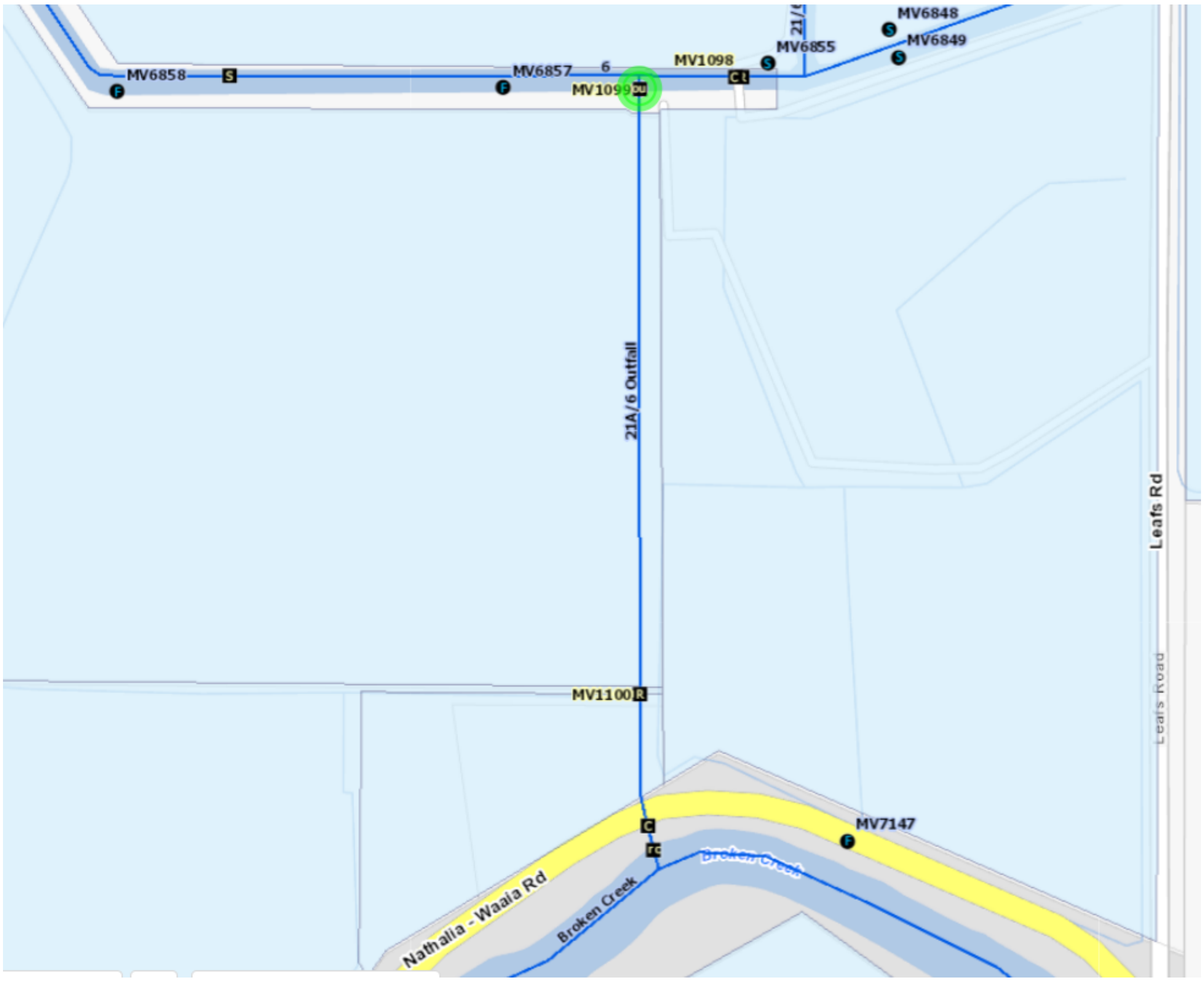

Figure 31. *Location of the MV 21A/6 outfall channel and structures (from the green dot and to the South)*

Flow capacity

The MV 6 channel directly upstream of the MV1099 outfall regulator (CH012139) has a design capacity of 196 ML/day. GMW advise that the current capacity of the outfall is 30 ML/day, limited by the outfall infrastructure. This outfall is actively used for supplying the Lower Broken Creek. **Figure 32** confirms the current maximum sustained delivery was 30ML/day from the most recent water year. Note that higher flow volumes were temporarily delivered at the end of May 22 (up to 60 – 70 ML/day), however this during the draining of the channels, and is not a sustainable flow rate for the outfall without infrastructure upgrades.

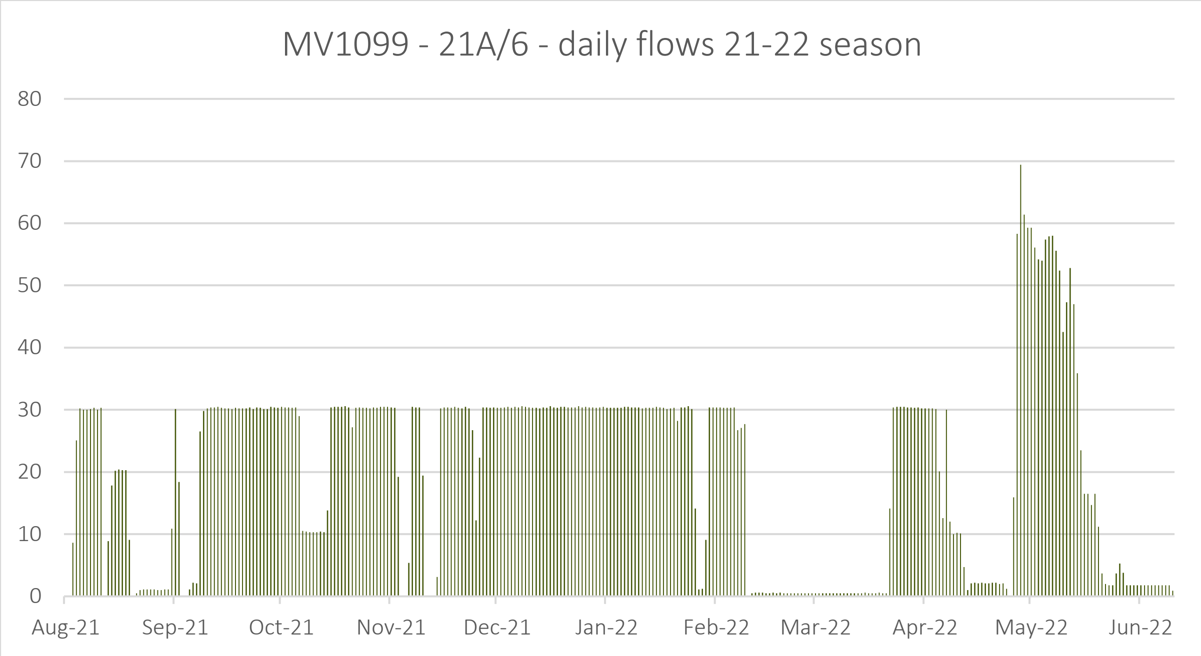

Figure 32. *Daily flow delivered through the MV1099 regulator during the 2021-22 water year*

For the purposes of this feasibility study, it is assumed that the outfall infrastructure could be upgraded to deliver a sustainable flow of 60 ML/day without needing to upgrade any infrastructure on the upstream channel. This would allow an additional 30 ML/day to be delivered.

Infrastructure works

The existing infrastructure has been reviewed at a high-level to determine likely upgrade works required to deliver a flow of 60 ML/day. **Table 13** summarises the existing infrastructure and the proposed works.

Table 13. Infrastructure upgrades required to support additional MV21A/6 outfall capacity

Infrastructure	Proposed works
Regulator – MV 10999	Replace with a new 60 ML/day capacity regulator (2-bays)
Regulator – MV1100	Remove regulating structure
Channel – CH012138	De-silt and re-profile channel as required (0.6km)
Road crossing (x1)	Replace road crossing with a 1200mm diameter crossing (existing structure is 750mm)
Pipe and headwall discharge structure	Replace structure with a 1050mm diameter pipe and headwall into the Lower Broken Creek

Site photographs

CH012138 channel (de-silt and re-profile as required)

MV1100 regulator (remove)

Existing road crossing (replace)

Discharge structure to creek (replace)

Figure 33. *Site photographs of the existing infrastructure for the MV 21A/6 outfall*

MV 15/6 outfall (MV 1033)

The MV 15/6 outfall is an outfall regulator and buried pipeline system supplied from the Murray Valley 15/6 channel. The existing infrastructure supports flows of 15 ML/day. The outfall is actively used by GMW to provide flows into the Lower Broken Creek, delivering around 2.4 GL during the 2021-22 water year. There is potential to increase the capacity of the outfall through infrastructure upgrades.

Outfall infrastructure and arrangement

The MV1033 regulator is located off the MV 15/6 channel near the intersection of Katamatite-Nathalia Rd and Kampsters Bridge Rd, approximately 9km South-East of the Nathalia township. The regulator outfalls into a buried pipeline which runs for approximately 125m before discharging through a structure into the Lower Broken Creek.

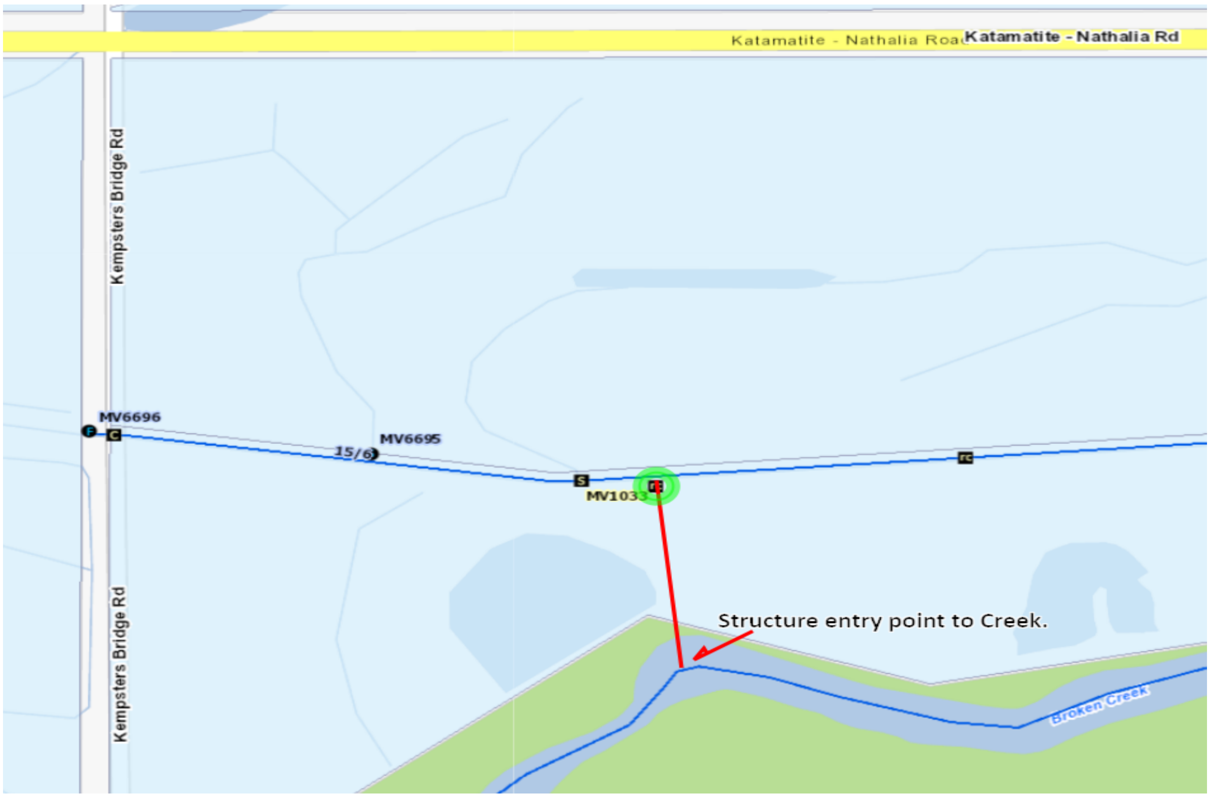

Figure 34. *Location of the MV 15/6 outfall channel and structures (green dot and red channel)*

Flow capacity

The MV 15/6 channel directly upstream of the MV1033 outfall regulator (CH009562) has a design capacity of 35 ML/day. GMW advise that the current capacity of the outfall is 15 ML/day, limited by the outfall infrastructure. This outfall is actively used for supplying the Lower Broken Creek. Figure 35 confirms the current maximum sustained delivery was 15 ML/day from the most recent water year.

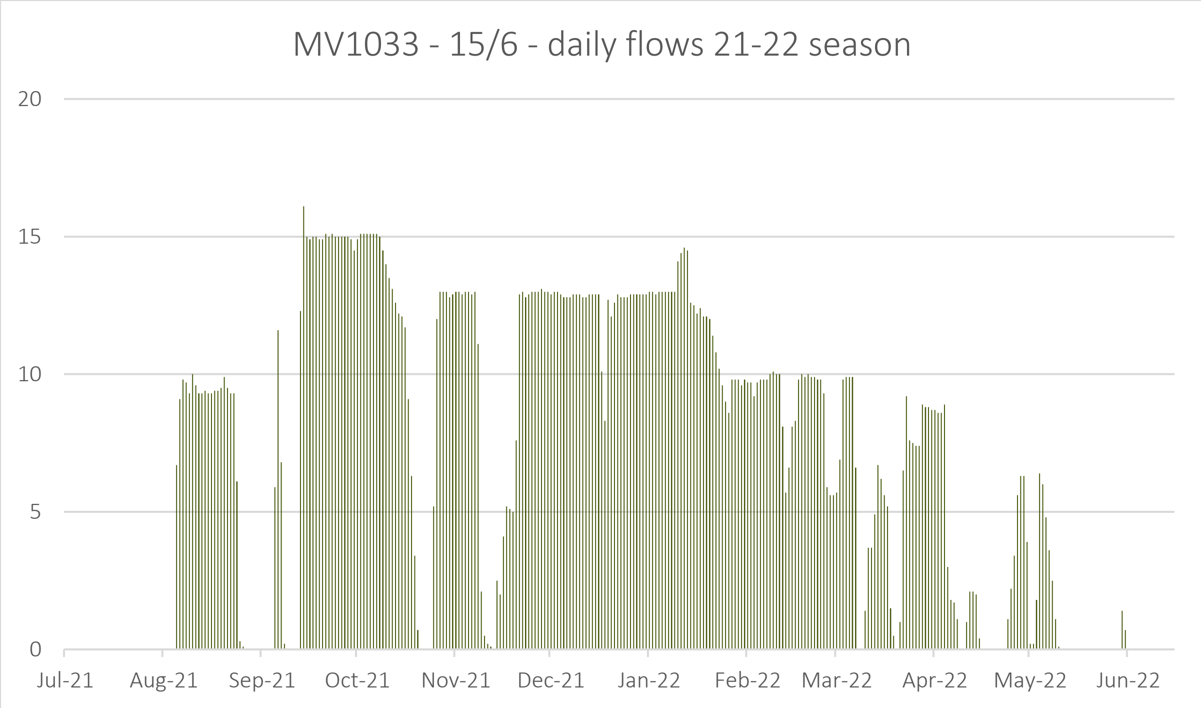

Figure 35. *Daily flow delivered through the MV1033 regulator during the 2021-22 water year*

For the purposes of this feasibility study, it is assumed that the outfall infrastructure could be upgraded to deliver a sustainable flow of 30 ML/day without needing to upgrade any infrastructure on the upstream channel. This would allow an additional 15 ML/day to be delivered.

Infrastructure works

The existing infrastructure has been reviewed at a high-level to determine likely upgrade works required to deliver a flow of 30 ML/day. **Table 14** summarises the existing infrastructure and the proposed works.

Table 14. Infrastructure upgrades required to support additional MV15/6 outfall capacity

Infrastructure	Proposed works
Regulator – MV1033	Replace with a new 30 ML/day capacity regulator (1 bay)
Pipeline	Existing pipeline is 600mm diameter. Replace with a new 30 ML/day pipeline, indicatively 900mm RC (125m)
Discharge structure	Replace headwall into Lower Broken Creek to suit increased pipe size.

Site photographs

MV1033 offtake regulator (replace)

MV1033 offtake regulator (replace)

Discharge headwall (replace)

Discharge headwall (replace)

Figure 36. *Site photographs of the existing infrastructure for the MV 15/6 outfall*

Murray Valley outfalls – summary of proposed works

The potential increases in outfall capacity and the expected works to support are summarised in **Table 15.** It is important to note that this upgraded capacity is based on the GMW channel system capacity and the outfall structures. The following section considers the ecological implications of providing additional flows to the Lower Broken Creek.

Table 15. Potential increased capacity and infrastructure works MVIA outfalls

Outfall	Existing capacity	Upgraded capacity	Proposed works
MV 6 main outfall (MV 1143)	15 ML/day	50 ML/day (+ 35 ML/day)	• Replace regulator (50ML/day) • Remove regulator • Desilt & reprofile channel (4.3km) • Replace crossing (50ML/day) • Replace discharge structure
MV 26A/6 outfall (MV 1122, 'Flanners')	30 ML/day	60 ML/day (+ 30 ML/day)	• Replace regulator (60ML/day) • Desilt & reprofile channel (0.1km) • Modify spillway
MV 21A/6 outfall (MV 1099, 'Jewells')	30 ML/day	60 ML/day (+ 30 ML/day)	• Replace regulator (60ML/day) • Remove regulator • Desilt & reprofile channel (0.6km) • Replace road crossing (1,200mm) • Replace discharge structure
MV 15/6 outfall (MV 1033)	15 ML/day	30 ML/day (+ 15 ML/day)	• Replace regulator (30ML/day) • Replace pipeline with 900mm RC (0.12km) • Replace headwall structure
MV 6/6 outfall (MV 848)	20 ML/day		• No works
MV 4 main outfall (MV 276)	10 ML/day		• No works
MV 7/3 outfall (MV156)	60 ML/day		• No works
TOTAL	180 ML/day	290 ML/day (+ 110 ML/day)	

6.3 Ecological considerations

Flora, fauna and water quality considerations

The Lower Broken Creek is the regulated section of Broken Creek between Katamatite and the River Murray. The creek has been highly modified from its natural state, with its main source of water being the Goulburn system through the East Goulburn Main Channel (EGM) and flows from the Murray system via MVIA outfalls. For the purposes of describing system characteristics and flow recommendations, the Lower Broken Creek is further delineated into four reaches as shown in **Figure 37**. The existing outfalls that have potential for bypass of the Barmah Millewa reach are located mostly within Reaches 3 and 4 of Broken Creek.

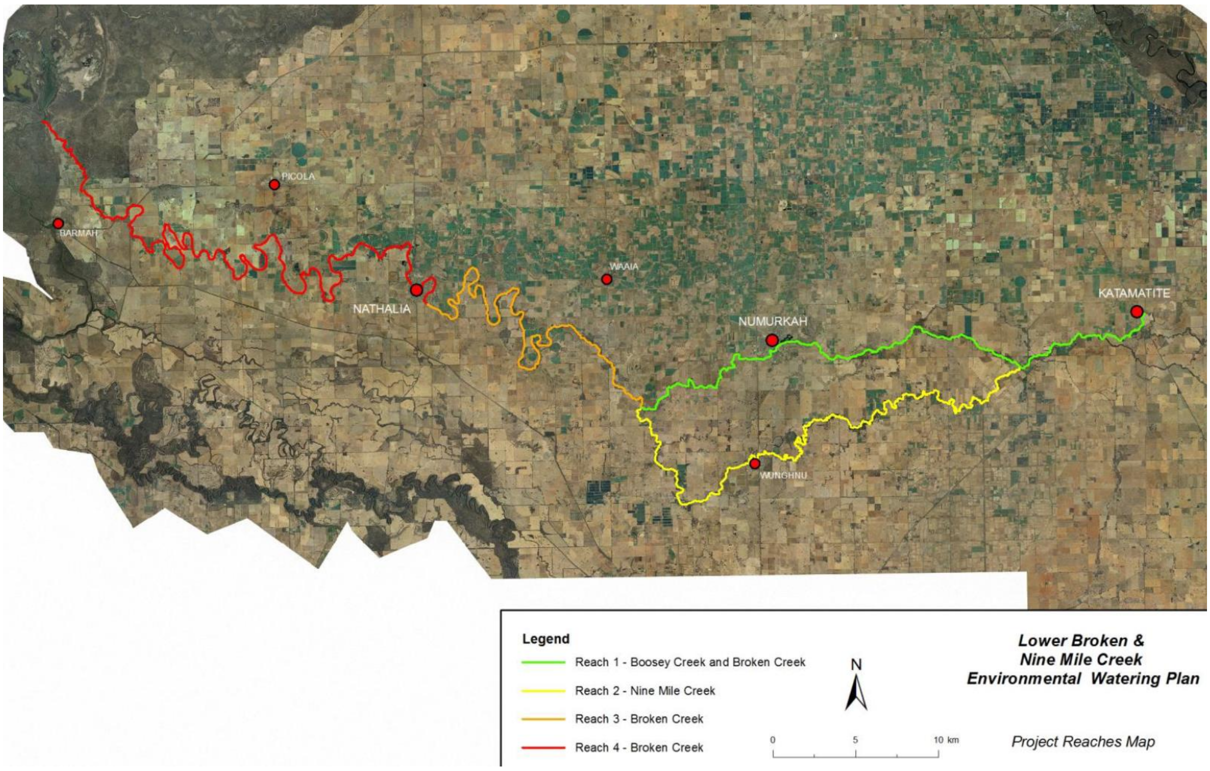

Figure 37. *The reaches of the Lower Broken Creek*[27]

There are 11 weir structures located in the Lower Broken Creek, with eight of these located downstream of Nathalia in Reach 4. As a result, there are a series of weir pools in this reach, which are generally operated to maintain a target and near constant high water level during the irrigation season to support the reliable extraction of irrigation and stock and domestic water. As a result of this operation, the hydrological regime has been highly modified and reversed from a natural flow regime, with flows highest in summer and lowest in winter[28].

The vegetation of the lower reach is dominated by mature red gums with little sign of regeneration. The understory is dominated by weeds and grasses with limited rushes and sedges. The macroinvertebrate community is dominated by tolerant species common to lowland rivers. There has been limited assessments of the fish community in the Lower Broken creek, however, the 2019 Flows study expects the lower reach to support 7 native species, including Murray cod (*Macullachella peelii*), Golden perch (*Macquaria ambigua*), Silver perch (*Bidyanus bidyanus*), unspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) and Murray-Darling rainbowfish (*Melanotaenia fluviatilis*). Increases in Murray cod numbers between 2000 and 2006 have been reported and attributed to the construction of fishways. It is also worth noting that 6 introduced species

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[27] SKM (2010), *Lower Broken Creek and Nine Mile Creek Hydrology, Prepared for the Goulburn Broken CMA, April 2010.*
[28] Jacobs (2019), *Lower Broken Creek Flows Study – Issues and Flow Recommendations Paper, Prepared for the Goulburn Broken CMA, March 2019.*

represent 80% of the abundance of fish in the system (ARI, 2008) and that Murray cod and Golden perch are both stocked in the creek.

The environmental flow objectives established for the creek are to maintain water quality, maintain existing fish population and macroinvertebrates, protect extent of littoral and riparian vegetation, and provide suitable conditions for platypus and turtles. The platypus objective appears redundant as the species has only been recorded since 2003 at the extreme upper end Reach 1[29]. A recent stakeholder workshop identified similar objectives, specifically, diverse fish community, good water quality and a balance between water delivery, cultural and environmental values. The main risk identified is erosion associated with delivery of water through the system which are perceived to be a threat to both in-stream values (e.g. large bodied native fish) and landscape values including the riparian reserve.

Water quality has also been identified as a risk. Low flows and freshes are critical in meeting water quality and refuge habitats along the creek. High base flow and freshes are required to prevent growth of azolla and limit temperature to manage potential dissolved oxygen risks in the weir pools over summer[30].

Accordingly, in the context of the Barmah-Millewa Feasibility Study, opportunities to provide for a flow regime that supports the water quality objectives but limit erosion and floodplain inundation over the peak demand season (summer) are most likely to be supported by outfalls which supply directly into Reaches 3 and 4.

Geomorphic considerations

Reach 4 of Broken Creek is a meandering, anabranching stream system that has been highly modified since European settlement. A combination of ongoing flow regulation, land use practices (including clearing of riparian vegetation) and direct intervention in the waterway (weir pools), have created the current state: an erosion-prone and geomorphically degraded waterway that is a challenge to recover. Overall, the channel becomes much wider in the downstream section where weir pools control channel form, with the upstream to downstream increase in width being a sudden jump from approximately 10 m to 30 m.

The combination of consistently high and continuous flows in summer irrigation season, small wind-generated waves and the permanent saturation of the bank face means that erosion is concentrated in a narrow zone along the bank face, creating a notch that results in block failure and bank retreat (Figure 38). Although water level does recede during periods of lower flows, this difference is small (~ 0.5 m) and is sometimes accompanied by mass failure of the saturated banks[31]. Even in the winter months when weir pool elevation is reduced, water levels are high enough to prevent any vegetation from establishing at the toe of the bank, so that the process repeats when water level next rises.

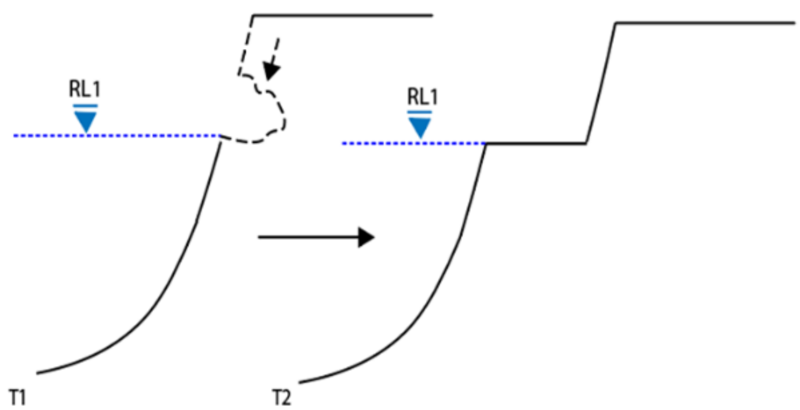

Figure 38. *The formation of a notch on the bank face of a weir pool which causes block failure and bank retreat*

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[29] *Op. Cit.*
[30] *Op. Cit.*
[31] Goulburn Broken Catchment Management Authority, Pers Comms. 10/05/2022

The sediment liberated from the retreating banks is deposited into low energy weir pools rather than being transported downstream. The retreat of the channel banks and accumulation of sediment leads to the simultaneous widening and shallowing of the river, high turbidity levels and is a major inhibitor of riparian vegetation establishment (that may otherwise limit this process of widening and shallowing).

In sections of the channel where the backwater effect of weir pools is more muted, consistently high summer flows due to delivery of IVT flows since 2018 have also maintained high water levels. High summer flows limit the opportunity for weir pool drawdown (either natural or intentionally by river operators), which increases the likelihood that weir pool water levels will remain at a constant elevation for long periods of time. Any increase in the duration of a static water level in weir pools will contribute to, and may accelerate, the existing notching on the channel banks.

Although these sections of the waterway have higher sediment transport capacities, which flushes sediment eroded form the channel banks downstream (and into weir pools) those higher flows also generate fluvial scour on the bank face, which accelerates the bank erosion process. Under current river operations, and without major change to the flow regime, the geomorphic trajectory of the Lower Broken Creek is:

- Continued sediment accumulation in weir pool, causing shallowing, elevated turbidity, and high temperature.
- Ongoing erosion of the channel/weir pool banks.
- Loss of riparian land and any remnant vegetation within that riparian zone.

The delivery of any additional flows to Lower Broken Creek during the summer months is likely to exacerbate the instabilities described above and contribute to the processes of bank erosion and the ongoing deterioration of instream and riparian habitat, water quality and associated amenity and cultural values in the waterway.

Discussion
The current summer operating limit for Broken Creek is based on GBCMA's environmental water target of 350 ML/day, corresponding with a flow rate for a fresh which has a flow range from 300 to 450 ML/d[32] as indicated in the flow recommendations in **Table 16**.

Table 16. Relevant flow recommendations for Broken Creek environmental reaches 3 and 4 at Nathalia Weir to the River Murray confluence[33]

Flow component	Flow objective	Flow recommendations
Fresh	Flush Azolla and trigger fish movement	300 – 450 ML/d, 1 – 3 events from July to October, to last 1 – 2 weeks. Can be timed based on observations of Azolla accumulation from July onwards.

The 350ML/day operating limit reflects consideration of the minimum flows needed to maintain water quality risks and maximum flow rates to avoid erosion[7]. Bankfull flows through the most downstream reach are estimated to be around 3,000 ML/day, however, there is community concern that operating the system at bankfull would be associated with increased erosion and further degradation of environmental and cultural values. More detailed investigations would be required to assess the environmental risks and management options associated with operations at or approaching bankfull discharge in summer.

Figure 39 provides a schematic of the Lower Broken Creek and Nine Mile Creek system, with regulating structures in red, outfalls from the MVIA (and East Goulburn systems) in green, and drainage in blue.

[32] *Op. Cit.*
[33] Jacobs (2019), *Lower Broken Creek FLOW study*

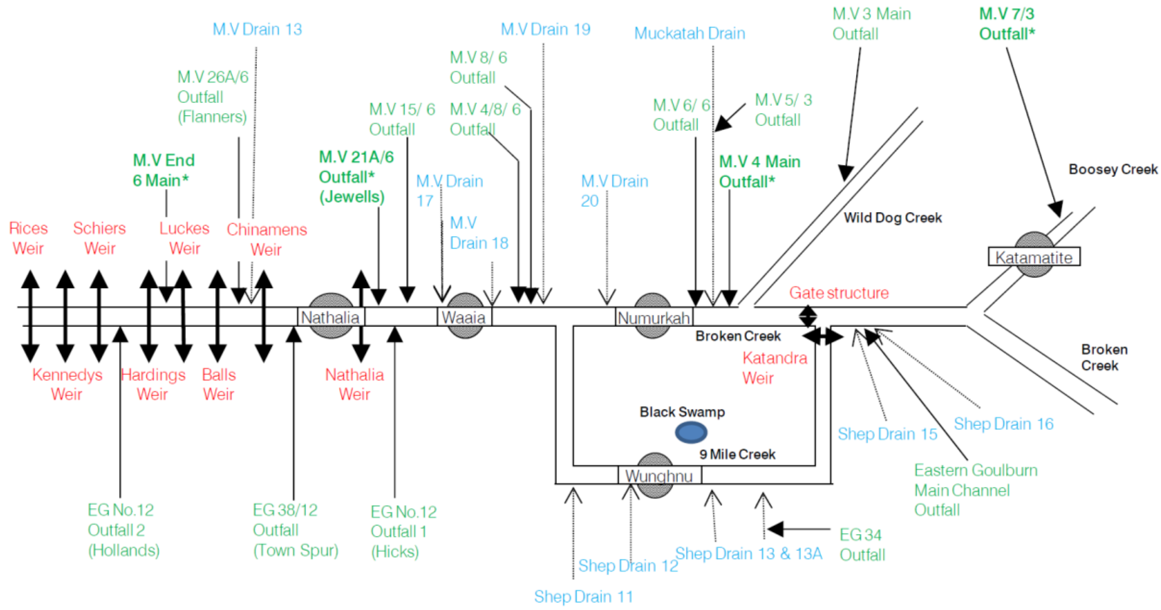

Figure 39. *A schematic of the Lower Broken Creek and Nine Mile Creek system*[34]

The recent Goulburn to Murray Trade Review assumed that a combined average of 350 ML/day can be delivered via the Campaspe River and the Lower Broken Creek. The Campaspe River is recommended to have a 70 ML/day baseflow, meaning that intervalley transfers in the Lower Broken Creek are expected to be consistently delivered at around 265 - 280 ML/day from November to April (as measured at Rice's Weir)[35].

In recent years, the bypass volumes delivered for the Murray system using the MVIA outfalls have averaged around 110 – 150 ML/day, with most of the flow delivered from the MV 7/3 outfall (which outfalls into Reach 1)[36]. **Table 17** shows the average flows delivered from MVIA from December 2021 to February 2022 based on flow data provided by GMW.

Table 17. Average River Murray bypass flows delivered from the MVIA over summer months (2021-22)

Outfall	Average flow delivered (Dec 21 – Feb 22)	Outfall location
MV 6 main end outfall (MV 1143)	0 ML/day	Lower Broken Creek Reach 4 (Broken Creek: Nathalia Weir to River Murray)
MV 26A/6 outfall (MV 1122)	20 ML/day	
MV 21A/6 outfall (MV 1099)	28 ML/day	Lower Broken Creek Reach 3 (Broken Creek: Nine Mile Creek to Nathalia Weir)
MV 15/6 outfall (MV 1033)	12 ML/day	
MV 6/6 outfall (MV 848)	15 ML/day	Lower Broken Creek Reach 1 (Broken Creek: Boosey Creek to Nine Mile Creek)
MV 4 main outfall (MV 276)	10 ML/day	
MV 7/3 outfall (MV156)	60 ML/day	
TOTAL	**145 ML/day**	

[34] SKM (2003), *Broken Creek Model – Stage 2, Final Report, Prepared for Goulburn Murray Water, January 2003.*
[35] DELWP (2022), *Goulburn to Murray Trade Review – Final Report and Recommendations, June 2022.*
[36] GMW (2022), *pers. comms*

Based on the above, it is expected that summer flows for the Lower Broken Creek will continue to be on average around 380 – 425 ML/day. These flows are consistent with the 2019/20 and 2020/21 seasons, as shown in **Figure 40**.

These expected future flow volumes assume that the River Murray outfall deliveries remain consistent with recent seasons (i.e., no increase or decrease). These flow rates are at or near the current base flow and fresh requirements suggesting limited prospects for the provision of additional water for the bypass of the Barmah Millewa Reach without finding an alternate means of delivering some of the IVT volumes (such as the Rochester 14 bypass option considered in this study).

On the basis that flow rates in the Lower Broken Creek remain within the range of a summer fresh (300 to 450 ML/day), the environmental values within the reach are likely to be sustained in their current state, supporting the 7 species of native fish, native vegetation, and lowland river macroinvertebrate species currently resident within the reach.

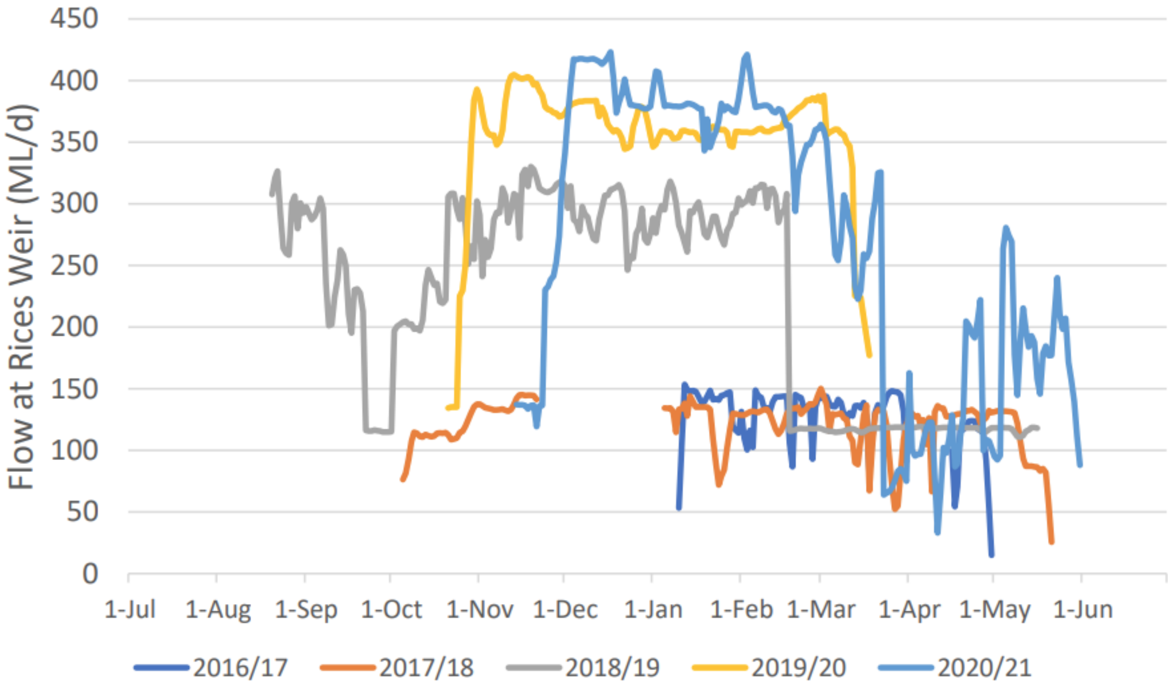

Figure 40. *Historical flow deliveries in the Lower Broken Creek, as measured at Rice's Weir at the downstream end of Reach 4.*

6.4 Proposed works and flow capacity

The engineering and ecological investigations have determined that:

- The capacity of the GMW channel outfalls could be increased by approximately 110 ML/day by undertaking relatively minor infrastructure upgrades. No works would be expected to be necessary on the channels upstream of the offtake regulators.
- The current operating limit of 350 ML/day is likely to be met or exceeded through delivering the IVT volumes (265 – 280 ML/day over summer, in accordance with the Goulburn to Murray Trade Rules Review) and River Murray bypass volumes consistent with recent practices (110 – 150 ML/day)
- The delivery of additional flows to Lower Broken Creek during the summer months are likely to exacerbate geomorphic instabilities and contribute to the processes of bank erosion and the ongoing

deterioration of instream and riparian habitat, water quality, and associated amenity and cultural values in the waterway.

- The operating limit in the lower reaches is subject to review and could change, noting current investigations into erosion in the Lower Broken Creek in particular. However, these investigations are unlikely to substantially change our understanding of the geomorphic and ecological trajectory of the waterway.
- It is unlikely that the volume of River Murray bypass water could be increased from current practices, unless some of the IVT volumes are delivered by an ecologically tolerance alternate means, such as the Rochester 14 bypass option considered in this study (see Section 8).

For the purposes of the option assessment, it is assumed that an additional 110 ML/day can be delivered using this option, noting that this would require an ecologically tolerable alternate means of delivering the IVT commitments to the Murray, in accordance with the trade rules.

6.5 Cost to implement

The cost estimates for this option were developed using actual construction costs from similar projects as provided by GMW. To calculate the 2022 present value, inflations rates were sourced using the publicly available Producer Price Indexes published by the Australian Bureau of Statistics[37]. The total costs for the Murray Valley Outfalls are summarised in **Table 18**.

Complexity levels (high, medium, and low) have been applied to estimate program management, survey, design, approval, overhead, operational and maintenance costs. These complexity levels correspond with a percentage to be applied and qualitatively estimates the amount of work required in each of those categories to deliver the works.

GMW and its customers would not contribute to the capital, operational, or maintenance costs associated with bypass deliveries.

Additional asset maintenance and renewal costs have been calculated in present annual value as a percentage of the capital cost. A 2% per annum allowance has been included. This recognises that the assets are mostly static and long-lived, existing assets are being updated which would reduce maintenance and asset renewal liability, and new or expanded assets are being installed which would increase the maintenance and asset renewal liability. This allowance generally considers the above factors; however, the actual contribution for asset maintenance and renewal costs would need to be further detailed and negotiated as part of any further option development.

The total O&M cost has been assessed over a 50-year period using a 7.0% discount rate.

Where bypass water is delivered, it is expected that GMW would charge:

- In the likely scenario that the MDBA acquired delivery shares to secure access, a fixed Infrastructure Access Fee ($2,547/ML/day is the published charge rate, per 2022/23).
- A variable Infrastructure Use Fee:
    - If the MDBA acquired delivery shares, an Infrastructure Use Fee ($5.15/ML).
    - If the MDBA did not acquire delivery shares, a casual Infrastructure Use Fee ($43.36/ML).

Any such agreement would involve negotiation of charges, recognising the very large annual volumes and the contribution to renewing existing GMW assets that would be involved.

[37] Producer Price Indexes, Australia, March 2022 | Australian Bureau of Statistics (abs.gov.au)

Table 18. Murray Valley outfalls cost estimate

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	Infrastructure cost				1,188,700
1.1	MV 6 main outfall (MV 1143				493,900
1.1.1	Replace regulator (50ML/day)	1	$136,000	/ regulator	136,000
1.1.2	Remove regulator	1	$8,000	/ regulator	8,000
1.1.3	Desilt & reprofile channel (4.3km)	4.3	$63,000	/ km	270,900
1.1.4	Replace crossing (50ML/day)	1	$22,000	/ structure	22,000
1.1.5	Replace discharge structure	1	$57,000	/ structure	57,000
1.2	MV 26A/6 outfall (MV 1122, 'Flanners')				148,000
1.2.1	Replace regulator (60ML/day)	1	$136,000	/ regulator	136,000
1.2.2	Desilt & reprofile channel (0.1km)	1	$6,000	/ km	6,000
1.2.3	Modify spillway	1	$6,000	/ km	6,000
1.3	MV 21A/6 outfall (MV 1099, 'Jewells')				248,800
1.3.1	Replace regulator (60ML/day)	1	$136,000	/ regulator	136,000
1.3.2	Remove regulator	1	$8,000	/ regulator	8,000
1.3.3	Desilt & reprofile channel (0.6km)	0.6	$38,000	/ km	22,800
1.3.4	Replace road crossing (1,200mm)	1	$25,000	/ structure	25,000
1.3.5	Replace discharge structure	1	$57,000	/ structure	57,000
1.4	MV 15/6 outfall (MV 1033)				298,000
1.4.1	Replace regulator (30ML/day)	1	$136,000	/ regulator	136,000
1.4.2	Replace pipeline with 900mm RC (0.12km)	1	$105,000	/ structure	105,000
1.4.3	Replace headwall structure	1	$57,000	/ structure	57,000
2	Program Management, survey, design, approvals and overheads				297,175
2.1	Program management and overheads				178,305
2.1.1	Program management - Low complexity - 15% of infrastructure costs		15%	percentage	178,305
2.2	Survey, design and approvals				118,870
2.2.1	Survey and Design - Low complexity - 5% of infrastructure costs		5%	percentage	59,435
2.2.2	Regulatory approvals - Low complexity - 5% of infrastructure costs		5%	percentage	59,435
3	Contingency				594,350
3.1	Contingency				594,350
3.1.1	40% of infrastructure, program management, survey, design, approval, and overhead costs		40%	percentage	594,350
	Total capital cost				2,080,225
4	Operations and maintenance				1,355,985
4.1	Operations and maintenance (NPV over 50 years, 7% discount)				1,355,985
4.1.1	Additional maintenance and renewal costs as a result of upgrade works	1	2%	percentage	574,173
4.1.2	GMID Infrastructure Use Fee	11,000	$5.15	$/ML	781,812

7 Shortlisted option investigation: Barmah bypass gravity channel

7.1 Detailed description of the option

Overview

This option considers constructing an open channel extending from Lake Mulwala to the River Murray near the township of Barmah. The channel would be used to gravitate water around the Barmah-Millewa Reach.

There are no previous studies or engineering reports which have investigated this option in detail, and as such, this option is considered conceptual only at this stage.

There is a network of gravity irrigation channels in the Murray Valley Irrigation Area (MVIA) which are used by GMW to supply water from Lake Mulwala, upstream of the Barmah-Millewa Reach, to customers in the district. The channels flow from east to west, following the natural fall in grade across the Murray floodplain.

None of the existing channels in the MVIA discharge directly to the River Murray. There are however several channels in the MVIA that discharge to the Lower Broken Creek, which in turn flows into the River Murray. The use of these outfalls is considered as a separate option for the purposes of the BMFS (see Section 6 of this report).

Of the existing channels in the MVIA, the MV 5 and MV 9/6 channels are closest to the River Murray downstream of the Barmah-Millewa Reach. Both channels are, at their closest, a similar distance to the River Murray (around 15km), have similar existing capacities, and have a running distance of around 100km in channel from Luke Mulwala. For the purposes of this exercise, the MV 5 was selected as the indicative alignment for investigation of a Barmah bypass channel. If this project were to proceed to further stages of development, a detailed option assessment considering potential alignments should be undertaken to confirm a preferred alignment.

The indicative alignment follows the MV 5 channel, which is supplied from Lake Mulwala via the YMC and MV 2. The channel would require an approximate 19km extension from the end of the current channel system to discharge to the River Murray (see **Figure 41**). The new section of channel generally follows the road alignment.

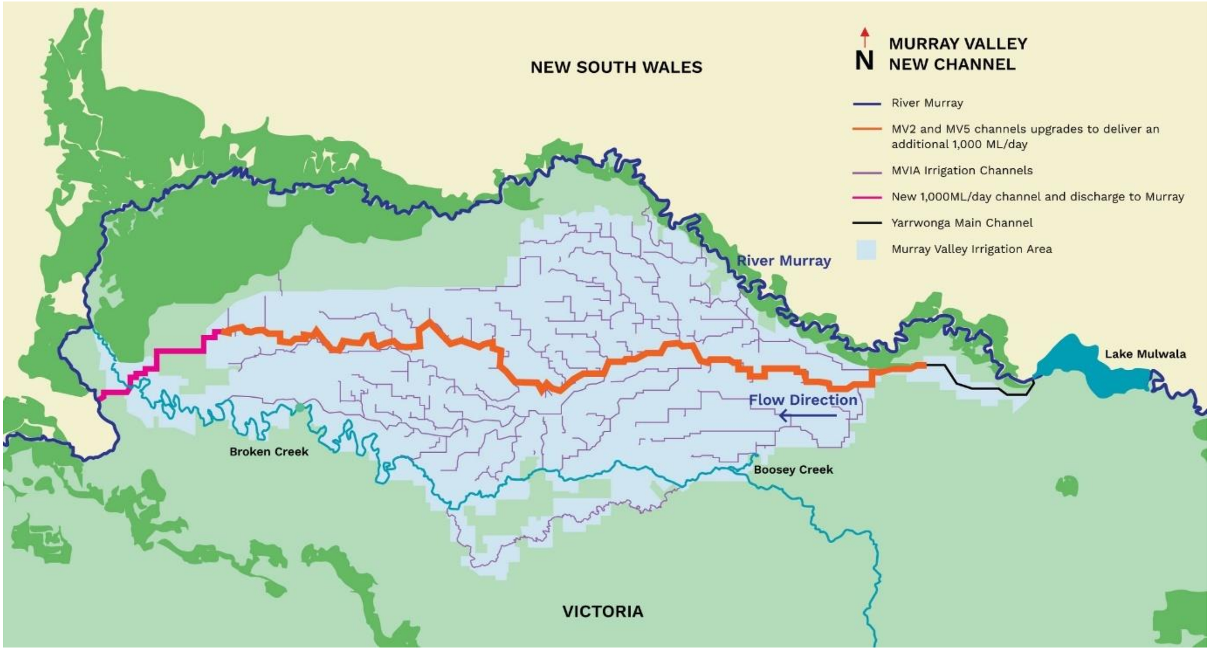

Figure 41. *Location and concept map for the Barmah bypass gravity channel option*

Limitations and Opportunities
This option presents an opportunity to utilise existing infrastructure as the basis for a Barmah bypass option. While the existing infrastructure would need to be substantially upgraded, the option could take advantage of the existing district offtake channel and structure at Lake Mulwala and the existing channel easement for much of its length. Additionally, utilising existing infrastructure in primarily disturbed landscapes potentially reduces the regulatory approval requirements compared to a channel constructed in a greenfield alignment.

The key limitations of the option under investigation include:

- following the alignment of existing channels results in a substantially longer route compared to a greenfield alignment.
- approximately 19.5 km of new channel needs to be constructed across a greenfield alignment, including a syphon under the Broken Creek.
- the construction of such a channel would require temporary disruption to supply arrangements for customers in the Murray Valley Irrigation Area throughout the construction period (refer Section 7.2).
- the construction of such a channel would directly impact on around 200 landholders, including those adjacent to the existing channel, and landholders along the new channel alignment, with requirement for new or additional channel easement and potentially relocation of on-farm assets.
- the work would involve constructing a very large syphon structure under the Lower Broken Creek and a very large discharge structure on the River Murray, both with consequential environmental and cultural heritage implications.

7.2 Engineering & works considerations

Supply channel infrastructure and arrangement
The YMC channel offtake (MV1) is located to the South side of the Yarrawonga Weir at Lake Mulwala. The YMC has an existing design capacity of 2,450 ML/day to regulator MV 1B, after which it reduces to 1,960 ML/day. The offtake regulator and YMC channel are significant infrastructure and, based on recent demand patterns, have more than 1,000 ML/day of spare capacity over the summer period available. Accordingly, for the purposes of this feasibility study, it is assumed that the available capacity to deliver bypass flows to the River Murray would be limited by using the spare capacity available in the existing YMC offtake regulator and channel.

Figure 42. *The existing YMC section where there is existing spare capacity and no works would be proposed*

Available system capacity

To understand the available spare capacity in the YMC and therefore the potential capacity available for River Murray bypass flows, GMW provided daily flow data from the 2021-22 water year at the MV 1B regulating structure. The demand within the YMC varies year-on-year; however, for the purposes of this feasibility study, the flows delivered during 2021-22 were used to provide an indication of the available capacity, noting that some years are expected to have higher demand in future.

The maximum daily flow delivered from December 2021 to February 2022 was 1,351 ML/day, with an average daily flow of around 900 ML/day (see **Figure 43**). The upstream channel has a design capacity of 2,450 ML/day, meaning that there was more than 1,000 ML/day of spare capacity available every day, and up to 1,500 ML/day spare capacity on average.

Accordingly, for the purposes of this feasibility study, there is a realistic opportunity to consistently deliver a flow of 1,000 ML/day for the River Murray bypass over the summer months from the YMC offtake to the MV 1B regulator, without needing any upgrades to infrastructure for this reach of the channel.

This brief analysis is based on the 2021-22 summer period and the maximum flow delivered in this time. If this project were to proceed to further stages of development, this exercise should be repeated with GMW operators to analyse years of higher demand volumes and account for future trends.

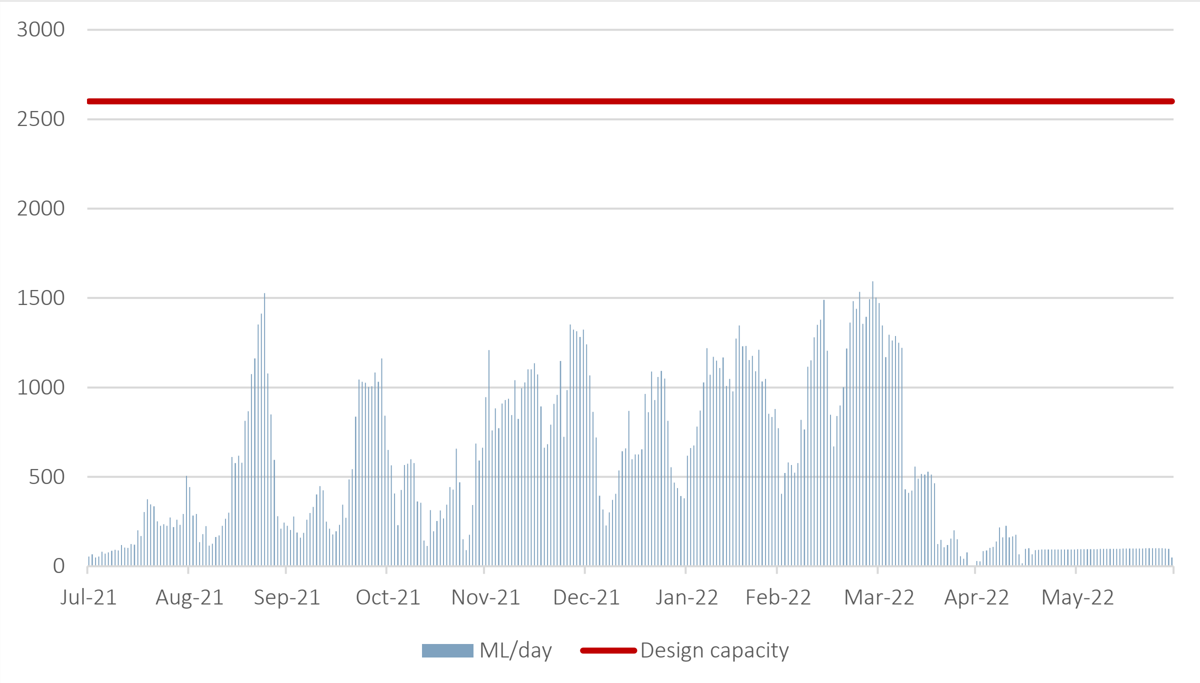

Figure 43. *Flow deliveries recorded during the 2021-22 water year at the MV 1B regulator*

Existing demand and potential capacity required

This option considers the consistent delivery of 1,000 ML/day from Lake Mulwala to the River Murray, in addition to meeting the existing demands of customers supplied from the Murray Valley irrigation channels.

The indicative alignment for the bypass channel follows the existing YMC, MV 2 and MV 5 channels, to the end of the MV 5 main.

To determine the indicative increase in flow capacity and works required, the existing system capacity was reviewed against demand volumes supplied in the 2021-22 water years. To support this analysis, GMW provided daily flows for the 2021-22 water year for representative regulating structures along the indicative alignment, including (see **Figure 44**):

- MV 100 – the MV 2 channel offtake from the YMC

- MV 500 – the MV 5 channel offtake from the MV 2
- MV 569, MV 721, MV 772 – regulating structures along the MV 5 main channel

Figure 44. *Key regulating structures along the indicative alignment for which 2021-22 flow data was provided*

GMW provided the design capacity for these key regulators.

Daily flow data was provided. For each regulator, the approximate spare capacity was determined by:

- for each month, taking the maximum flow rate from any day in that period.
- for the summer, taking the maximum daily flow rate delivered in any month in that period.
- subtracting this highest daily flow from the existing operating capacity.

The indicative operating capacity required was then calculated as the difference between the current operating capacity and the highest daily demand, plus 1,000 ML/day. Using this approach ensures that the current demand plus 1,000 ML/day could be delivered almost all throughout the summer. There would be some moments when the peak instantaneous demand is higher; however, these periods would be for very short periods (hours at most) and therefore not considered for this exercise. If this project were to proceed to the next stages of investigation, this exercise should be repeated in close consultation with GMW using hourly flow data across multiple years and considering potential future demand patterns.

Table 19 below summarises the indicative increase in capacity required along the YMC – MV 2 – MV 5 alignment. This high-level analysis indicates that, based on the 2021-22 irrigation demands, to deliver a consistent bypass flow of 1,000 ML/day over summer:

- The YMC would require enhancement works to increase the capacity by around 400 ML/day between the MV 1B regulator and the MV 2 offtake regulator (MV 100).
- The MV 2 channel has a consistent design capacity of around 1,900 ML/day. It is assumed that the top 5km would require enhancement works to increase the capacity by around 400 ML/day from MV 100.
- The MV 2 channel upstream of the MV 5 offtake regulator appears to have sufficient available spare capacity to deliver an additional 1,000 ML/day and would not require channel or regulator upgrades.
- The MV 5 channel would require enhancement works, varying from:
    - Around +750 ML/day additional capacity in the upper 10km.
    - Around +900 ML/day additional capacity in the middle 20km.
    - Around +1,000 ML/day additional capacity in the lower 30km.
- The new channel from the bottom of the MV 5 channel to the River Murray would be designed at 1,000 ML/day.

Table 19 Indicative capacity increase required for regulating structures and upstream channel sections

Regulator	Current design operating capacity (ML/day)	Indicative operating capacity required (ML/day)	Approx. upstream channel length (m)	Indicative capacity increase required (ML/day)
MV 1B (YMC)	2,600	2,600	13,000	-
MV 100 (MV 2 offtake)	2,000	2,381	5,000	+ 381
MV 500 (MV 5 offtake)	1,700	1,700	25,500	-
MV 569	500	1,268	10,000	+ 768
MV 721	250	1,149	20,000	+ 899
MV 772	100	1,061	18,500	+ 961
End of MV 5 (MV 799)	49	1,049	11,500	+1,000
New channel to River Murray	-	1,000	19,500	+1,000

Indicative work scope

The analysis above confirms that targeted upgrade works would be required on the YMC and MV 2 offtake structure, and significant capacity upgrades would be required along the entire length of the MV 5 channel.

For the purposes of this feasibility-level assessment, it is assumed that this would require:

- on the YMC,
  - the existing knife's edge structure downstream of MV 1B limits the channel flow capacity and would need to be re-constructed, with customer outlets re-configured accordingly.
  - the channel and structures would be upgraded to deliver an additional 400 ML/day.
- on the MV 2,
  - the MV 2 offtake (MV 100) and immediately downstream channel (assumed 5km, to MV202 regulator) would require upgrades to increase capacity by around 400 ML/day.
  - the regulators upstream of MV 500 (assumed 20km, from MV202 to MV500) generally appear to have sufficient available capacity. De-silting and re-profiling works would be required to support consistent delivery of the higher flows.
  - all existing road crossings and structures would likely need to be replaced to support the higher flows.
- on the MV 5,
  - all channel, regulators, structures (including road crossings) meter outlets and D&S connections to be re-constructed or re-located as needed to increase the channel capacity.

For the new channel section, an indicative alignment has been selected to generally following the road alignment to minimise impacts on private land. A significant consideration of the new channel is that, regardless of the selected alignment, the new channel will need to cross the Lower Broken Creek upstream of the Rice's Weir regulating structure. Discharging such large additional volumes into the Lower Broken Creek over the summer period is unlikely to be tolerable, therefore the new channel will likely need to cross under the Lower Broken Creek and extend on a new alignment to discharge into the River Murray near the township of Barmah.

The Lower Broken Creek in this reach is approximately 30m wide. The syphon required would be a significant structure and would require extensive environmental, cultural heritage and planning investigations.

The channel would require a significant drop structure to be constructed for discharging into the River Murray. Similarly, this would require extensive environmental, cultural heritage and planning investigations.

Table 20 lists the indicative quantities of work required to increase the channel capacity as considered. This assessment has been completed at a high-level only for the purposes of informing the feasibility study. If this project were to proceed to the next stages of investigation, a high-level engineering review should be completed to determine the potential alignments and solutions, and when a preferred solution is determined, asset-by-asset investigations and engineering calculations should be completed.

Table 20. Indicative quantities of work required to construct the Barmah gravity bypass channel

Asset Type	Qty
Channel works	
YMC (MV 1 to MV 1B) – retain channel, de-silt and re-profile as required	13,000
YMC (MV 1B to MV 100) – re-construct existing channel (30m bed width)	5,000
MV 2 (MV100 to MV202) – re-construct existing channel (30m bed width)	5,000
MV 2 (MV202 to MV500) – retain channel, de-silt and re-profile as required	20,500
MV 5 (MV500 to MV799) – re-construct existing channel (30m bed width)	60,000
New channel to River Murray (25m bed width)	19,500
Meter outlets	
YMC – Irrigation outlets – relocate on re-constructed channel section	7
MV 2 – Irrigation outlets – relocate on re-constructed channel section	8
MV 5 - Irrigation outlets – relocate on re-constructed channel section	140
D&S outlets - relocate on re-constructed channel section	94
Regulators	
MV 2 – main channel regulators + knife's edge – construct new (~2,350 ML/day capacity)	4
MV 5 – main channel regulators – construct new (~1,250 – 1,700 ML/day)	5
MV 5 – main channel regulators – construct new (~1,100 – 1,250 ML/day)	34
MV 5 – offtake channel regulators – construct new (< 100 ML/day)	26
New channel – regulators – construct new (1,000 ML/day capacity)	3
Road crossings & structures	
YMC – bridges, road crossings, other structures – replace	6

MV 2 - bridges, road crossings, other structures – replace	21
MV 5 - bridges, road crossings, other structures – replace	64
New channel - bridges, road crossings, other structures – construct new	20
New channel - syphon under the Lower Broken Creek	1
New channel - discharge structure to River Murray	1

7.3 Ecological considerations

This option removes water from Lake Mulwala and transfers it back into the River Murray downstream of the confluence with Broken Creek. In terms of the flow regime, the transfer along the channel will not influence the flow regime above Lake Mulwala or below the outfall. Within the bypassed reach, water managers will have greater control and opportunities to manage flows in ways that will optimise environmental and economic values. Within this context, we believe that there are no significant risks in ecological flow tolerances associated with this option. However, the option would introduce two elements with potential environmental impacts. The option would require construction of:

1. a major siphon under the Lower Broken Creek. This is likely to have significant short term construction impacts that would need to be appropriately investigated and mitigated (as far as practically achievable) as part of any statutory approval requirements to undertake the works.
2. a major outlet structure on the left bank of the River Murray. This would have some significant short term construction impacts and longer-term legacy issues including potential to become an attractant for native fish, with the potential for native fish to become stranded in the GMW channel network.

Within this context, we believe that there are no significant risks in ecological flow tolerances associated with this option.

7.4 Proposed works and flow capacity

The proposed works to deliver this option includes:

- re-construction of approximately 70km of very large channel,
- de-silting and re-profiling of approximately 34km of very large channel,
- construction of a new large channel for approximately 20km.
- construction of approximately 155 irrigation meter outlets.
- re-location of approximately 94 stock and domestic outlets.
- construction of approximately 46 very large regulators and 26 small regulators.
- construction of approximately 111 road and occupational crossings.
- construction of major infrastructure to cross the Lower Broken Creek and discharge to the River Murray.

This option generates a capacity of 1,000 ML/day which can be reliably accessed through the summer period and at lower flows during peak GMID irrigation season, subject only to maintenance requirements within the channel. This maximum capacity would be available on call, limited only by water levels in Lake Mulwala.

7.5 Cost to implement

The cost estimates for this option were developed using actual construction costs from similar projects as provided by GMW and MIL. To calculate the 2022 present value, inflations rates were sourced using the publicly available Producer Price Indexes published by the Australian Bureau of Statistics[38]. The total costs for the Barmah bypass gravity channel are summarised in **Table 21.**

Complexity levels (high, medium, and low) have been applied to estimate program management, survey, design, approval, overhead, operational and maintenance costs. These complexity levels correspond with a percentage to be applied and qualitatively estimates the amount of work required in each of those categories to deliver the works. GMW and its customers would not contribute to the capital, operational, or maintenance costs associated with bypass deliveries.

Additional asset maintenance and renewal costs have been calculated in present annual value as a percentage of the capital cost. A 2% per annum allowance has been included. This recognises that the assets are mostly static and long-lived, existing assets are being updated which would reduce maintenance and asset renewal liability, and new or expanded assets are being installed which would increase the maintenance and asset renewal liability. This allowance generally considers the above factors; however, the actual contribution for asset maintenance and renewal costs would need to be further detailed and negotiated as part of any further option development.

The total O&M cost has been assessed over a 50-year period using a 7.0% discount rate. Where bypass water is delivered, it is expected that GMW would charge:

- In the likely scenario that the MDBA acquired delivery shares to secure access, a fixed Infrastructure Access Fee ($2,547/ML/day is the published charge rate, per 2022/23).
- A variable Infrastructure Use Fee:
    - If the MDBA acquired delivery shares, an Infrastructure Use Fee ($5.15/ML).
    - If the MDBA did not acquire delivery shares, a casual Infrastructure Use Fee ($43.36/ML).

Any such agreement would involve negotiation of charges, recognising the very large annual volumes and the contribution to renewing existing GMW assets that would be involved.

Table 21. Barmah bypass gravity channel cost estimate

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	Infrastructure cost				296,394,887
1.1	Channel works				97,794,700
1.1.1	YMC (MV 1 to MV 1B) – retain channel, de-silt and re-profile as required	13	$437,368	/ km	5,685,790
1.1.2	YMC (MV 1B to MV 100) – re-construct existing channel (30m bed width)	5	$739,286	/ km	3,696,429
1.1.3	MV 2 (MV100 to MV202) – re-construct existing channel (30m bed width)	5	$739,286	/ km	3,696,429
1.1.4	MV 2 (MV202 to MV500) – retain channel, de-silt and re-profile as required	20.5	$437,368	/ km	8,966,053
1.1.5	MV 5 (MV500 to MV799) – re-construct existing channel (30m bed width)	60	$821,429	/ km	49,285,715
1.1.6	New channel to River Murray (25m bed width)	19.5	$1,357,143	/ km	26,464,286
1.2	Meter outlets				6,000,186
1.2.1	YMC – Irrigation outlets – relocate on re-constructed channel section	7	$37,499	/ outlet	262,494

[38] Producer Price Indexes, Australia, March 2022 | Australian Bureau of Statistics (abs.gov.au)

1.2.2	MV 2 – Irrigation outlets – relocate on re-constructed channel section	8	$37,499	/ outlet	299,993
1.2.3	MV 5 - Irrigation outlets – relocate on re-constructed channel section	140	$37,499	/ outlet	5,249,885
1.2.4	D&S outlets - relocate on re-constructed channel section	94	$1,998	/ outlet	187,814
1.3	**Regulators**				**86,600,000**
1.3.1	MV 2 – main channel regulators – construct new (~2,350 ML/day capacity)	4	$3,325,000	/ regulator	13,300,000
1.3.2	MV 5 – main channel regulators – construct new (~1,250 – 1,700 ML/day)	5	$2,350,000	/ regulator	11,750,000
1.3.3	MV 5 – main channel regulators – construct new (~1,100 – 1,250 ML/day)	34	$1,600,000	/ regulator	54,400,000
1.3.4	MV 5 – offtake channel regulators – construct new (< 100 ML/day)	26	$125,000	/ regulator	3,250,000
1.3.5	New channel – regulators – construct new (1,000 ML/day capacity)	3	$1,300,000	/ regulator	3,900,000
1.4	**Road crossings & structures**				**106,000,000**
1.4.1	YMC – bridges, road crossings, other structures – replace	6	$1,500,000	/ structure	9,000,000
1.4.2	MV 2 - bridges, road crossings, other structures – replace	21	$1,000,000	/ structure	21,000,000
1.4.3	MV 5 - bridges, road crossings, other structures – replace	64	$750,000	/ structure	48,000,000
1.4.4	New channel - bridges, road crossings, other structures – construct new	20	$750,000	/ structure	15,000,000
1.4.5	New channel - syphon under the Lower Broken Creek	1	$10,000,000	/ structure	10,000,000
1.4.6	New channel - discharge structure to River Murray	1	$3,000,000	/ structure	3,000,000
2	**Program Management, survey, design, approvals and overheads**				**133,377,699**
2.1	**Program management and overheads**	$59,278,977			**48,308,700**
2.1.1	Program management - High complexity - 20% of infrastructure costs	$59,278,977	20%	percentage	48,308,700
2.2	**Survey, design and approvals**	$74,098,722			**80,514,500**
2.2.1	Survey and Design - High complexity - 10% of infrastructure costs	$29,639,489	10%	percentage	32,205,800
2.2.2	Regulatory approvals including offsets - High complexity - 15% of infrastructure costs	$44,459,233	15%	percentage	48,308,700
3	**Contingency**				**171,909,034**
3.1	**Contingency**				**171,909,034**
3.1.1	40% of infrastructure, program management, survey, design, approval, and overhead costs	1	40%	percentage	171,909,034
	Total capital cost				**601,681,620**
4	**Operations and maintenance**				**173,180,492**

4.1	**Operations and maintenance (NPV over 50 years, 7% discount)**				**173,180,492**
4.1.1	Additional maintenance and renewal costs as a result of upgrade works	1	2%	percentage	166,073,108
4.1.2	GMID Infrastructure Use Fee	100,000	$5.15	$/ML	7,107,384

8 Shortlisted option investigation: Rochester 14 bypass channel

8.1 Detailed description of the option

Overview

The Goulburn system delivers water from the Goulburn headworks via tributaries to meet demands in the Murray system. The actual volumes that are delivered from the Goulburn to the Murray vary year-to-year depending on allocations and the uptake of opportunities to trade out of, and back into, the Goulburn. In most years there is at least 100 GL delivered, and in some years, there could be up to around 300 GL.

The capacity to deliver Goulburn commitments to the Murray when pressure on the Barmah-Millewa Reach is greatest and there is the highest risk of shortfalls occurring (i.e., over summer) is currently limited by operating rules, which consider the ecological flow tolerances for the major tributaries including the lower Goulburn River, lower Broken Creek, and Campaspe River[39]. Trade opportunities from Goulburn are limited to volumes that can be delivered within the ecological tolerances of the tributaries. This means that when there is full uptake of trade opportunity out of the Goulburn, the capacity of the Victorian tributaries is fully utilised during the peak demand period supplying the Murray demands arising from trade.

Creating an alternate delivery pathway to deliver Goulburn commitments to the Murray during the peak demand period (without exceeding ecological tolerances) could help reduce the risks of Murray system shortfalls and offset some of the reduced delivery capacity through the Barmah-Millewa Reach. This would directly contribute to the objectives of the Barmah-Millewa Feasibility Study.

One alternate option for delivering Goulburn IVT flows during summer would be the construction of a larger channel between the Waranga Western Channel (WWC) and the River Murray, such as along the alignment of the existing GMW Rochester 14 (RO 14) channel (see Figure 45). There is an existing irrigation channel and pipeline for much of this alignment which would be re-constructed to deliver additional capacity, as well as a new section of channel which would extend through to discharge into the River Murray.

This bypass channel could be used in three ways to provide beneficial outcomes.

Firstly, in times of high downstream demand and when there is a relatively higher risk of delivery shortfalls occurring (i.e., summer), the bypass channel could deliver existing Goulburn IVT flows in addition to deliveries through the lower Goulburn River, lower Broken Creek, and Campaspe River (managed in accordance with current operating rules). This would increase the volume of existing Goulburn IVT delivered to the River Murray in the time of the year when shortfall risk is greatest. As the bypass channel would not be used to create additional trade opportunities, these increased summer deliveries would decrease the volume of Goulburn IVT delivered at other times of the year, when downstream demand is lower, and the risk of shortfall is less. Decreases in spring IVT deliveries could also offer increased opportunities for environmental water delivery in both the Goulburn and in the Murray downstream of the Goulburn confluence.

Secondly, if the capacity of the MVIA outfalls is upgraded, the RO14 bypass channel could be used to deliver existing Goulburn IVT volumes that otherwise would have been delivered via the lower Broken Creek. Equivalent volumes to those delivered through the RO14 bypass channel could then be delivered to the lower Broken Creek from the River Murray via the MVIA outfalls (managed in accordance with the current operating rules), increasing the volume able to be delivered downstream of the Barmah-Millewa Reach from Lake Hume.

Thirdly, in times of lower downstream demand, the bypass channel could be used to deliver Goulburn IVT commitments instead of delivering via the lower Goulburn River, Broken Creek, and/or Campaspe River. This could be done to increase the flow regime variability in these natural waterways and reduce environmental pressures on these systems.

[39] https://www.waterregister.vic.gov.au/images/documents/Goulburn-to-Murray-Trade-Review-Fact-Sheet-2---long-term-operating-rules.pdf

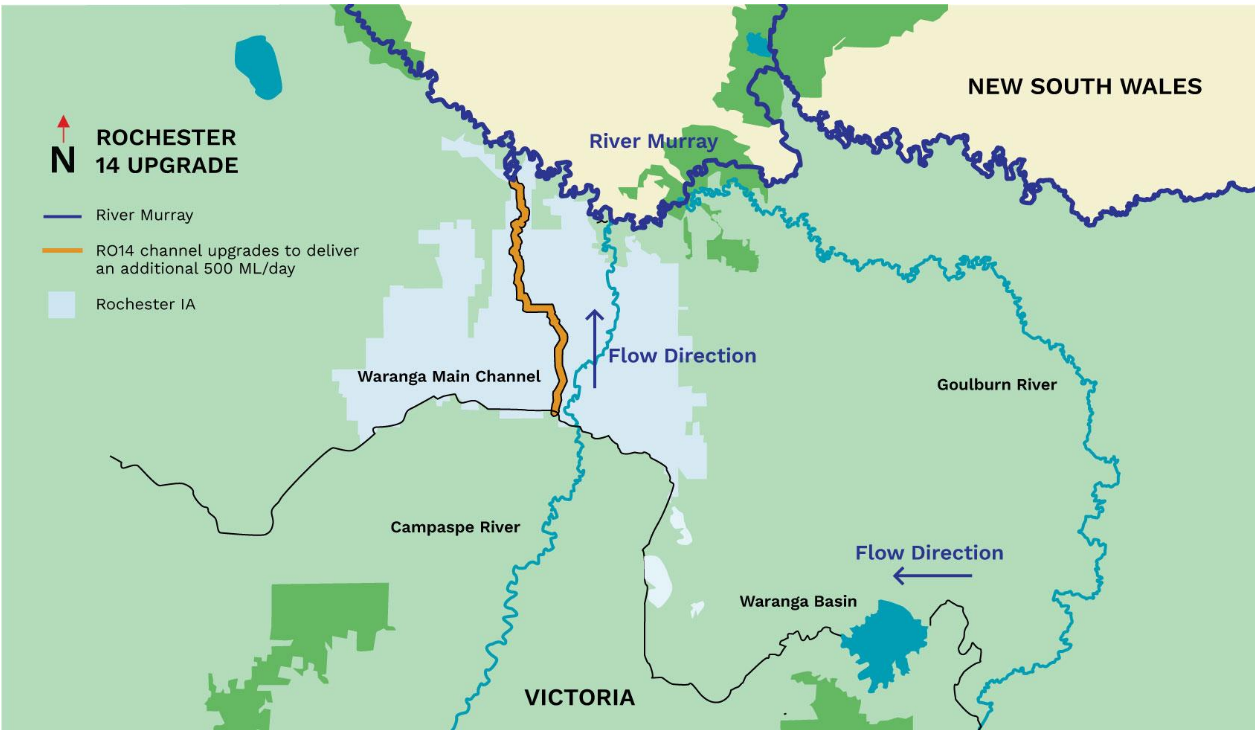

Figure 45. *Location of the Waranga Basin, Western Waranga Channel and potential bypass channel*

Limitations and opportunities

This option provides the opportunity to deliver additional supply from the Goulburn into the Murray downstream of the Barmah-Millewa Reach during periods of highest shortfall risk in the Murray. It therefore reduces the requirement to supply downstream demands through the capacity-constrained reach or via the ecologically-constrained tributaries.

The primary limitations of this option include:

- implementing this option would require an irrigation supply pump station and pipeline to be removed and replaced with a large channel. This pump station and pipeline were only recently installed (within the last decade) and were installed as a replacement to the existing channel system.
- the construction of this option would require temporary disruption to supply arrangements for customers supplied by the existing Rochester 14 channels throughout the construction period.
- the enlargement and construction of such a channel would directly impact on around 135 landholders, including those adjacent to the existing channel, and landholders along the new channel alignment, with requirement for new or additional channel easement and potentially relocation of on-farm assets.
- the availability of this option to provide flows to the River Murray would be limited by constraints in the existing capacity of infrastructure on the WWC and the existing demand patterns. Based on preliminary analysis, it is likely that a consistent flow around 500 ML/day could be delivered over summer.
- the work would involve constructing a large discharge structure on the River Murray, with consequential environmental and cultural heritage implications.

8.2 Engineering & works considerations

Supply channel infrastructure and arrangement

The RO 14 channel offtake (RO 321) is located approximately 3.5km downstream of where the Western Waranga Channel (WWC) crosses the Campaspe River through the Campaspe River siphon. The siphon is a significant structure, and it would be cost prohibitive to consider any capacity upgrades to the siphon or any of the upstream regulators for the purposes of this project. Accordingly, the capacity to deliver additional flows to the River Murray is limited by the existing capacity of the siphon and upstream regulators, and system demands. GMW confirmed that the design capacity of the Campaspe River siphon is managed to around 2,700 ML/day.

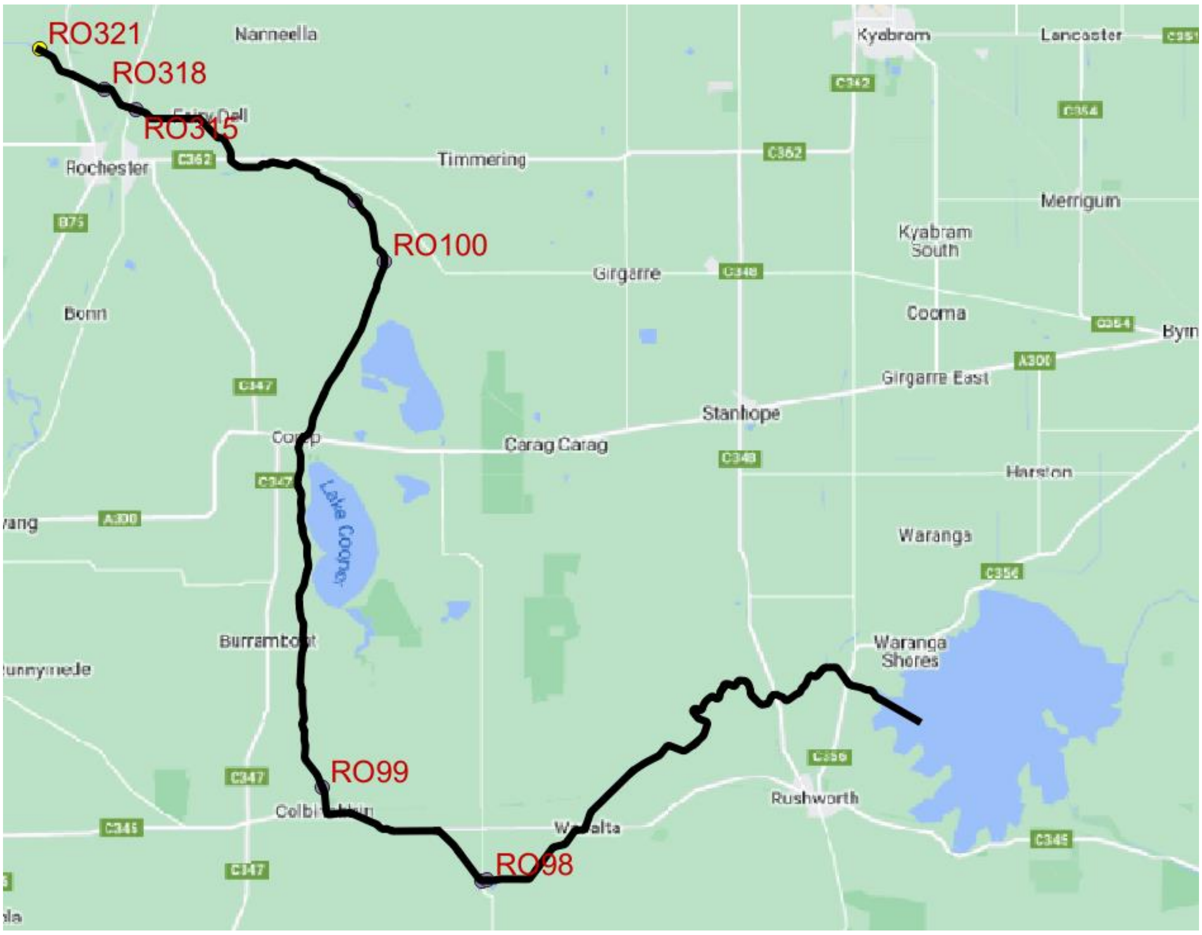

Figure 46. *Regulator locations between the Waranga Basin, the Campaspe Siphon (RO 318), and RO 14 offtake (RO 321).*

Available system capacity

To understand the available capacity to increase supply without requiring works to the siphon and upstream regulators, GMW provided hourly flows for the 2021-22 water year from the regulating structure at the siphon (RO318) and the four upstream regulators (RO98, RO99, RO100, RO315).

The demand within the WWC varies year-on-year; however, for the purposes of this feasibility study, the flows delivered during 2021-22 were used to provide a general indication of the available capacity, noting that some years are expected to have higher demand in future.

Flow volumes at each of the upstream regulators peaked during late winter – early spring and in autumn, with lower flows recorded over the December – February period (see **Figure 47** as an example from the RO 315 regulator). This indicates that there would likely be spare available capacity over this period.

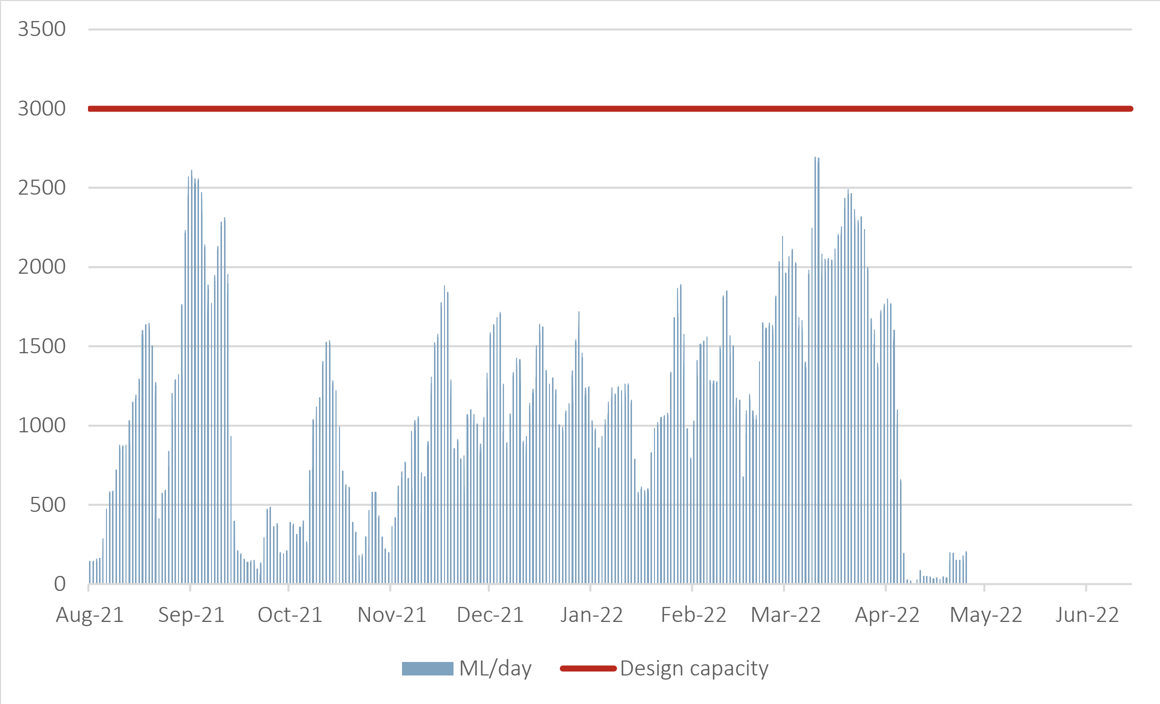

Figure 47. *Flow deliveries recorded during the 2021-22 water year at the RO 315 regulator*

Table 22 summaries the design capacity for each of the structures, the monthly average daily flow, the highest daily average flow, and the highest hourly daily flow recorded in the summer months at each regulator.

Table 22. Flows v. design capacity for the five regulators upstream of Campaspe Siphon from Dec 21 – Feb 22

Regulator	Design capacity (ML/day)	Monthly average flow (Dec – Feb)	Highest average daily flow (Dec – Feb)	Highest flow in any hour (Dec – Feb)
RO 98	2,695	1,296	1,974	2,061
RO 99	2,695	1,257	2,008	2,100
RO 100	3,185	1,239	1,913	2,033
RO 315	3,000	1,086	1,786	1,892
RO 318	3,307 (Siphon 2,700)	1,160	2,026	2,214

Figure 48 below plots the peak flow recorded in any one hour and the highest flow delivered on any one day against the design capacity for each regulator. For the entire 2021 – 2022 summer period, the design capacity for each regulator is more than 500 ML/day higher than the peak hourly and daily volumes in this period. The RO98, RO99 and RO318 structures are typically the structures limiting the spare available capacity.

Accordingly, for the purposes of this feasibility study, there is a realistic opportunity to consistently deliver a flow of 500 ML/day over the summer months from the Waranga Basin to the RO 14 offtake regulator. Using the peak hourly and peak daily flows to determine the available capacity for delivering higher flow volumes is considered conservative and would account for future years where demand over the summer months is higher than in 2021-22. If this project were to proceed to further stages of development, this exercise should be repeated with GMW operators to analyse years of higher demand volumes and account for future trends.

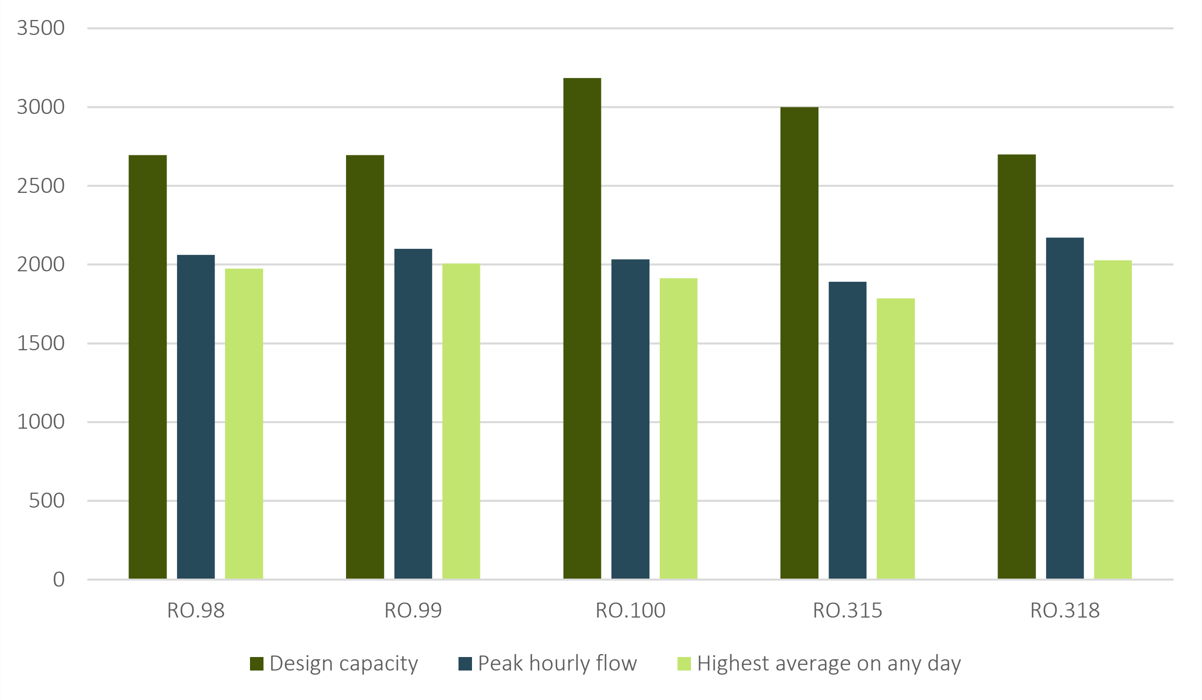

Figure 48. *Regulator design capacities vs. peak hourly flow and highest daily flow recorded in the 2021-22 summer period*

Rochester 14 channel infrastructure and arrangement

The Rochester 14 (RO 14) channel is supplied from the Western Waranga Channel, with the offtake regulator located around 5km North-West from the township of Rochester. The channel flows in a typically Northerly direction, supplying customers through the Strathallan, Echuca West and Wharparilla areas. The channel supplies the RO1/14, 2/14 and 3/14 spurs. The RO14 main runs North adjacent to the Warparilla Rd towards Wharparilla, where it comes within 350m of the River Murray (see **Figure 49**).

As part of the GMW Connections Project, the Northern-most 12km of the RO 14 channel was replaced with pump station and buried pipeline (from RO 421). While the channel has been backfilled in this area, it is understood that GMW continues to hold an easement over the land to access and maintain the pipeline.

The corridor of interest for this option is the RO 14 channel alignment between the WWC offtake and the Wharparilla end of the channel. The existing channel would need to be up-sized as required to allow the additional 500 ML/day capacity to be delivered whilst continuing to provide for current system demands. This would require the existing channels and structures between the WWC and the pump station to be up-sized as appropriate, and likely requires the pipeline to be removed and replaced with a channel to deliver the higher demand. The removal and replacement of a recently installed pipeline would be a key social and reputational consideration for this option. A new section of channel would need to be constructed to discharge to the River Murray.

The concept of replacing the pumped pipeline with the gravity channel is to minimise the easement footprint required by GMW, thereby reducing the amount of private land impacted. Alternately, if the pipeline were kept in place and a new channel constructed, the channel would likely follow a different alignment to the pipeline in places, to avoid existing impact and reduce the total length. This would reduce the need for some of the intermediate regulating structures, but not all. This concept would be expected to be similar in construction cost, however, may have more of an impact on local landholders due to the need for two separate GMW assets to be located on several properties. If this option were to proceed to further investigation, the next steps should include an options assessment to investigate and confirm a preferred arrangement.

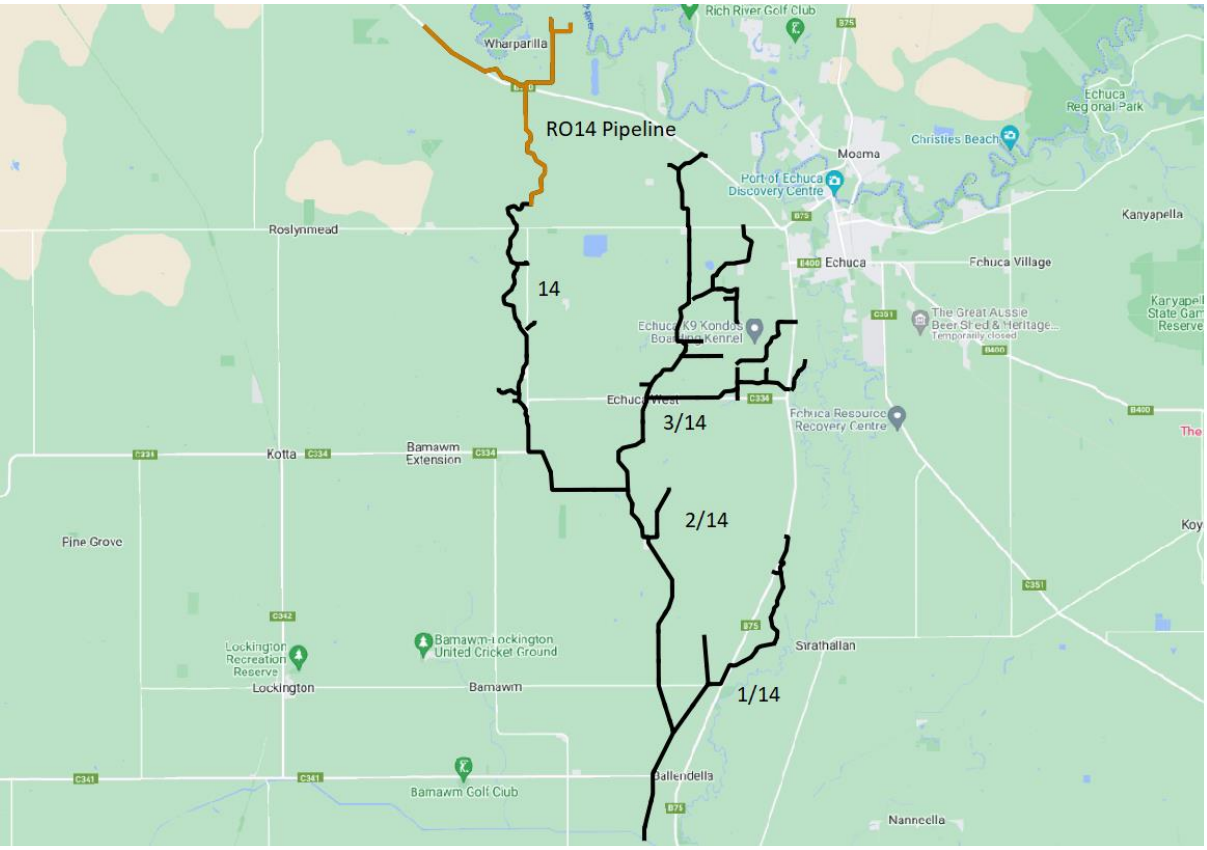

Figure 49. *The existing RO 14 channel network. The Northern end of the RO 14 channel (highlighted in orange) was replaced with a pumped pipeline within the past decade.*

Potential capacity required

This option considers the consistent delivery of 500 ML/day from the WWC to the River Murray, in addition to meeting the existing demands of customers supplied from the RO 14 channels.

To determine the indicative increase in flow capacity and works required, the existing system capacity was reviewed against demand volumes supplied in the 2021-22 water years. To support this analysis, GMW provided hourly flows for the 2021-22 water year for all regulating structures along the RO 14 main channel alignment (RO321, RO322, RO323, RO325, RO339, RO341, RO342, RO344, RO347, RO352, RO353, RO402, RO404, RO405, RO412, RO413, RO415, RO416, RO418, RO419, RO420 and RO421 – the pump station supplying the pipeline).

GMW provided the design capacity and maximum operating capacity for each structure.

Hourly flow data was provided. For each regulator, the approximate spare capacity was determined by:

- for each day, calculating the average flow rate as delivered across that 24-hour period.
- for each month, taking the maximum average flow rate from any day in that period.
- for the summer, taking the maximum daily flow rate delivered in any month in that period.
- subtracting this highest daily average from the existing operating capacity.

The indicative operating capacity required was then calculated as the difference between the current operating capacity and the highest daily average demand, plus 500 ML/day. Using this approach ensures that the current demand plus 500 ML/day could be delivered almost all throughout the summer. There would be some moments when the peak instantaneous demand is higher; however, these periods would be for very short periods (hours at most) and therefore not considered for this exercise. If this project were to proceed to the next stages of investigation, this exercise should be repeated in close consultation with GMW using flow data across multiple years and considering potential future demand patterns.

Table 23 below summarises the indicative increase in capacity required along the RO 14 main. Generally, the upper ~11km of the channel would need deliver an additional 350–400 ML/day, ~16km deliver an additional 400-450 ML/day, and the pipeline would need to be replaced with a channel which can deliver 500-535 ML/day.

Table 23. Indicative capacity increase required for regulating structures and upstream channel sections

Regulator	Current maximum operating capacity (ML/day)	Indicative operating capacity required (ML/day)	Approx. upstream pool length (m)	Indicative capacity increase required (ML/day)
RO.321	350	703	100	+353
RO.322	350	691	401	+341
RO.323	350	694	899	+344
RO.325	350	691	1,025	+341
RO.339	270	674	1,586	+404
RO.341	270	681	877	+411
RO.342	300	686	907	+386
RO.344	300	681	1,667	+381
RO.347	300	674	1,613	+374
RO.352	300	651	2,035	+351
RO.353	300	652	530	+352
RO.402	150	603	2,555	+453
RO.404	150	590	2,090	+440
RO.405	150	571	2,470	+421
RO.412	100	576	935	+476
RO.413	100	567	1,352	+467
RO.415	100	563	1,243	+463
RO.416	150	556	2,124	+406
RO.418	150	558	568	+408
RO.419	100	556	630	+456
RO.420	80	539	1,543	+459
RO.421	35	535	947	+500
Discharge to River Murray	-	500	12,003	+500

Indicative work scope

The analysis above confirms that significant capacity increases would be required for the entire length of the RO 14 channel, from the offtake at the WWC (RO 321) to the new discharge to the River Murray.

For the purposes of this feasibility-level assessment, it is assumed that this would require:

- all existing channel sections to be re-constructed to increase the delivery capacity.
- all existing regulating structures to be re-constructed.
- all existing structures (bridges, occupational crossings, culverts) to be re-constructed.
- all existing irrigation meter outlets and D&S connections on the existing channel to be relocated.
- the RO14 pump station and pipeline to be decommissioned and replaced with a new channel.
- all irrigation meter outlets on the existing pipeline to be replaced.
- all D&S outlets on the existing pipeline to be reconnected.

Table 24 lists the indicative quantities of work required to increase the RO 14 channel capacity as considered. This assessment has been completed at a high-level only for the purposes of informing the feasibility study. If this project were to proceed to the next stages of investigation, a high-level engineering review should be completed to determine the potential alignments and solutions, and when a preferred solution is determined, asset-by-asset investigations and engineering calculations should be completed.

Table 24. Indicative quantities of work required to increase the RO 14 channel capacity

Asset Type	Qty
Channel works	
Re-construct existing channel (20 – 25m bed width)	28,097 m
Replace pumped pipeline with new channel (20m bed width)	12,003 m
New channel to River Murray (20m bed width)	750 m
Meter outlets	
Irrigation outlets – relocate on re-constructed channel section	85
Irrigation outlets – replace on pipeline section replaced by channel	39
D&S outlets – relocate on re-constructed channel section	77
D&S outlets – re-connect on re-constructed channel section	52
Regulators	
Main channel regulator – construct new	32
Offtake channel regulator – construct new	10
Road crossings & structures	
Bridges, road crossings, other structures – replace	42
New discharge structure to River Murray	1

Site photographs

RO 14 channel offtake regulator (RO321)

RO 14 pumped pipeline offtake structure (RO421)

RO 14 end channel alignment (pipeline buried, channel easement visible)

Approximate banks of the River Murray near where the channel would discharge

Figure 50. *Site photographs of the existing infrastructure for the RO 14 option*

8.3 Ecological considerations

This option proposes the enlargement of channel capacity between Waranga Basin and the River Murray. The water will enter the River Murray downstream of the confluence with the Campaspe River.

The primary purpose of the option is to increase the volume of Goulburn IVT able to be delivered to the Murray during summer, when delivery shortfall risks are most likely to occur. This increased summer delivery capacity could be used to substitute flows that would otherwise have been delivered from Lake Hume through the Barmah Millewa Reach.

Until the introduction of operating rules and recent changes to Victorian trading rules, unseasonably high flows to meet trade demands led to bank erosion and degradation in the lower Goulburn River. Sustained, high flows over summer and autumn are detrimental to river health as they reduce hydraulic diversity and associated reductions in habitat for fish and macroinvertebrates.

By constructing the bypass channel, the option has the potential to reduce the volume of Goulburn IVT delivered via the lower Goulburn River and Broken Creek, by providing an alternate, preferred delivery path for existing IVT's when that capacity is not required for the purpose of Barmah-Millewa Reach substitution flows.

Two potential adverse impacts are foreseen. These include:

1. **Use of the mid-Goulburn River for the delivery of the increased summer IVT**. However, the additional flow would be less than that previously delivered in summer via the mid Goulburn River prior to the establishment of environmental water entitlements. The implication of increased flow in the mid Goulburn River should be assessed if this option is progressed beyond the feasibility assessment.
2. **Construction of a major outfall structure at the confluence of the proposed RO14 channel and the River Murray.** This would have some significant short term construction impacts and longer-term legacy issues including potential to become an attractant for native fish, with the potential for native fish to become stranded in the GMW channel network.

Within this context, we believe that there are no significant risks in ecological flow tolerances associated with this option.

8.4 Proposed works and flow capacity

The proposed works to deliver this option includes:

- re-construction of approximately 28km of large channel.
- replacement of an existing 12km pumped pipeline with a large channel.
- construction of approximately 1km of new large channel to allow discharge to the River Murray.
- construction of approximately 124 irrigation meter outlets.
- re-location of approximately 149 stock and domestic outlets.
- construction of approximately 32 large regulators and 10 small regulators.
- construction of approximately 42 road and occupational crossings.
- construction of major infrastructure to discharge to the River Murray.

There are no significant ecological flow considerations which would prohibit the construction of the channel.

This option generates a capacity of 500 ML/day which can be delivered all year round, subject only to maintenance requirements within the channel. This maximum capacity would be available on call, limited only by irrigation demands on the WWC and for customers on the RO 14 channel.

8.5 Cost to implement

The cost estimates for this option were developed using actual construction costs from similar projects as provided by GMW and MIL. To calculate the 2022 present value, inflations rates were sourced using the publicly available Producer Price Indexes published by the Australian Bureau of Statistics[40]. The total costs for the Rochester 14 bypass channel option are summarised in **Table 25.**

Complexity levels (high, medium, and low) have been applied to estimate program management, survey, design, approval, overhead, operational and maintenance costs. These complexity levels correspond with a percentage to be applied and qualitatively estimates the amount of work required in each of those categories to deliver the works. GMW and its customers would not contribute to the capital, operational, or maintenance costs associated with bypass deliveries.

Additional asset maintenance and renewal costs have been calculated in present annual value as a percentage of the capital cost. A 2% per annum allowance has been included. This recognises that the assets are mostly static and long-lived, existing assets are being updated which would reduce maintenance and asset renewal liability, and new or expanded assets are being installed which would increase the maintenance and asset renewal liability. This allowance generally considers the above factors; however, the actual contribution for asset maintenance and renewal costs would need to be further detailed and negotiated as part of any further option development.

The total O&M cost has been assessed over a 50-year period using a 7.0% discount rate.

Where bypass water is delivered, it is expected that GMW would charge:

- In the likely scenario that the MDBA acquired delivery shares to secure access, a fixed Infrastructure Access Fee ($2,547/ML/day is the published charge rate, per 2022/23).
- A variable Infrastructure Use Fee:
    - If the MDBA acquired delivery shares, an Infrastructure Use Fee ($5.15/ML).
    - If the MDBA did not acquire delivery shares, a casual Infrastructure Use Fee ($43.36/ML).

Any such agreement would involve negotiation of charges, recognising the very large annual volumes and the contribution to renewing existing GMW assets that would be involved.

Table 25. Rochester 14 bypass channel cost estimate

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	Infrastructure cost				87,667,105
1.1	Channel works				29,619,273
1.1.1	Re-construct existing channel (20 – 25m bed width)	28.1	$505,000	/ km	14,249,193
1.1.2	Replace pumped pipeline with new channel (20m bed width)	12	$1,215,000	/ km	14,609,366
1.1.3	New channel to River Murray (20m bed width)	0.75	$1,015,000		760,714
1.2	Meter outlets				6,117,180
1.2.1	Irrigation outlets – relocate on re-constructed channel section	85	$35,000	/ outlet	3,187,430
1.2.2	Irrigation outlets – replace on pipeline section replaced by channel	39	$55,000	/ outlet	2,048,783

[40] Producer Price Indexes, Australia, March 2022 | Australian Bureau of Statistics (abs.gov.au)

1.2.3	D&S outlets – relocate on re-constructed channel section	77	$2,000	/ outlet	153,848
1.2.4	D&S outlets – re-connect on re-constructed channel section	52	$15,000	/ outlet	727,120
1.3	**Regulators**				**26,055,652**
1.3.1	Main channel regulator – construct new	32	$770,000	/ regulator	24,695,652
1.3.2	Offtake channel regulator – construct new	10	$135,000	/ regulator	1,360,000
1.4	**Road crossings & structures**				**25,000,000**
1.4.1	Bridges, road crossings, other structures – replace	42	$500,000	/ structure	21,000,000
1.4.1	Major road crossing - Murray Valley Highway - replace	1	$2,500,000	/ structure	2,500,000
1.4.2	New discharge structure to River Murray	1	$1,500,000	/ structure	1,500,000
1.5	**Land transactions**				**875,000**
1.5.1	Easement creation for new channel section	3.75	20,000	ha	75,000
1.5.2	Easement creation for channel widening	40	20,000	ha	800,000
2	**Program Management, survey, design, approvals and overheads**				**30,683,487**
2.1	**Program management and overheads**				**15,341,743**
2.1.1	Program management - Medium complexity - 17.5% of infrastructure costs	1	17.5%	percentage	15,341,743
2.2	**Survey, design and approvals**				**15,341,743**
2.2.1	Survey and Design - Medium complexity - 7.5% of infrastructure costs	1	7.5%	percentage	6,575,033
2.2.2	Regulatory approvals including offsets - Medium complexity - 10% of infrastructure costs	1	10%	percentage	8,766,710
3	**Contingency**				**47,340,237**
3.1	**Contingency**				**47,340,237**
3.1.1	40% of infrastructure, program management, survey, design, approval and overhead costs	1	40%	percentage	47,340,237
	Total capital cost				**165,690,828**

4	**Operations and maintenance**				**49,286,834**
4.1	**Operations and maintenance**				**49,286,834**
4.1.1	Additional maintenance and renewal costs as a result of upgrade works	1	2%	percentage	45,733,142
4.1.2	GMID Infrastructure Use Fee	50,000	$5.15	$/ML	3,553,692