9

Suite of Options Report

BARMAH-MILLEWA FEASIBILITY STUDY

March 2023

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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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Contents

1 Background

1.1 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 'Suite of Options Report' has been prepared to assess how each of the six options under investigation as part of the BMFS may contribute to managing risks and provide opportunities, and how a combination of complementary options (or 'suites of options') may be needed to achieve the best outcomes.

1.2 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 120 m at Tocumwal to 40 m 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].

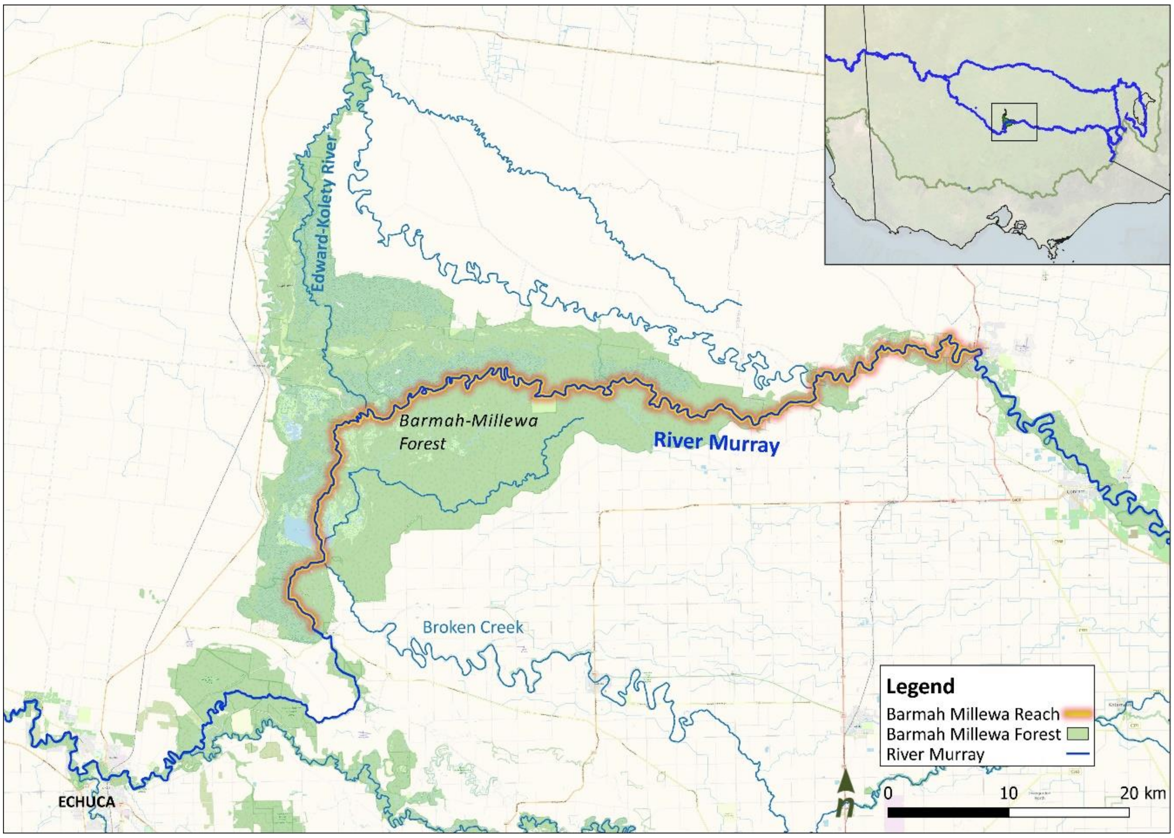

Figure 1. *Location of the Barmah-Millewa Reach of the River Murray*

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 2.6 m at Picnic Point. This allows flows to be managed within the riverbank, avoiding unseasonal overbank flows.

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

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.

These 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].
- increase the risk of shortfall events, with adverse economic impacts on water users[5].
- increase the risk of unseasonal flooding (and water diverted from the river) 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 the Barmah-Millewa Forest through 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:

- Option 1 - River works within the Barmah-Millewa Reach: targeted river works to stabilise banks and avoid new breakaways into the surrounding forest.
- Option 2 - Sediment management: selectively removing the sand from key locations.
- Option 3 - Tar-Ru (Lake Victoria) transfers: 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 (MIL) 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 Releases to the Murrumbidgee: transferring River Murray releases from the Snowy to the Murrumbidgee River, 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 is an additional potential option discussed in this report relating to the use of the Murrumbidgee Weirs to help mitigate delivery shortfall risks. The use of these weirs is discussed as a complementary opportunity to the Snowy Hydro option and it is proposed that this be explored in more detail in any future investigations.

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 options in detail.

An 'Options Summary Report' has been prepared to introduce each of the six options and provide 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 'Feasibility Study Report' has also been prepared to collate and present the findings of the study[7].

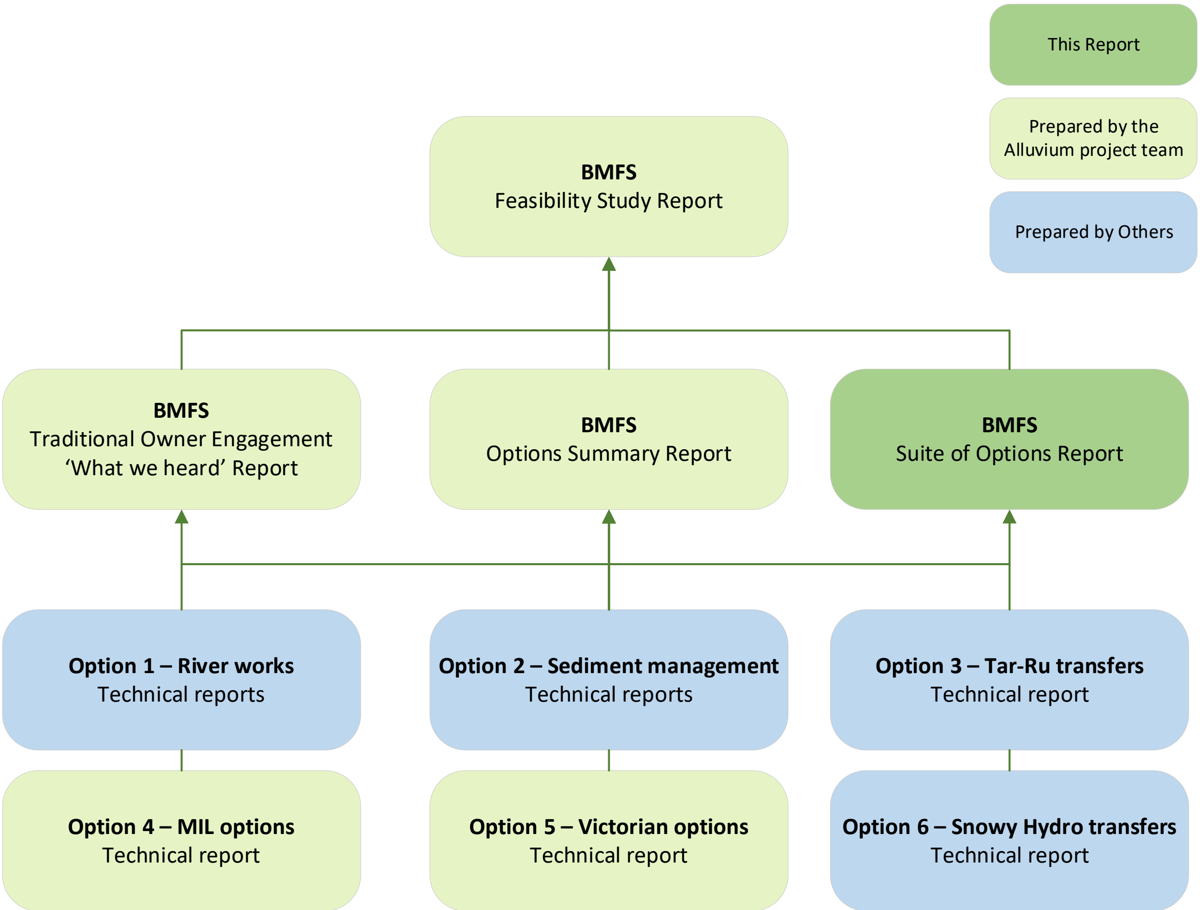

Figure 2. *The various reports being prepared to support the Barmah-Millewa Feasibility Study.*

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

1.3 Options to be assessed

As detailed above, there are six options which are being investigated as part of the BMFS. Options 4 (MIL system) and 5 (Victorian infrastructure) contain several sub-options. These are standalone options and therefore can be considered and assessed individually. More detail on each of these sub-options, including their identification and scoping, are contained in separate reports[8,9]. These sub-options include:

- Option 4A.1: MIL Options – Optimised use of the channel escapes (no works)
- Option 4A.2: MIL Options – Optimised use of the channel escapes (upgrade works)
- Option 4B: MIL Options – Perricoota Escape expansion
- Option 4C: MIL Options – Mulwala Canal extension
- Option 5A: Victorian Options – Enhanced use of the Victorian Mid-Murray Storages
- Option 5B: Victorian Options – Enhancement of the Murray Valley Irrigation Area outfalls
- Option 5C: Victorian Options – Barmah bypass gravity channel
- Option 5D: Victorian Options – Rochester 14 bypass channel

1.4 Method of assessment

A key outcome from the Barmah-Millewa Feasibility Study is to transparently assess each option for managing delivery risk and reducing stress on the River Murray against an agreed set of key criteria.

Specific project objectives have been set out as part of this study. These project objectives guide the outcomes sought from the project, including the risks to be addressed and potential opportunities to be realised.

Achieving all project objectives will require several of the options to be considered, referred to as 'suites of options'. This recognises that there are several issues and opportunities to be addressed by this study, including water resource and ecological outcomes, within the Barmah-Millewa Reach as well as the broader River Murray System. The individual options contribute differently to the project objectives, and therefore multiple options will be required.

The method for assessing the options and the 'suites of options' was developed in consultation with the MDBA and a Technical Oversight Committee (TOC). The TOC was established as a key part of the governance arrangement for this study. The purpose of the TOC was to provide technical support and advice to governments and the MDBA on the options for future management to reduce stress on the Barmah-Millewa Reach and the River Murray System. The TOC included representatives from the NSW, Victorian, and South Australian governments involved in river management, as well as the MDBA.

A Decision-Making Framework (DMF) was used to assess the suites of options. The framework was originally developed for the MDBA by the Independent Panel for Capacity Project Review (IPCPR) to provide Governments with a transparent and standardised process for making decisions on river operation practices.

The key steps in the method for assessing the options and suites of options are summarised in Table 1 below. Detail for each of these steps are provided throughout this report.

[8] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*
[9] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation.*

Table 1. Key steps for assessing options and suites as part of the BMFS

Define the objectives	• Define the key objectives of the BMFS project.
Detailed scoping of options	• Identify the range of flow rates each option is capable of delivering. • Identify lead time to implement option. • Undertake detailed assessment of engineering feasibility and ecological impact.
Assess the options	• Define key assumptions that will be used for assessing the options. • Rank options on time-to-implement. • Assess the options using a multi-criteria analysis (MCA) framework and qualitative assessment. • Use results of the MCA to identify the preferred options.
Define flow scenarios for the suites	• Define the scenarios for the suites • Define the key assumptions that will be used for assessing the suites.
Combine the options into suites	• For each scenario, combine the options into a suite based on cost, combined with expert judgement on benefits achieved. • Prioritise inclusion of options that can be implemented in the short-term. • Conduct a detailed review to ensure cohesiveness of the suite.
Assess the suites	• Assess the suites including applying the Independent Panel for Capacity Project Review (IPCPR) Decision Making Framework.

1.5 Project objectives

The Project Objectives (PO) for the Barmah-Millewa Feasibility Study (BMFS) are summarised in **Table 2**. These objectives have been interpreted from the study objectives as set out in the Project Plan and the objectives for the feasibility study as set out in Terms of Reference (as approved by the Ministerial Council in June 2020).

The project objectives were used to identify the individual options available as part of developing the BMFS study. To be considered as part of this study, each option had to directly contribute to at least one of the project objectives and, preferably, contribute to multiple objectives.

For the purposes of assessment, these project objectives are explicitly considered when compiling potential suites of options, to ensure that contributions are being made to the achievement of all the objectives.

Table 2. Barmah-Millewa Feasibility Study project objectives

PO#	Project objectives
PO1	Maintain or enhance the ability to meet peak demand downstream of the Barmah-Millewa Reach (managing delivery shortfalls)
PO2	Maintain or enhance the ability to deliver water downstream of the Barmah Millewa Reach throughout the year (managing system shortfalls).
PO3	Provide greater opportunity for more desirable flow regimes to be delivered through the Barmah-Millewa region, including avoided undesirable inundation of the forest
PO4	Reduce the localised environmental impacts associated with the ongoing sedimentation of the river reach (i.e., loss of fish habitat, etc)
PO5	Reduce the risks of bank failure at the Barmah Forest protecting the significant environmental and cultural values of the forest floodplain
PO6	Provide improved ability to deliver environmental water along the River Murray
PO7	Further facilitate the delivery of environmental water into sites within the Edward/Kolety-Wakool system
PO8	Benefits generated by the project will need to be resilient to a range of potential future demand and management scenarios, including with and without constraints relaxation
PO9	Benefits generated by the project will need to be resilient to a range of climatic and water availability conditions.

Together, project objectives PO1 and PO2 seek to address a key project requirement to maintain or increase reliability of water delivery. Further information on these project benefits, including ‘to maintain or increase reliability of water delivery’, can be found in the Feasibility Study Report.

2 'Do Nothing' scenario

One option to be assessed in this study is to 'do nothing' further. Defining this scenario provides an important reference point when considering the need to take action. The 'do nothing' further scenario can be broadly described as:

- do nothing to prevent further decline or restore the flow capacity in the Barmah-Millewa Reach.
- do nothing to directly manage the sand accumulation in the reach.
- do nothing to directly manage the accelerated bank erosion in the reach.

A continual decline in flow capacity and increase in the risk of delivery shortfall events is expected to have a wide-range of impacts, including on the ability of river operators to meet downstream commitments to South Australia, an increasing risk of accelerated environmental degradation, a reduction in environmental watering opportunities during periods of peak irrigation demand, and a reduction in the reliability of entitlements and the ability to irrigation demands across New South Wales, Victoria, and South Australia.

This 'do nothing' scenario has been considered over the next 10 years. This section describes the outcomes that could reasonably be expected under this scenario. This scenario provides background context when considering the various options that could be implemented as part of this study.

Declining flow capacity
The capacity of the Barmah-Millewa Reach has declined by around 20% over the past three decades[10]. Investigations have determined that the cause of the decline in capacity is primarily sediment from historic mining and land use changes accumulating in the reach[11].

The MDBA has modelled the expected River Murray capacity changes if the sand continues to accumulate. This modelling found that, without intervention, the flow capacity could decrease by around a further 1,000 ML/day in the next 10 years[12]. This modelling is preliminary in nature and reliant on a range of assumptions. However, it provides the best available insight into the additional decline in flow capacity under a 'do nothing' scenario.

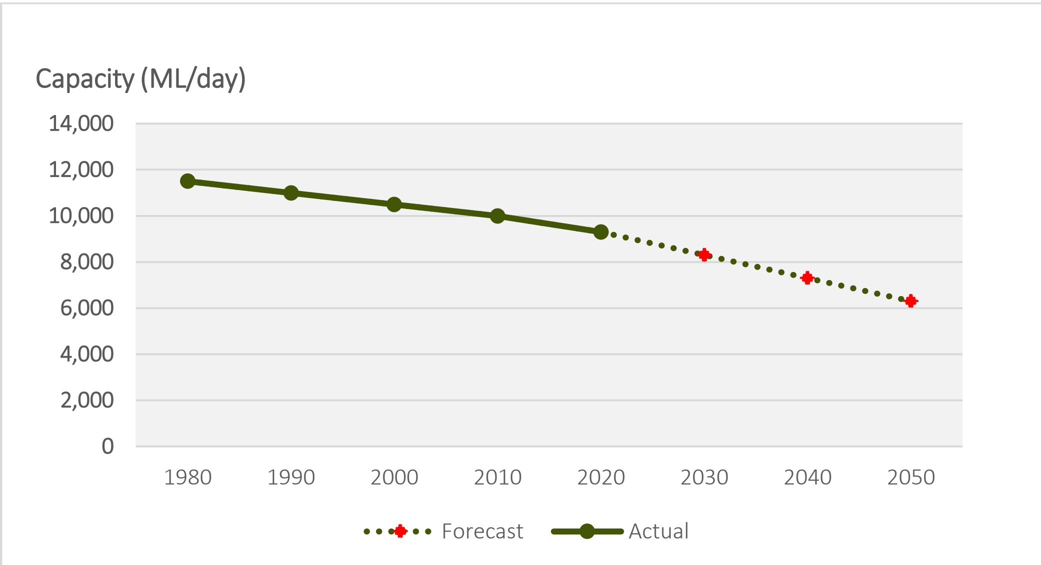

Figure 3. *Change in estimated River Murray capacity in the Barmah-Millewa Reach*[13]

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[10] Water Technology (2020). *Barmah Choke Channel Capacity and Geomorphic Investigation*
[11] Grove James R (2021) *A fluvial geomorphic investigation into channel capacity changes at the Barmah choke using multiple lines of evidence.* pg 21
[12] MDBA (2022), *Preliminary investigation into Murray River at Gulpa (409006) Capacity Changes Resulting from Sand Removal/Aggradation*
[13] *Ibid.*

Risk to irrigated agriculture as a result of declining flow capacity

Horticultural crops in the lower Murray

Horticultural crops can be grown above or below the Barmah-Millewa Reach, but are preferentially grown in the lower Murray, due to a range of factors including favourable climatic conditions and proximity to infrastructure, services, labour, and soil quality[14]. Irrigated agriculture in the semiarid lower Murray relies on water from the River Murray system to sustain the industry.

Water use delivered to the lower Murray[15] in 2020-21 was approximately 1,012 GL[16]. Of this total, 56% was used to irrigate fruit and nut trees, 27% was used on grapevines, and 14% on pastures and cereal crops further grazing and silage.

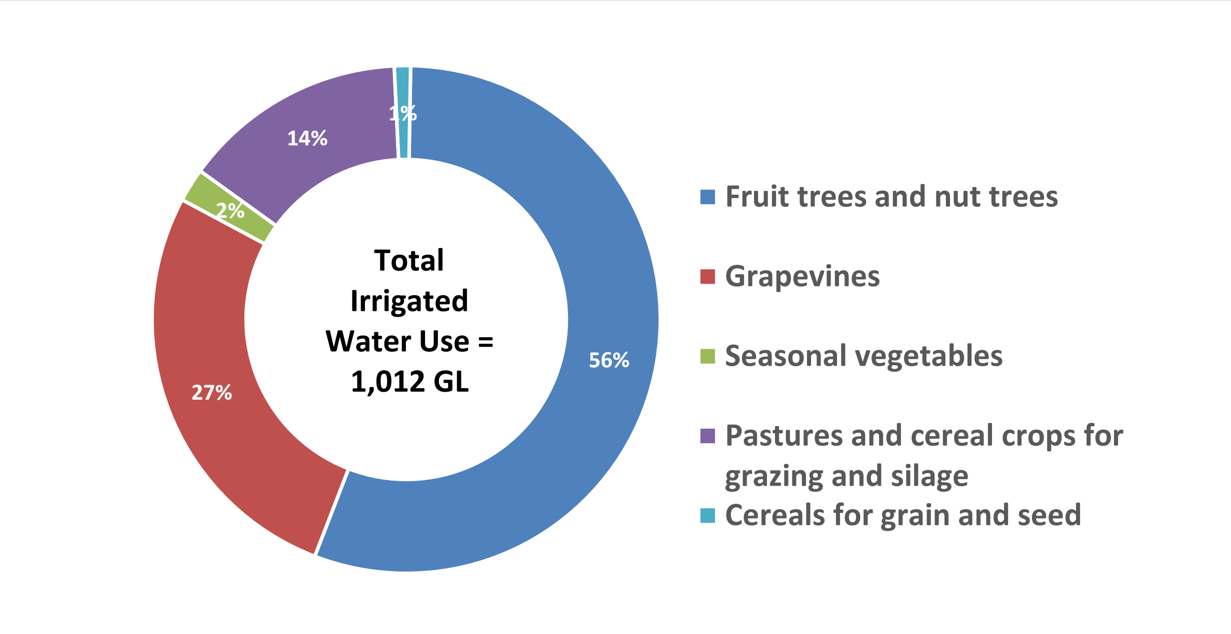

Figure 4. *Breakdown of irrigated agricultural water use in the 'lower Murray'*[17]

Volumetric impact of declining capacity

Limited and declining flow capacity within the Barmah-Millewa Reach presents a challenge to river operators delivering water to irrigated agriculture in the lower Murray. When demand peaks during hot weather events in summer, there is a risk that there is insufficient capacity in the system to deliver the water in the timeframe required, resulting in a potential delivery shortfall event. The risk of a delivery shortfall event occurring can be somewhat mitigated by reinstating channel capacity and having options which can deliver water on short notice from storages nearby where the demand occurs. The risk of a delivery shortfall event is ever-present however and cannot be managed to zero, particularly in the context of a changing climate.

It is possible to provide an indication of the potential future impact on water availability for irrigated agriculture as a result of further reductions in the flow capacity in the Barmah-Millewa Reach by drawing on historical data. Over the past decade, an average of approximately 975 GL/year of regulated flows have been delivered through

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[14] Cummins T. et al. (2022*) An Investigation into the Location of Horticultural Water Demands*

[15] Farms supplied from the River Murray System below the Barmah Millewa reach or the 'lower Murray' have been defined by reference to land classifications sourced from https://www.agriculture.gov.au/abares/aclump/catchment-scale-land-use-of-australia-update-december-2020 and digital boundary files sourced from https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/digital-boundary-files. The 'lower Murray' is assumed to comprise ASGS Regions: Barmera, Gannawarra, Kerang, Loxton, Loxton Surrounds, Mildura – North, Mildura – South, Mildura Surrounds, Red Cliffs, Renmark, Renmark Surrounds, Robinvale, Swan Hill, Swan Hill Surrounds, Waikerie, Wentworth – Buronga and Wentworth-Balranald Region

[16] Data from Australian Bureau of Statistics: WUAFDCASGS202021 - Water Use on Australian Farms, 2020-21 ASGS 3 Regions. Downloaded from https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/2020-21/WUAFDCASGS202021.xlsx

[17] *Ibid.*

the Barmah-Millewa Reach during the summer irrigation peak period (from 15 December to 30 March)[18]. Of this volume, approximately 83 GL/year has been delivered at flow rates above 8,300 ML/day. This is the flow capacity that would be expected in the Barmah-Millewa Reach in 2032 if nothing is done to manage the ongoing sand that is accumulating on the riverbed.

Note, elsewhere in this study, the potential flow rate in the next decade if no action is taken to manage the flow capacity of the reach is estimated as 7,700 ML/day. This assumes a 1,000 ML/day reduction as a result of sand aggradation, and a further 500 ML/day as a result of bank erosion lowering the river operating height. For the purposes of the economic assessment, the reduction as a result of sand accumulation is only considered. The potential economic impact would be higher if bank erosion resulted in a further flow capacity reduction.

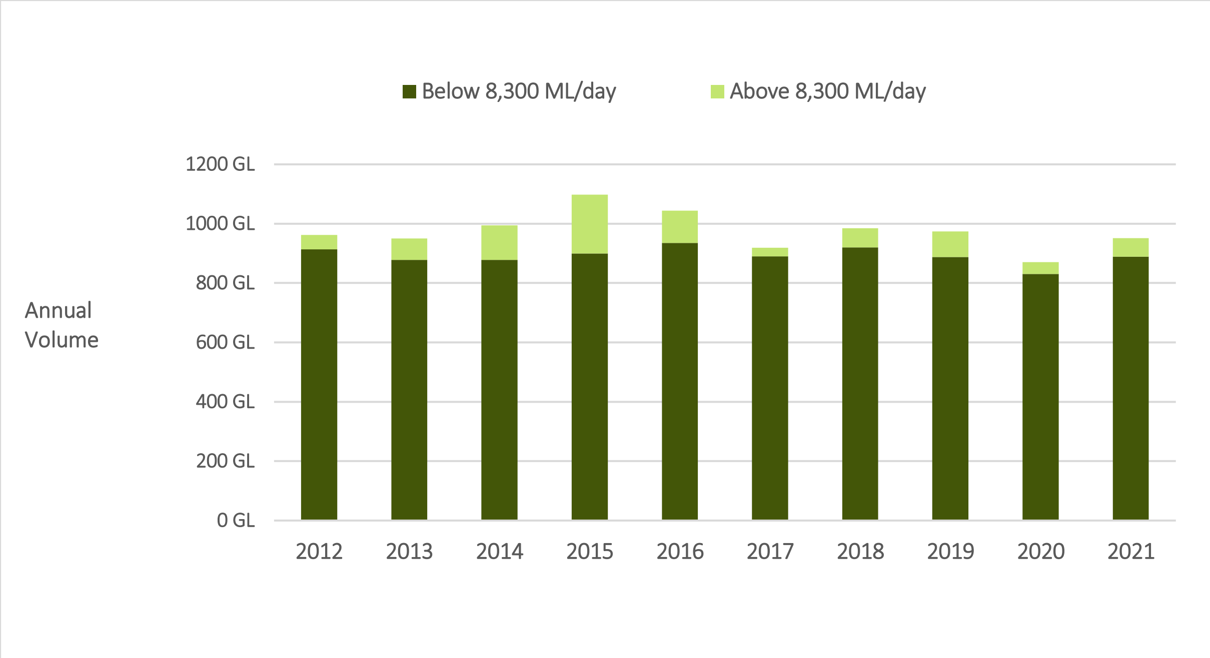

Figure 5. *Estimated volume of regulated deliveries through the Barmah-Millewa Reach made during the peak irrigation season from 15 December to 30 March each year.*

Economic impact of declining capacity

Whilst shortfall events have not occurred in the Murray system recently, permanent horticultural plantings would be highly susceptible to shortfalls. Depending on the timing of the shortfall of water both crop yields and quality of produce can be impacted. For example, water stress affects both in-season and future almond yields. For these crops, generally, every percent of reduced water application leads to the same percentage of crop loss. An estimate of the value of irrigated agricultural production at risk from reduced channel capacity is provided in **Table 3**. This data shows the estimated gross value of horticultural production and irrigation water usage for farms supplied by the River Murray system in the lower Murray[19].

A further reduction in the volume of regulated flow of 83 GL delivered downstream through the Barmah-Millewa Reach would represent approximately 8% of the total water used by irrigated agriculture within the lower Murray in 2021-22.

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[18] Flow data from gauge no. 409202a accessed from https://riverdata.mdba.gov.au/tocumwal. Regulated flow is assumed to be all flow below10,600 ML/day during the peak irrigation season – source HARC (2021) Historical Flows in the southern connected Murray Darling Basin

[19] Data from Australian Bureau of Statistics: VACPDCASGS202021 - Value of Agricultural Commodities Produced, Australia, 2020-21. Downloaded from https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/latest-release

Assuming a one-on-one reduction in agricultural production as a result of a reduction in water use, the economic impact of the declining capacity in the Barmah-Millewa Reach would be an 8% decline in the value of agricultural production from the lower Murray horticultural industry. This would be equivalent to more than $200 million in 2020-21 terms.

In practice, a reduction in the flow capacity of the reach would not lead to a directly equivalent loss of delivery to irrigators, and in turn lost agricultural production value or of irrigated production. However, this analysis does provide a useful insight into the potential scale of irrigated horticulture which may be susceptible to shortfall events and would be more likely to occur with a reducing flow capacity.

Recent research undertaken by the MDBA found that horticultural developers in the lower Murray are conscious of shortfall risks, but in the context of all the other risks they contend with, and in the absence of the shortfall events having yet materialised, shortfall risks are seen as being outweighed by significant advantages to locating new developments in that area[20].

Table 3. An indicative estimated value of horticultural production in the lower Murray which could be at risk from further reductions in flow capacity through the Barmah-Millewa Reach

Crop Type	Irrigation Water Usage 2020-21 (GL)	Value of Agricultural Production ($k)
Fruit trees and nut trees	561	1,316,000
Grapevines	272	900,000
Seasonal vegetables	22	158,000
Total	**854**	**2,374,000**
Value of agricultural production potentially at risk from further reductions in flow capacity through the Barmah-Millewa reach (based on 2032 forecasts)	**83**	**230,000**

The equivalent impact in terms of the area of irrigated agriculture in the Lower Murray is shown in **Table 4**. A reduction in the volume of regulated flow of 83 GL would translate to a 11,000-hectare reduction in the area of irrigated agriculture.

Table 4. An indicative estimate of irrigated area of horticultural production in the lower Murray potentially at risk from reduced capacity in the Barmah-Millewa Reach

Crop Type	Irrigation Water Usage 2020-21 (GL)	Area of Agricultural Production (hectares)
Fruit trees and nut trees	561	70,000
Grapevines	272	40,000
Seasonal vegetables	22	5,000
Total	**854**	**115,000**
Area of irrigated production potentially at risk from further reductions in flow capacity through the Barmah-Millewa Reach (based on 2032 forecasts)	**83**	**11,100**

[20] Cummins T. et al. (2022*) An Investigation into the Location of Horticultural Water Demands*

Risk of further accelerated bank erosion
Erosion of the riverbank is a natural process as the river meanders across the landscape. However, in the Barmah-Millewa Reach, bank erosion has increased markedly since the commencement of river regulation[21]. Recent surveys found that approximately 40% of the reach is affected by accelerated erosion[22].

To supply downstream demands the river runs at bankfull level for extended periods during the summer months. During warm, dry summers that coincide with times when seasonal irrigation water allocations are high, the river can flow at near or above the estimated capacity of the Barmah-Millewa Reach for most of the January-April period[23].

High regulated flows at constant levels, which will become increasingly common if the capacity of the Barmah-Millewa Reach continues to decline, scour the bank, resulting in bank collapse and slumping. The removal of large snags over time to increase the capacity of the river has also caused the river to run faster and in turn caused greater erosion[24].

Figure 6. *Example of accelerated erosion on the riverbanks in the Barmah-Millewa Reach*[25]

Accelerated erosion has a number of impacts, including environmental degradation (trees falling into the river, destruction of riparian vegetation, etc.), damage to cultural heritage values (scarred trees, etc.), and deterioration of recreational qualities for more passive river users[26]. Accelerated bank erosion also contributes sediment loads in the river, impacting on stream habitat. It is estimated that approximately 8% of the total sediment load in the Barmah-Millewa Reach is the result of accelerated bank erosion[27].

Under a 'do nothing' scenario, it can reasonably be expected that the accelerated bank erosion will continue as a result of bankfull flows being delivered through the Barmah-Millewa Reach for sustained periods of time.

[21] Cardno (2020) *Yarrawonga to Torrumbarry river works program feasibility business case*
[22] *Ibid.*
[23] HARC (2021), *Op. Cit.*
[24] https://www.mdba.gov.au/community-updates/why-erosion-occurring-river-murray-particularly-through-barmah-choke
[25] *Ibid.*
[26] MDBA (2017) *Bank erosion along the River Murray between Hume Dam and the Ovens junction*
[27] Grove (2021) *Murray bed sediment calculations*

Risk of unseasonal flooding of the Barmah-Millewa Forest

The Barmah-Millewa Forest contains a mosaic of floodplain ecosystems which evolved under natural conditions, with frequent winter and spring flooding alternating with dry conditions during summer and autumn[28]. The Forest is ecologically significant and is listed under the Convention on Wetlands of International Importance (the Ramsar Convention), the Directory of Important Wetlands in Australia, and is one of six Living Murray icon sites.

With river regulation, flooding of the Barmah-Millewa Forest became much more frequent in summer and autumn. Historically, unseasonal flooding occurred primarily as a result of irrigation rainfall rejections[29]. Increased summer inundation caused changes in the patterns of vegetation with red gums and rushes expanding at the expense of Moira grass Plains[30]. The changed natural pattern of unseasonal summer inundation in the Barmah-Millewa Forest has resulted in a 90% reduction in the extent of Moira grass wetland since the 1970s[31].

In recent years the extent of rainfall rejections has been reduced due to more accurate forecasting of irrigation demand and lower demands. However, unseasonal flooding of the forest can still occur when the River Murray is run at bankfull level and the river flow overtops eroded sections of the riverbank levee.

Under a 'do nothing' scenario, it can reasonably be expected that the risk of unseasonal flooding of the forest could increase as a result of bankfull flows being delivered through the Barmah-Millewa Reach for sustained periods of time.

In designating a Ramsar site, countries agree to set up and oversee a management framework aimed at conserving and maintaining the wetland and its ecological character. Increased unseasonal flooding of the Barmah-Millewa Forest due to declining capacity in the reach potentially results in ecological damage to the wetland that may contravene Australia's obligations under the Ramsar Convention.

Risk of increased conveyance losses

Following regulation of the Murray in the 1930s, works were undertaken to build up and reinforce the natural levees throughout the Barmah-Millewa Reach, to increase the conveyance capacity of the main river channel[32]. Regulators were constructed within the channel banks that could be operated to enable regulated flows to be conveyed through the Barmah-Millewa Forest through floodplain anabranch waterways back to the river downstream of the reach.

Reduced capacity in the main river channel as a result of sedimentation increases the likelihood that regulated flows may need to be conveyed through floodplain anabranch waterways to manage potential shortfalls. When regulated flows are conveyed by the anabranch waterways, conveyance losses may be higher than would be the case if the flow was delivered by the main channel of the river[33].

Conveyance losses are the difference between the volume of water released from storages into the river system and the volume delivered at demand points such as bulk offtakes and metered diversion points on the river. Evaporation, transpiration, and seepage are the main contributors to river losses. In the River Murray system, conveyance water is set aside before water is allocated to consumptive uses, and therefore higher rates of conveyance loss result in less water allocated to users.

Under a 'do nothing' scenario, there is an increased risk of higher conveyance losses as a result of river operators needing to manage potential shortfall risks and increase the use of floodplain anabranches for delivery.

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[28] Ladson et al (2005) *Unseasonal flooding of the Barmah-Millewa forest*
[29] https://www.mdba.gov.au/sites/default/files/pubs/The%20Barmah%20Choke%20fact%20sheet.pdf
[30] Chong (2003) *Analysis and management of unseasonal surplus flows in the Barmah- Millewa Forest*
[31] https://www.environment.nsw.gov.au/news/rare-grassland-at-home-in-southern-wetlands
[32] Chong et al (2003) *Analysis and management of unseasonal flooding in the Barmah-Millewa Forest, Australia*
[33] MDBA (2019) Losses in the River Murray system, 2018 – 19

Increased risk of river avulsion

Accelerated rates of sedimentation increase the likelihood that the mainstem of the River Murray in the Barmah-Millewa Reach could change its course[34]. An avulsion is the term used to describe when a river rapidly changes its course and forms a new main channel on the floodplain. Avulsions generally result from the accumulation of sediment on the riverbed elevating the river above the surrounding floodplain. The avulsion occurs abruptly during major flood when the river breaches its natural levee and spills into a new water course.

The likelihood, timeframe, and impact of a River Murray avulsion event in the Barmah-Millewa Reach is unknown. One of the key factors that determines the impact is whether the avulsion re-occupies an abandoned river channel from the mainstem near the avulsion or constructs a new channel on the floodplain[35]. Worldwide river avulsions have caused major flooding, loss of life, and property damage[36]. An avulsion of the River Murray would have significant environmental, social and cultural impacts across the river system, and would make it increasingly difficult for river operators to meet demands.

Historical avulsions on the Murrindindi and Yea rivers in the Goulburn catchment (Victoria) have been attributed to sedimentation resulting from gold mining and land clearing[37]. In these situations, the avulsion lagged behind the input of sand because of the time needed for the sand to be transported downstream.

Under a 'do nothing' scenario, the continued aggradation of sand in the Reach and the accelerated bank erosion reasonably infers that there is a continually increasing risk of an avulsion of the River Murray in the future.

Cultural, environmental, and social impacts

The acceleration of bank erosion can lead to the loss of levees on the riverbanks, in turn increasing the risk of damage to and loss of cultural sites located on the riverbanks and through the floodplain. This includes cultural sites such as middens and scar trees. Continual aggradation of sand in the bed of the river means:

- deep pools will continue to fill in and smother habitat such as woody debris changing the riverine environment. This has significant impacts for a broad range of native fish and other aquatic species by reducing species diversity, population abundance and recruitment[38].
- increased unseasonal flooding and limited access for:
    - recreation throughout the forest, and potentially negative impacts on camp sites and tracks.
    - beekeeping and tourism businesses utilising the National Park, particularly during the Christmas and Easter peak visitation periods.
    - fire suppression when floods block off access tracks.

'Do nothing' – summary of expected outcomes

Over the next 10 years, modelling has indicated that the flow capacity will continue to decline. This decline could be further accelerated if erosion of the riverbanks caused the operating height of the river to be reduced. This continual decline in flow capacity could reasonably be expected to:

- increase the risk of delivery shortfall events, having the potential to indicatively affect around $230 million and 11,000 hectares of irrigated agriculture in the lower Murray.
- increase the risk of continued accelerated bank erosion within the reach, adversely impacting environmental, cultural, and social values.
- increase the risk of unseasonal flooding in the Barmah-Millewa Forest, adversely impacting an ecologically significant site as recognised under the Ramsar convention.
- increase the risk of higher conveyance losses.
- increase the risk of impact to cultural, environmental, and social values.
- increase the risk of a future avulsion of the River Murray.

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[34] MDBA (2019) Losses in the River Murray system, 2018 – 19
[35] Valenza J.M et al (2020) *Downstream changes in river avulsion style are related to channel morphology*
[36] Singerland R.L et al (2004) *River avulsions and deposits*
[37] Erskine et al (2014) *River management on a reach basis highlights lagged channel responses to multiple catchment disturbances: Yea and Murrindindi Rivers, Victoria*
[38] Streamology (2021) *Options for managing sediment in the Barmah-Millewa reach of the River Murray, preliminary investigations*

3 Individual option assessment

3.1 Method for assessing the individual options

Detailed scoping of the individual options

A detailed description is provided for each option[39] in the following sections of this report. This includes a description of the works or changes required to implement the option, the capacity outcomes that could reasonably be expected from the option, and other considerations when assessing the viability of the option.

Assessing the individual options

To provide a relative assessment for each of the individual options, each option has been assessed using four elements. The scores or assessment of these four parts have then been considered in the development of suites of options. The elements used to assess the individual options are:

- **Part 1**: Implementation readiness
- **Part 2**: Multicriteria analysis against (scorable) project objectives
- **Part 3:** Qualitative assessment (non-quantified)
- **Part 4:** Cost effectiveness

Traditional Owner perspectives and cultural value considerations have been captured through engagement and are available in a separate report. The assessments in this report should be considered in the context of the perspectives provided through this engagement.

Part 1 – Implementation readiness

An assessment has been completed to determine a realistic timeframe to implement and commence operation for each individual option. Options which can be readily implemented can assist with the issue of ongoing declining capacity in the short-term.

Part 2 – Multi-criteria analysis against project objectives

A multi-criteria analysis (MCA) has been developed and used as part of assessing each of the options. An MCA is a form of analysis that can include variables such as environmental and social impacts that may be quantified. The MCA includes assessment against nine measures, as shown in **Table 5**. The particulars of the MCA were developed in consultation with the Technical Oversight Committee for this study and considered key elements of the MDBA's Decision Making Framework (DMF).

Part 3 – Qualitative assessment and descriptive benefits/disbenefits

There are many factors that are not easy or appropriate to quantify, such as resilience to climate change and the ability to adapt to potential changes resulting from relaxed constraint scenarios or the Enhanced Environmental Water Delivery (EEWD) program[39]. A summary of the qualitative matters will be determined for each of the options using the following:

✓	No key matters identified
!	Key matters to be resolved
⚠	Unresolvable matters

Part 4 – Financial cost

Financial criteria will be incorporated into the analysis for each individual option. The financial criteria include consideration of the capital and administrative cost to implement the option, and the operational, maintenance and delivery costs to deliver flows through the option once operational.

[39] https://www.mdba.gov.au/basin-plan/sustainable-diversion-limits/sustainable-diversion-limit-adjustment-mechanism-projects

Table 5. Multi-criteria analysis (MCA) measures to be used for assessing individual options

Measure grouping	Unit of measure	Means of measurement	Weighting of grouping	Weighting of individual criteria	MCA Scoring				
					-20	-10	0	10	20
Water availability	Change in system water	Total losses from point of diversion to return to the River Murray, relative to current losses through the Barmah-Millewa Reach	25%	12.5%	Potentially large increase in losses	Small increase in losses expected	No or very small change expected	Small reduction in losses expected	Potentially large reduction in losses
	Change in State water shares	Potential for change in State water shares as a result of implementing the option		12.5%	High risk that State water shares will be adversely affected	Low to moderate risk that State water shares will be adversely affected	No change in State water shares	Low to moderate opportunity to improve outcomes for Share water shares	High opportunity to improve outcomes for State water shares
Environmental	Environmental flows in Reach	Change in environmental risk within the Barmah-Millewa Reach as a result of implementing the option	20%	5%	High increase in environmental risk	Low to moderate increase in environmental risk	No change	Low to moderate decrease in environmental risk	High decrease in environmental risk
	Environmental flows outside Reach	Change in environmental risk outside of the Barmah-Millewa Reach as a result of implementing the option		5%	High increase in environmental risk	Low to moderate increase in environmental risk	No change	Low to moderate decrease in environmental risk	High decrease in environmental risk
	Sediment accumulation in Reach	Change in sediment accumulation risk in the Barmah-Millewa Reach as a result of implementing the option		5%	High increase in sedimentation accumulation risk	Low to moderate increase in sedimentation accumulation risk	No change	Low to moderate decrease in sedimentation accumulation risk	High decrease in sedimentation accumulation risk
	Environmental outcomes in Southern Connected Basin	Potential for localised environmental harm because of implementing the option (i.e., construction impacts)		5%	High potential for environmental harm	Low to moderate potential for environmental harm	No potential for environmental harm	Low to moderate potential for positive environmental outcomes	High potential for positive environmental outcomes
Delivery	Peak demand deliveries	Volume deliverable to the lower Murray within 5 days	50%	25%			No contribution within 5 days	0 – 2.5 GL in 5 days (0 - 500 ML/day)	> 2.5 GL in 5 days (> 500 ML/day)
	System demand deliveries	Volume deliverable to the lower Murray as a sustainable flow over 100 days (December - February)		25%			0 – 15 GL/season (< 150 ML/day)	15 – 40 GL/season (150 – 400 ML/day)	> 40 GL/season (> 400 ML/day)
Social	Social	Potential for social impacts based on direct landholders and the general community	5%	5%	Significant social impacts	Low to moderate social impacts	No social impacts expected	Low to moderate beneficial social outcomes	High beneficial social outcomes

3.2 Option 1 – River works within the Barmah-Millewa Reach

Description of the option

Accelerated riverbank erosion is an ongoing issue throughout and downstream of the Barmah-Millewa Reach. When the riverbank erodes, it is at risk of slumping or breaking off in large sections into the river. The River Murray is perched through the Barmah-Millewa Reach. Bank erosion can remove the natural levee adjoining the river and as a result reduce the capacity of the reach. In a similar manner, erosion can also result in the loss of the sills that limit the discharge of water into distributary channels.

This option proposes to undertake targeted works to minimise further loss of water from the main channel via breakaways. The works program will endeavour to temporarily prevent further loss of water delivery capacity by targeting sections of bank that are of high risk of erosion. However, with the sediment accumulating on the riverbed, bank protection works is not considered a sustainable or long-term option. The works will not reinstate channel capacity but aim to minimise further loss by targeting sites at risk of bank failure that could result in increased loss of water in the adjoining forests. In the process, this will also address both loss of consumptive water to the forest and the undesirable summer inundation of low-lying areas of the forest. The works also have the potential to prevent the potential loss of cultural material located on the riverbank.

The program has identified that the stretch of river between Bullatale Creek and the Barmah Sand Dunes as containing the highest risk of breakaways. This area is therefore the initial focus of the program.

Figure 7. *Location of the Barmah-Millewa Reach, where the riverbank works are proposed. The initial focus of the program is between Bullatale Creek and the Edward-Kolety River.*

Accelerated erosion in the Barmah-Millewa Reach
When River Murray flows are high, flow can break out over lower sections of the riverbank into effluent channels, inundating the floodplain. Breakaway flows are a natural behaviour of distributary systems during winter floods. However, in the Barmah-Millewa Reach, they may occur during summer, as the river is regularly operated at near full capacity for much of its length during this season to meet downstream demands.

Assessments of the Murray riverbanks from Yarrawonga to Torrumbarry Weir undertaken over the last two decades have documented accelerated rates of bank erosion, with some reaches exhibiting more than 40% of all banks to be undergoing erosion. Recent surveys undertaken in February 2021 and May 2022 in the Barmah-Millewa Reach have found some sections of the bank had retreated by up to 1 m between the survey periods[40].

Scoping and flow capacity
The objective of the Yarrawonga to Torrumbarry Interim River Works Program 2022 – 2027 (Y2T IRWP) is to manage sites of new breakaway flows to maintain downstream conveyance and prevent unseasonal flooding.

The works will not reinstate channel capacity. The works will, however, minimise the potential of further loss by targeting sites at risk of bank failure that could result in increased loss of water in the adjoining forests.

A risk-based assessment has been completed to identify and prioritise sites of potential breakaway flows along the River Murray in the Barmah-Millewa Reach where works could be undertaken. Existing and potential breakaway locations were identified by mapping channel and floodplain features across the reach which do, or could, form breakaways resulting in the possible loss of flow capacity in the River Murray channel. The risk of a potential breakaway occurring was determined through a detailed desktop review and spatial analysis combined with field verification survey. The likelihood and consequence for each breakaway location were then derived and used to evaluate risk.

A total of 243 current or potential breakout sites were identified in the desktop mapping process. Field verification was completed for all sites initially considered to be of *Very High* or *High* risk rating. Following the field verification, 4 sites were confirmed as having a *Very High* risk rating, and 19 sites with a *High* risk rating. All sites considered to be *Very High* or *High* risk are located between Bullatale Creek and Barmah Sand Dunes, a river distance of around 107km. Most of the identified sites occur on the outside of meander bends. The report recommends that[41]:

- 4 sites classed as Very High risk should be a very high priority for works.
- 19 sites classed as High risk should be a medium to high priority for works and monitoring.
- All other sites should not be a priority for works but should be monitored.

Monitoring will be an important component of the program as potential breakout sites are identified and additional works are scoped and implemented as part of the ongoing management. The works proposed are specific to the conditions and needs of each site. The type of remedial works generally include stabilisation of the riverbank, reinforcement of existing levees or tracks, installation of structures, and removal of failed or ineffective rock stabilisation where it is found to be exacerbating bank erosion of adjacent areas.

Whilst this option will not reinstate capacity, the primary objective of the program is to treat and maintain breakaways to allow the operational water level at Picnic Point of 2.6m to be maintained. The program aims to achieve this through proactively identifying areas susceptible to new breakaways forming and undertaking targeted works.

Under a 'do nothing' scenario, there is an increased risk that sections of accelerated bank erosion lead to new breakaways which in turn, result in a change in river operating practices to manage the reach at a lower height to avoid unseasonal flooding of the surrounding floodplain.

[40] Streamology (2022), *Condition Assessment and Works Prioritisation – Report for Water Infrastructure NSW*
[41] *Ibid.*

Figure 8. *Examples of where accelerated bank erosion of the natural levee bank has caused water to flow into the forest, resulting in unseasonal flooding*[42].

The elevations of potential breakaway locations have been plotted alongside water level based on Light Detection and Ranging (LiDAR) information. Most of the potential breakaway locations identified are between 2,500 and 10,000 ML/day water levels. The likelihood of new breakaways increases in a downstream direction as channel capacity decreases.

From this plotting, it can be seen that there are a number of potential breakaway locations within the Barmah-Millewa Reach which would form within 0.5m of the water level at 10,000 ML/day. For the purposes of assessing this option, it is assumed that any such breakaway forming and remaining untreated would result in a step-change reduction in the managed flow capacity in the reach of around 500 ML/day.

[42] MDBA (2016), *Strategy of addressing erosion through the Barmah choke*

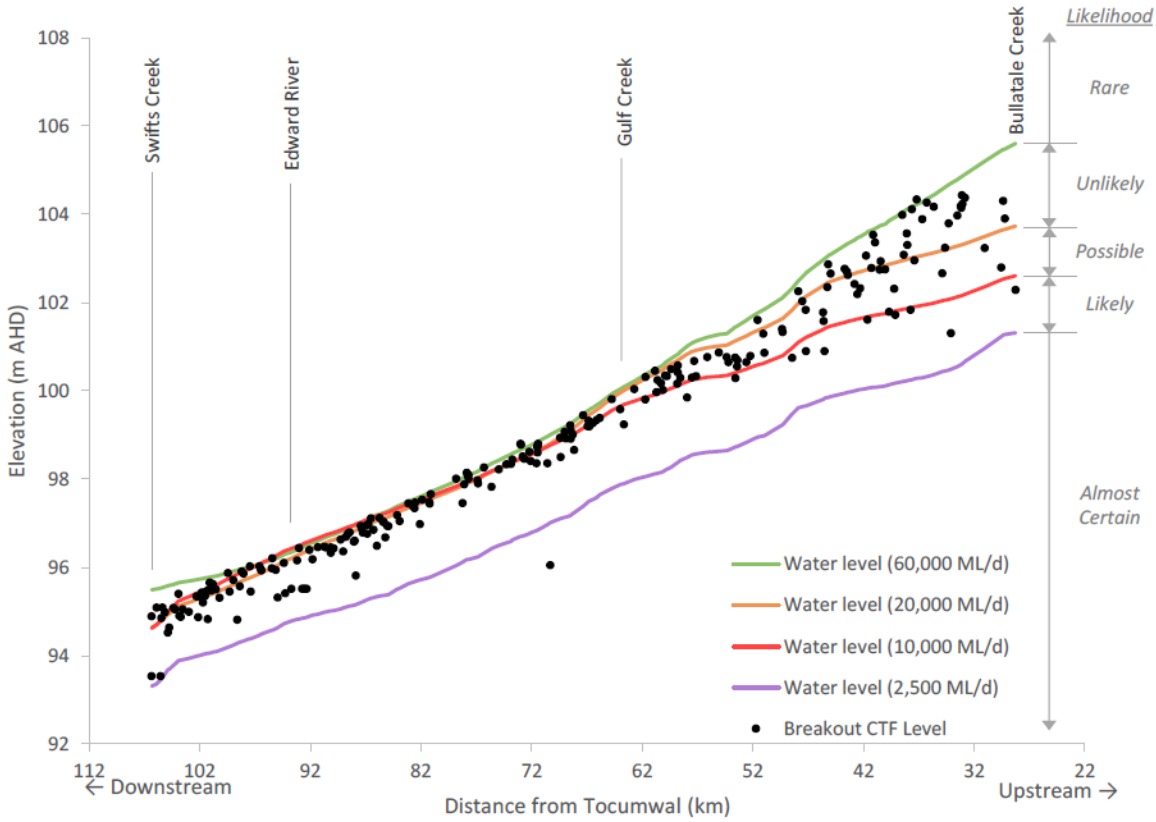

Figure 9. *Plot of breakaway CTF elevations (black dots) and water levels for four flow scenarios, with distance from Tocumwal provided*[43].

Option assessment part 1: implementation readiness

A condition assessment and works prioritisation report was completed in May 2022, providing recommendations for the initial priority of sites for delivering works. Refinement of the scope of ground works is recommended for the priority sites, including site-specific designs, site access requirements, on-ground delivery requirements, work health and safety issues and constraints, and cultural heritage considerations.

It is understood that Water Infrastructure NSW (WI NSW) plans to seek approval and funding to proceed with on-ground works in late 2022. Accordingly, subject to securing funding, it is assumed that the works would commence implementation within the next year and would extend for the next five years.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water

Undertaking targeted works to avoid potential additional breakaways will not change system water compared to current conditions. If the program was not undertaken and new breakaways formed, it is assumed that river operators would adjust operations in the Barmah-Millewa Reach to avoid breakouts into the forest and thus avoid losses. Therefore, this option is scored to have no change on system water.

MCA2: change in State water shares

There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach

One of the primary objectives of the river works program is to minimise the potential for undesirable inundation of the Barmah-Millewa Forest beyond the margins of the river channel. If new breakaways form, there would be

[43] Streamology (2022), *Condition Assessment and Works Prioritisation – Report for Water Infrastructure NSW*

an increased risk of unseasonal inundation into the forest. By implementing a monitoring and works program to actively manage potential new breakaways, this option directly contributes to the ability to manage environmental risk within the Barmah-Millewa Reach.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
This option would not directly alter any flow regime outside of the Barmah-Millewa Reach. As such, there is no change.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
Bank erosion can be a source of sediment delivered to the river, noting however that studies have shown that the sediment accumulation observed in the Barmah-Millewa Reach is primarily the result of upstream gold mining and land clearance[44]. Accordingly, by undertaking targeted works at a small number of sites to manage potential new breakaways, this option would provide a marginally positive contribution to the risk of sediment accumulation in the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves construction activities within areas of environmental and cultural sensitivity. It is assumed that any potential impact on the local environment in undertaking this work would be appropriately managed through the design, approvals and site controls used to implement the work. As such, there is no anticipated impact on environmental values in the implementation of this option.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
This option is not expected to contribute (positively or negatively) to the risk of delivery shortfalls in the system. This assessment does not consider how a reduced or increased system capacity may influence the risk of system shortfall events (as this is assessed in MCA8) and focusses more so on the travel time from the upstream storages to respond to a peak demand in the lower Murray (noting the key assumption relating to base load capacity).

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
Undertaking these targeted works will not reinstate channel capacity. The works will, however, minimise the potential of further loss by targeting sites at risk of bank failure.

If this program is not undertaken, it is assumed that new breakaways would occur and river operators would have to reduce flows through the Barmah-Millewa Reach to avoid flows through the new breakaways providing unseasonal flooding in the Barmah-Millewa Forest. Therefore, this option is considered to substantially benefit the potential to manage system shortfalls.

As described above, there are several potential breakaway locations which are typically within 0.5m lower than a 10,000 ML/day flow in the reach. If new breakaways were to form and be unmanaged in these locations, the change in height to manage the river could result in a step-change reduction of 500 ML/day in flow capacity.

There is a moderate confidence that, through undertaking this targeted monitoring and works program to manage riverbank erosion, this option would reliably contribute to managing the potential increasing risk of shortfalls. The uncertainty reflects the nature of ongoing accelerated erosion throughout the reach, meaning that there is an inherent risk that shortfall impacts may increase even with the program being implemented.

MCA9: social impacts
Riverbank erosion and the unseasonal flooding of the Barmah-Millewa Forest are matters of social importance. This option contributes to managing these matters. Furthermore, this option would protect access tracks and some areas used by the public for social and recreational purposes. Therefore, these works are expected to provide some beneficial social outcomes compared to the base case scenario.

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[44] Grove (2021), *A fluvial geomorphic investigation into channel capacity change at the Barmah Choke using multiple lines of evidence. Draft report for the Murray Darling Basin Authority*

Summary of MCA outcomes
Table 10 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 6. Multi-criteria assessment outcomes for the river works option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	0	0.0
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	10	0.5
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	**MCA9** – Risk of social impacts	0	0.5
	TOTAL WEIGHTED SCORING		**6.5**

Option assessment part 3: qualitative assessment

This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- Climate change is expected to result in the increased frequency of extreme weather events, potentially increasing the occurrence of prolonged hot weather creating potential risk of delivery shortfalls, and reduced water availability increasing the risk for system shortfalls. This option helps to maintain the flow capacity in the Barmah-Millewa Reach, which will be increasingly important in future climatic conditions.
- Undertaking this option helps to maintain the resilience and adaptability for river operators, as reducing flow capacity in the reach would increase the need for other options to be more frequently used to meet system demands.

Option assessment part 4: financial cost

This program is being implemented by Water Infrastructure NSW in collaboration with the MDBA. Initial estimates provided indicate that around $4.5 million will be required for these works over the next five years. It is expected that this budget would be prioritised to remediate *Very High* and *High Risk* sites, as identified currently and over the next five years through the monitoring program.

While there are some asset treatments proposed, the operations and maintenance costs are expected to be minimal and are not currently able to be quantified.

Assessment summary

Table 11 summarises the key outcomes for this option based on the assessment.

Table 7. Assessment summary of the river works option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	500 ML/day (avoided potential loss from new breakaways over the next 10 years)
Confidence that option is accessible	Medium
Part 1: Implementation readiness	**1 year**
Part 2: MCA scoring	
Water availability	0.0
Environmental conditions	1.0
Delivery risk	5.0
River communities and Traditional Owners	0.5
Total MCA score	**6.5**
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$4.5 million
Operational cost (50 years)	-
Total cost (capital + operational) / bypass capacity	**$9k / ML / 100-day capacity**

3.3 Option 2 – Sediment management works

Description of the option

The MDBA has completed a range of preliminary investigations into the cause and consequences of declining channel capacity in the Barmah-Millewa Reach. These investigations have concluded that historic land use practices have caused an influx of sand into the River Murray between Yarrawonga and Picnic Point[45], which is reducing the already limited flow capacity of the river,[46].

An options analysis for managing the sand determined that a 'do nothing' scenario would have considerable negative outcomes for environmental, social, cultural, and economic values. This analysis recommended that a combination of works programs was required to effectively manage the reduction in flow capacity, increasing sedimentation, and loss of habitat and diversity in the reach. This includes physically removing sand (this option), targeted bank protection (option 1) and moving water around the reach (options 3 to 6 of this report)[47].

This option proposes the targeted removal of sand from the bed of the River Murray between Yarrawonga and Echuca. The removal would target specific areas, likely including:

- Upstream of the Barmah-Millewa Reach, to reduce the volume of sand moving into the reach.
- Downstream of the Edward-Kolety River confluence (near Picnic Point), which has the greatest bed thickness of sediment, with an estimated 33% of the channel capacity filled with sand[48].

The objective of these works is to maintain or restore flow capacity of the river through the reach, in turn helping to mitigate potential adverse impacts including increased risk of shortfalls, as well as localised impacts on environmental, social, cultural, and economic values.

Figure 10. *Location of the Barmah-Millewa Reach, where the targeted sand removal works are proposed.*

[45] Grove (2021), *A fluvial geomorphic investigation into channel capacity changes at the Barmah Choke using multiple lines of evidence*
[46] Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bedload Transport and Thickness Investigation Memorandum*
[47] Streamology (2021) *Options for Managing Sediment in the Barmah-Millewa Reach of the River Murray*
[48] Streamology (2022) *Options for Managing Capacity in the Barmah-Millewa Reach (proposal)*

Scoping and flow capacity

Several studies are currently underway to further investigate the issue and scope the works program.

It is estimated that there is more than 20 million m^3 of coarse sand in the bed of the river between Yarrawonga to Picnic Point, including more than 8 million m^3 in the Barmah-Millewa Reach[49]. Downstream of the Edward-Kolety River confluence, there is a significant increase in the average depth of the sand, including the section of the river where the flow capacity is at its lowest[50].

Sand is continuing to move downstream in the Barmah-Millewa Reach, with approximately 240,000 m^3 entering the reach and approximately 80,000 m^3 leaving the reach each year[51].

The works program is expected to target removing sand from upstream to reduce the volume of sand moving into the reach and downstream of the Edward-Kolety River confluence (in the vicinity of Picnic Point), which has the greatest bed thickness of sediment (**Figure 11**).

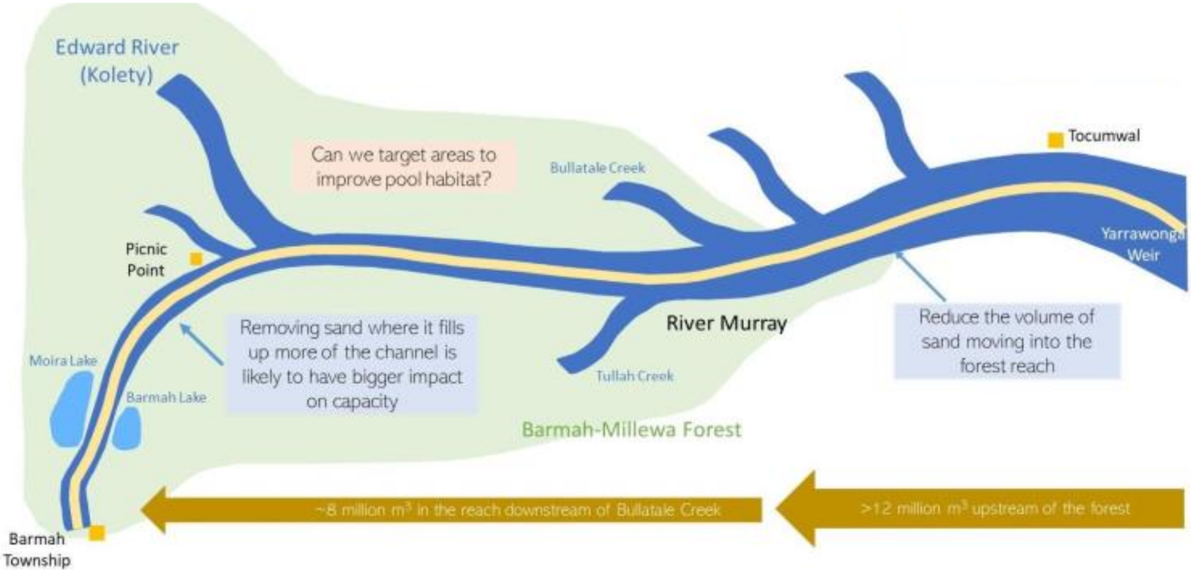

Figure 11. *Conceptual illustration of approach to sediment removal in the Barmah-Millewa Reach*[52]

Initial investigations have confirmed that removing the sand accumulating in the reach (around 160,000 m^3/year) is realistic[53]. By way of comparison, the River Murray mouth dredging is removing 1,000,000 m^3/year from the river mouth. Due to the large volumes and extent of the sand, any extraction would be ongoing over multiple years[54].

If no sand removal works are undertaken, modelling has shown that the flow capacity of the Barmah-Millewa Reach is likely to further decline by around 1,000 ML/day over the next ten years[55].

Removing the sediment involves loosening the material (using suction or a cutting blade), raising the materials to the surface, transporting the materials onshore, then placing or disposing of the material. There are many different methods which can be used to achieve this. The method to be used is subject to investigations, including consideration of Traditional Owner perspectives gained through engagement.

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49 Grove (2021), *Op. Cit.*
50 Streamology (2022), *Options for Managing Capacity in the Barmah-Millewa Reach: Stage 2 Assessment – Bedload Transport and Thickness Investigation Memorandum*
51 *Ibid.*
52 Streamology (2022) *Options for Managing Capacity in the Barmah-Millewa Reach (proposal)*
53 Grove James R (2021) *op cit.*
54 *Ibid.*
55 MDBA (2022), *Preliminary investigation into Murray River at Gulpa (409006) capacity changes resulting from sand removal/aggradation*

Option assessment part 1: implementation readiness

The MDBA is currently undertaking further investigation works into a sediment management program. These investigations aim to assess the technical feasibility of sand removal and to identify the environmental, cultural, economic, and social impacts and opportunities of any such works. This information will include the preparation of a final options report and be used to inform Governments about the problem, the potential options, and the scope of any further investigations.

The next stage of implementation is proposed to include a pilot program. The pilot program would provide an insight into the workability of the sand removal program. The program aims to remove sand from the bed of the channel on a small enough scale such that it has no adverse effects environmental, cultural, or historical matters. Two locations are being investigated as potential pilot sites, with around 4,000 m^3 of material (15m wide x 175m long x 1.5m deep) planned to be removed from each site with the works taking around four weeks. The pilot program would use much smaller plant and equipment than recommended for the main works, likely using a small pump in combination with a cutter head to remove the sand from the riverbed. The pump would be suspended from an excavator or a barge[56].

Following the pilot program, if a decision is made by the Basin Governments to proceed, a business case would likely then be developed. The business case would explore in detail the requirements and implications of implementing the preferred option, including the key activities to be undertaken and the budget and time requirements. This would include identifying the range of field investigation, design, regulatory approvals, early works, and consultation activities required, including ongoing and detailed engagement with Traditional Owners.

A key activity which will drive the timeframe for implementation is securing the necessary statutory approvals to undertake the works. As part of the scoping study for this option, Streamology convened an expert panel to identify the statutory frameworks relevant to the works, the ecological values of the subject area, and the activities needing to be undertaken which could cause impacts. This study confirmed that the project would require consideration under international (Ramsar convention), Commonwealth, NSW, and Victorian legislations. The key stressors associated with undertaking the works were identified as increased suspended sediments, decreased water clarity, increased nutrient loads, increased contaminants, entrainment, alterations to instream habitats, noise, and vegetation removal. Given the significant ecological values of the area and the scale of the activities, the project will trigger requirements for assessment under several Acts, likely including referrals needing to be lodged and the preparation of an Environmental Impact Statement[57].

At this preliminary stage, the timeframe to implement such a complex option is not well defined. The current expectation is that the timeframe to implement this option could be around 2 - 4 years[58], depending on the success of the pilot program, development of the business case, and engagement with key stakeholders.

In recognising the complex and sensitive nature of the works proposed by this option, there will be a need for an extensive investigation, consultation, and approvals process, plus establishment. Accordingly, for the purposes of this option assessment, it is reasonable to assume that it could take around 5 years for this option to become operational.

[56] Streamology (2022), *Barmah-Millewa Reach - Sand management options report*
[57] Streamology (2022), *Managing Sediment in the Barmah-Millewa Reach of the River Murray: scoping for environmental approvals.*
[58] *Streamology, pers. comm., August 2022.*

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water
Undertaking targeted works to remove sand from the riverbed will not change system water compared to current conditions.

If the program of sand removal works was not undertaken, the continued aggradation resulting from sand deposition would likely further reduce the capacity of the Barmah-Millewa Reach. Under such a scenario, it is assumed that river operators would continue their practice of managing flows within the reach within the river channel to avoid unseasonal flooding of the Barmah-Millewa Reach, and in turn avoiding additional losses.

Therefore, this option is scored to have no change on system water.

MCA2: change in State water shares
There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
Hydraulic modelling has shown that targeted sand removal could have a significant impact on flow capacity and water level in the Barmah-Millewa Reach[59].

If the program of sand removal works was not undertaken, the regulated flow capacity of the Barmah-Millewa Reach would be expected to continue to decline. As described above, whilst it is assumed that river operators would continue to manage flows within the river channel, the frequency and duration of bankfull flows over summer would be expected to increase. This in turn would increase the risk to the preferred environmental flow regime through the Barmah-Millewa Reach.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
This option would not directly alter any flow regime outside of the Barmah-Millewa Reach. As such, there is no change.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would directly contribute to mitigating or reducing the risk of sediment accumulation in the Barmah-Millewa Reach by undertaking the targeted removal of sand from the riverbed. The scale and design of the works program would be tailored to best manage these risks.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves the physical removal of sediment from the bed of the River Murray. The disposal of the sediment then requires the transport of the material through ecologically sensitive areas to a location for treatment and disposal. There are several significant environmental risks associated with such a works program.

Whilst it is assumed that these risks would be investigated in detail and appropriate mitigation measures would be implemented, given the sensitive ecological environments that these activities are occurring in, it is reasonable to state that there would be residual risk to environmental outcomes through the Southern Connected Basin. Conversely, by removing sediment from the reach, it could be expected that there would be some significant positive environmental outcomes as a result of this work, particularly by reinstating pool habitat for native fish within the reach.

Accordingly, this option would contribute to positive long-term restoration of environmental values but would introduce the potential for increased environmental risk associated with the works program which would need to be appropriately managed.

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[59] Streamology (2022), *Barmah-Millewa Reach - Sand management options report*

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
This option is not expected to contribute (positively or negatively) to the risk of delivery shortfalls in the system (noting the key assumption relating to base load capacity).

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
The flow capacity of the Barmah-Millewa Reach is likely to further decline by around 1,000 ML/day over the next ten years if no intervention works are undertaken. Hydraulic modelling has shown that targeted sand removal could have a significant impact on flow capacity and water level in the Barmah-Millewa Reach[60]. While the scale of the works program is under investigation and to be confirmed, preliminary investigations have suggested that removing the volume of sand accumulating in the reach is realistic.

If the program of sand removal works was not undertaken, the capacity of the Barmah-Millewa Reach would be expected to continue to decline. If demand patterns downstream of the reach are unchanged, this will exacerbate the risk for river operators to meet demands and avoid shortfall risk. Therefore, this option is considered to substantially benefit the potential to manage system shortfalls. There is a high confidence that, through undertaking the sand removal works program, this option would contribute to managing the potential increasing risk of shortfalls.

MCA9: social impacts
There could be negative impacts on social values with the extraction of sediment from the riverbed, such as the closure of areas of the river for recreation while the works are underway, or the removal of vegetation to install pipes and pumps to move the sand[61]. It is likely that there will be concern within river communities about the environmental, social, and cultural impacts of undertaking such works and how these will be managed.

However, if the program of sand removal works was not undertaken, social impacts could be expected as well. This includes potentially significant risks to native fish populations having an adverse impact on recreational fishing. By reducing sedimentation and maintaining or reinstating the flow capacity in the reach, local environmental, social, and cultural values of the reach can be better managed.

For this reason, the social impacts of this option have been rated as neutral.

If this option proceeds to further development, social impact studies should inform any such business case development to further explore the potential social consequences of such works and recommend how these could be appropriately managed.

[60] *Ibid.*
[61] Streamology (2021), *Op. Cit.*

Summary of MCA outcomes

Table 10 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 8. Multi-criteria assessment outcomes for the sediment removal option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	0	0.0
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	20	1.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	-10	-0.5
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social impact	**MCA9** – Risk to social use	0	0.0
	TOTAL WEIGHTED SCORING		**6.0**

Option assessment part 3: qualitative assessment

This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- Climate change is expected to result in the increased frequency of extreme weather events, potentially increasing the occurrence of prolonged hot weather creating potential risk of delivery shortfalls, and reduced water availability increasing the risk for system shortfalls. This option directly addresses the declining flow capacity in the Barmah-Millewa Reach, which will be increasingly important in future climatic conditions.
- Undertaking this option helps to maintain the resilience and adaptability for river operators, as reducing flow capacity in the reach would increase the need for other options to be more frequently used to meet system demands.

Option assessment part 4: financial cost

The cost to further develop this option is estimated at around $7.0 million[62]. This includes additional sediment sampling, a pilot program development and implementation, preparation of a business case, and environmental, social, and cultural investigations and approvals. The cost to establish the onshore infrastructure is estimated at around $5.0 - $7.4 million, including contingency[63].

The total capital cost to implement the option is therefore around $14.5 million.

For operational costs, preliminary estimates were developed for two scenarios - an annual removal of 300,000 m^3 per annum (based on day shifts only), and an annual removal of 560,000 m^3 per annum (double shifts). The estimated cost ranges from around $31/m^3 to $43/m^3 (including costs of fuel)[64], with the cost per unit increasing depending on the annual quantity removed. The minimum quantity required to be removed is 160,000 m^3 per annum to maintain the status quo.

[62] Streamology (2022), *Stage 3 Barmah Sand Management Pilot Study – Cost Estimates – November 2022*
[63] Fifteen 50 (2022), *Barmah Sand Management – Options Assessment for provision of onshore infrastructure – November 2022*
[64] Streamology (2022), *Barmah-Millewa Reach – Sand management options report – September 2022*

For the purposes of assessing this option, it has been assumed that the works program would target 'holding the line', requiring the removal of 160,000 m^3 per annum. Extending the cost estimates above, the cost range for this lesser volume would be around $50/$m^3$, equating to a cost of around $8 million per year.

For the purposes of comparing with other long-term, permanent asset-based options, this equates to a present value of around $110 million over a 50-year period with a 7% discount rate.

Analysis of the sand material has indicated that it could have a re-sale value as a commercial product[65], which could partially offset this cost.

The cost to further develop the option and business case, complete a detailed work design, secure the relevant approvals, consult with Traditional Owners, community, and other stakeholders, and be ready to implement would be additional to the above figures. This cost for the next phases of developing this option will be estimated by the consultants undertaking the scoping studies.

Assessment summary

Table 11 summarises the key outcomes for this option based on the assessment.

Table 9. Assessment summary of the sediment removal option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	1,000 ML/day (avoided potential loss over the next 10 years)
Confidence that option is accessible	Medium
Part 1: Implementation readiness	5 years
Part 2: MCA scoring	
Water availability	0.0
Environmental conditions	1.0
Delivery risk	5.0
River communities and Traditional Owners	0.0
Total MCA score	6.0
Part 3: Qualitative assessment of non-scored elements	!
Part 4: Cost effectiveness	
Capital cost (per annum)	$14,500,000
Operational cost (present value, 50 years)	$110,405,970
Total cost (capital + operational) / bypass capacity	$125k / ML / 100-day capacity

[65] Streamology (2022), *Technical memorandum – Sediment sampling pilot program – Data results and analysis – September 2022*

3.4 Option 3 – Tar-Ru (Lake Victoria) Transfers

Description of the option

Tar-Ru (Lake Victoria) is a naturally occurring shallow freshwater lake with a capacity of approximately 677 GL. It is located approximately 60 km downstream of the Murray–Darling Junction in south-western New South Wales, close to the borders of South Australia and Victoria (**Figure 12**).

The lake is operated in accordance with formal operating rules designed to minimise shoreline erosion to protect Aboriginal cultural heritage sites. It is filled so that the active storage is near or at full supply as late as possible in spring[66]. The lake is then drawn down over summer and autumn to supply downstream demands. There is a target minimum active storage volume of 250 GL on the 31st of May[67]. Filling recommences from the start of June each year.

Tar-Ru can be filled from either unregulated River Murray flows or by transferring water from Lake Hume. The general practice is to wait for inflows from unregulated tributaries of the River Murray to fill Tar-Ru, in preference to Hume transfers, to reduce the potential risk of resource loss to upstream States from lost harvesting opportunities, spills from Tar-Ru or conveyance losses.

Filling the lake has historically been a challenge in dry years, but since the mid-2010s filling the lake in late spring and meeting the minimum reserve level in May have become a more frequent challenge. In response, the MDBA commissioned a scoping study in 2021 to explore the issues surrounding water availability and management in the southern connected Murray-Darling Basin that influence the filing and operations of Tar-Ru. This study showed that reduced tributary inflows to the River Murray system in the recent historic record has meant that more transfers of water from Lake Hume have been needed to fill Tar-Ru[68], and recommended that a risk-based framework be developed to support decision making about the timing and volume of Hume – Tar-Ru transfers.

For the purposes of the Barmah-Millewa Feasibility Study, if the Hume – Tar-Ru transfers that are occurring in the January to April months could be shifted to other months, there may be an opportunity to contribute to the objectives of the BMFS.

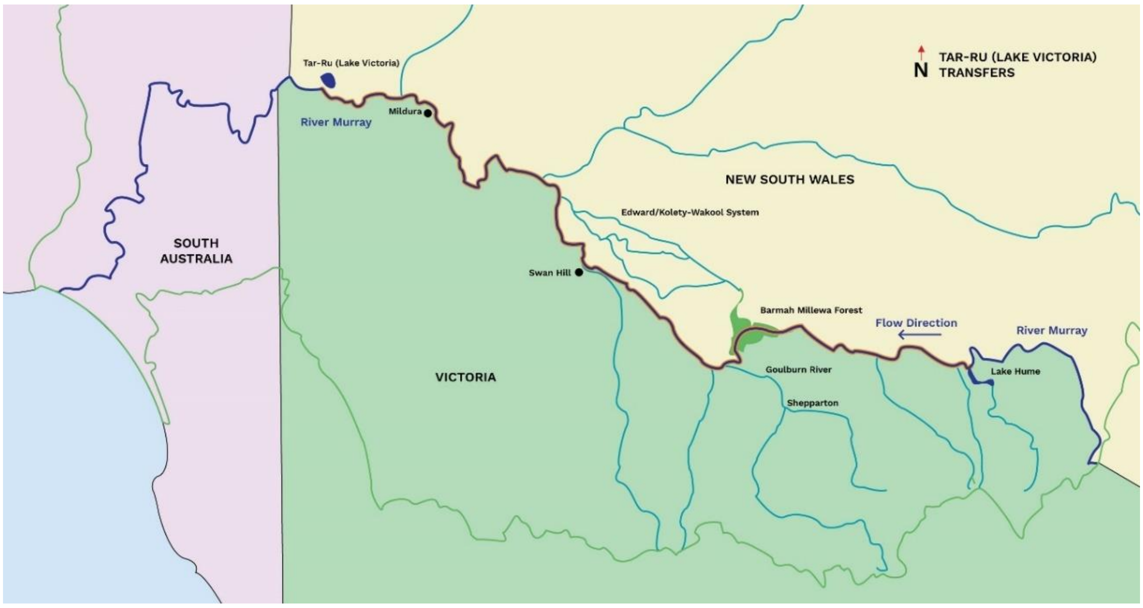

Figure 12. *Tar-Ru (Lake Victoria) location map*

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[66] MDBC (2002), *Lake Victoria Operating Strategy.*
[67] *Murray-Darling Basin Agreement, subdivision C*
[68] HARC (2021), *Review of impacts of system-wide drivers on Tar-Ru – scoping report – Stage 1, November 2021*

Scoping and flow capacity

The scoping study[69] identified four broad drivers that have affected the filling frequency of Tar-Ru:

- reduced tributary inflows.
- operational constraints and efficiencies, including changes to the Barmah-Millewa Reach capacity.
- demands for water.
- limits on Tar-Ru water level changes needed to meet cultural and environmental obligations and objectives.

Whilst the study did not consider the BMFS or the objectives of this project, it does provide an insight into whether there could be an opportunity for changed operational practices to support both the filling of Tar-Ru and to take pressure off the Barmah-Millewa Reach during the summer period. This opportunity may arise if some Hume – Tar-Ru transfer volumes could be delivered in late spring to support the filling target, rather than occurring over the summer months. This would support the BMFS objectives by either increasing the system capacity or by allowing reduced flows to be delivered through the reach during the summer months.

In analysing the last 20 years, such an opportunity for earlier transfers would have been present if:

- Tar-Ru was not already filled by the end of the calendar year (**Figure 13**) and Hume – Tar-Ru transfers were made in the following January – April period (**Figure 13**).
- The Barmah-Millewa Reach was being run at a consistently high level from January to April (**Figure 14**).
- Menindee Lakes was not available as a shared resource under MDBA control (**Figure 15**).

The water years of 2018/19 and 2019/20 are prime examples of where the option for earlier transfers could have been available. In these years, the volume stored in Tar-Ru peaked at 550 – 560 GL in spring (**Figure 13**) meaning there was – with perfect foresight – about 120 GL of airspace in Tar-Ru that could have been filled with additional transfers in winter/spring. Additional transfers in winter/spring would have reduced the need for transfers that were made in the January – April period, thus freeing some channel capacity in the Barmah-Millewa Reach for deliveries to consumptive users and the environment. Another example is 2014/15, where there was approximately 50 GL of airspace that could have been used in Tar-Ru – again with perfect foresight – to reduce the transfers that were made in the subsequent January – April period.

However, this option will not be applicable in all or even most years. For example, in 2006/07 and 2007/08 there was also airspace in Tar-Ru that could have been used for additional winter/spring transfers. However, in the January – April periods of 2007 and 2008, the river levels in the Barmah-Millewa Reach were below channel capacity (**Figure 14**), and therefore the transfers were not denying delivery capacity to other water users.

In the other years post-2001, when there have been significant Hume – Tar-Ru transfers over summer, Tar-Ru has reached full supply level (FSL) in the preceding winter/spring. Therefore, bringing transfers forward would not have been a viable option to reduce pressure on the Barmah-Millewa Reach over summer/autumn.

In summary, over the past 20 years, there were three water years in which bringing forward Hume – Tar-Ru transfers could have reduced the need for January – April transfers. In these years, earlier transfers would have reduced summer deliveries through the reach by approximately 50 GL to 120 GL, which is an average of approximately 420 ML/d to 1,000 ML/d over a 120-day period. For the purposes of the BMFS options assessment, it is assumed that this option would provide around 750 ML/day when it is available (approximately every 1 in 10 years).

The ability to recognise these earlier transfer opportunities in the historical record is based on having perfect foresight. In practice, earlier transfers to Tar-Ru increases the risk of foregone harvesting opportunities, resulting in resource loss for upstream States. Whilst this option was available around 1 in 10 years in the recent historic record, the future availability of this option is highly dependent on river operating conditions, particularly inflows from the Darling River and the storage volumes in Menindee Lakes.

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[69] HARC (2021), *Review of impacts of system-wide drivers on Tar-Ru – scoping report – Stage 1, November 2021*

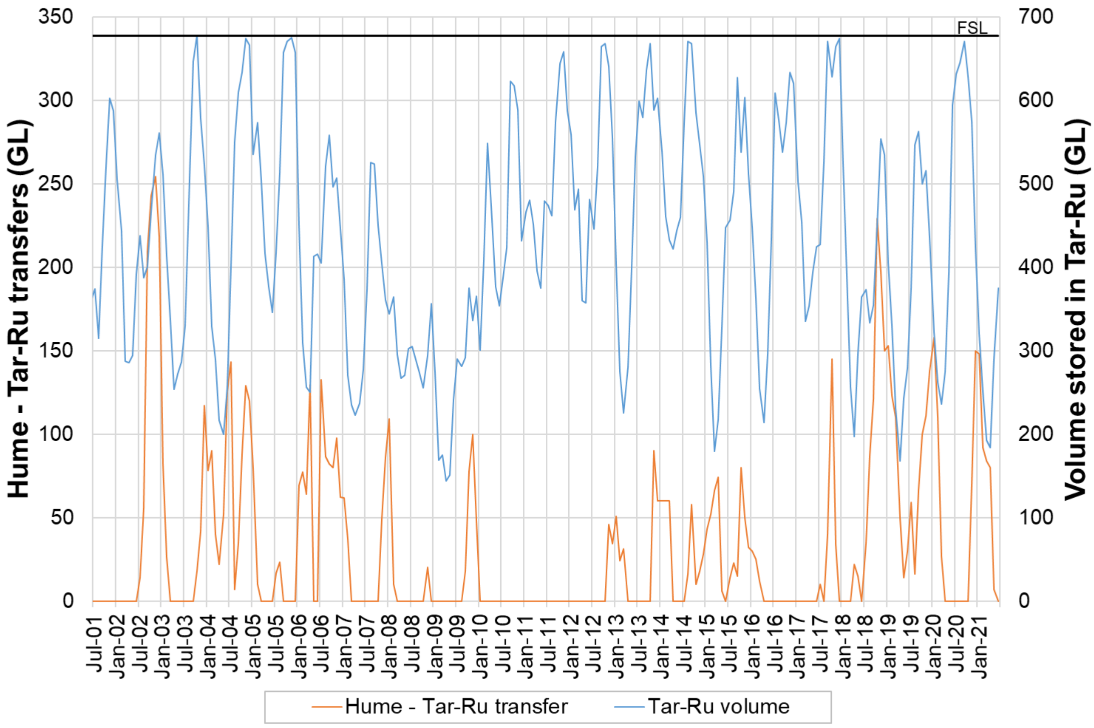

Figure 13. *Monthly time-series of Hume – Tar-Ru transfers and volumes stored in Tar-Ru.*

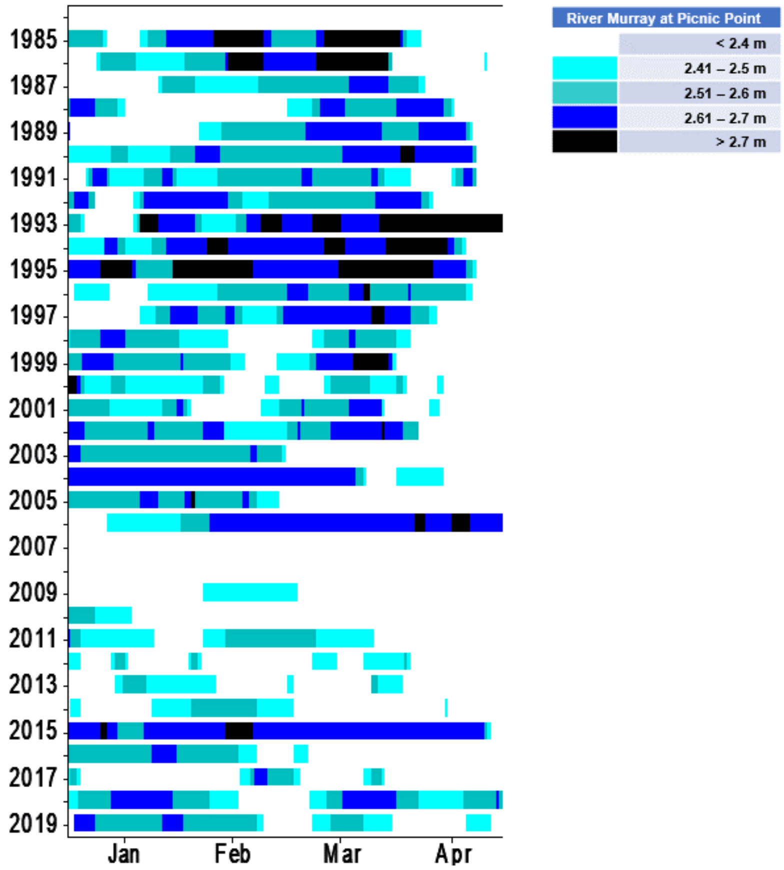

Figure 14. *January to April spells of river levels at Picnic Point. A river level of 2.6 m corresponds the Barmah Choke channel capacity*

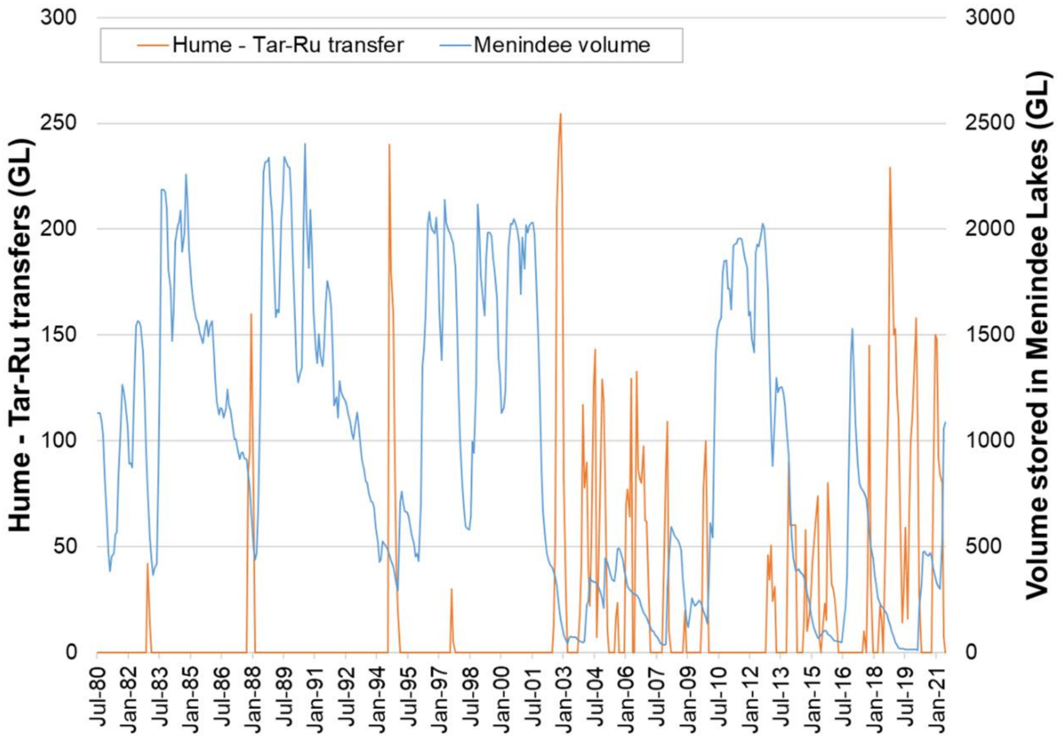

Figure 15. Hume – *Tar-Ru transfers versus a time-series of volume stored in Menindee Lakes*[70]

The scoping study proposed that future work include the development of an agreed risk-based framework for making decisions about the Hume – Tar-Ru transfers, including:

- Developing a fit-for-purpose model for future investigations (using the Source Murray Model).
- Confirming or re-visiting the water resource management policies and procedures that influence the operation of Tar-Ru (Lake Victoria), to identify system operations that could be refined.
- Developing a risk-based framework for Hume – Tar-Ru (Lake Victoria) transfers using 'what if' scenario testing, to explore whether transfer rules can be modified to balance or minimise risks.
- Reporting and communicating the outcomes.

It is noted that the primary purpose of the Tar-Ru transfers study and these recommendations for further works are independent of the BMFS project objectives. Accordingly, regardless of whether the options assessment for the BMFS project determines if the Tar-Ru option may viably contribute to this project's objectives, the Tar-Ru study and future stages may proceed, nonetheless.

Further detail on the description of this option and how it may contribute to the BMFS is available in the BMFS: Option Summary Report[71].

[70] HARC (2021), *Op. Cit.*
[71] Alluvium (2022), *Barmah-Millewa Feasibility Study: Options Summary Report*

Option assessment part 1: implementation readiness
The scoping study suggests that a 2–4-year timeline is needed to complete the proposed tasks[72].

This includes undertaking the detailed investigations and the development and implementation of the risk-based framework. If any changes were proposed to policies, the operating rules or provisions in the MDB Agreement, these timeframes are likely to be longer. For this reason, a conservative four-year timeframe has been assumed for the purposes of assessing this option.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water
There is a potentially large increase in losses associated with implementing this option.

This recognises that any potential to bring Hume – Tar-Ru transfers from the January – April period to winter / spring could result in lost opportunities to subsequently divert unregulated River Murray flows into Tar-Ru (e.g., tributary inflows caused by rainfall-runoff).

Seasonal streamflow forecasts can be used to predict tributary inflows over three-month periods. However, the nature of these forecasts is that they are unlikely to become accurate and precise enough to completely remove the risk that bringing forward Hume – Tar-Ru transfers will result in undesirable changes to system water resources and sharing.

MCA2: change in State water shares
As noted above, this option may reduce overall water harvesting opportunities, with a reduction in state shares for Victoria and/or NSW.

In some situations, earlier transfers may be able to be managed so that there is no subsequent physical spills or lost harvesting opportunities overall at Tar-Ru. However, the earlier transfer volumes may have the effect of changing internal spills behaviour in Tar-Ru, which could result in changes to relative state shares between NSW and Victoria. Given the number of Victorian tributaries that can contribute to Tar-Ru harvesting opportunities and the historical record (**Figure 16**), this could mainly relate to increased internal spills from Victoria to NSW. This issue would need to be assessed in more detail and confidence provided that any potential resource risk or impact to state shares could be appropriately managed as part of any further development of this option.

It is noted that there is a potential opportunity to coordinate environmental water deliveries during the winter/spring period on top of early transfers. In this circumstance, the risk of foregone harvesting opportunities may be underwritten by the environmental water holders to reduce the risk of third-party impacts on state water shares. This opportunity should be further considered and explored as part of any further development of this option.

Any potential agreement for earlier seasonal transfers would likely require negotiation between States on the risk to changes in State water shares in the event of internal spills. Mitigations might require changes to the Murray-Darling Basin Agreement.

This has been scored as having a moderate risk that state shares may be adversely affected. This has been assessed separately from the impact of the lost opportunity for harvesting, which was considered for MCA1.

If the opportunity for the environmental water holder to underwrite the risk of internal spills is realised, the assessment of this option would be more positive, as some of the water availability risks would be mitigated.

[72] HARC (2021), *Op. Cit.*

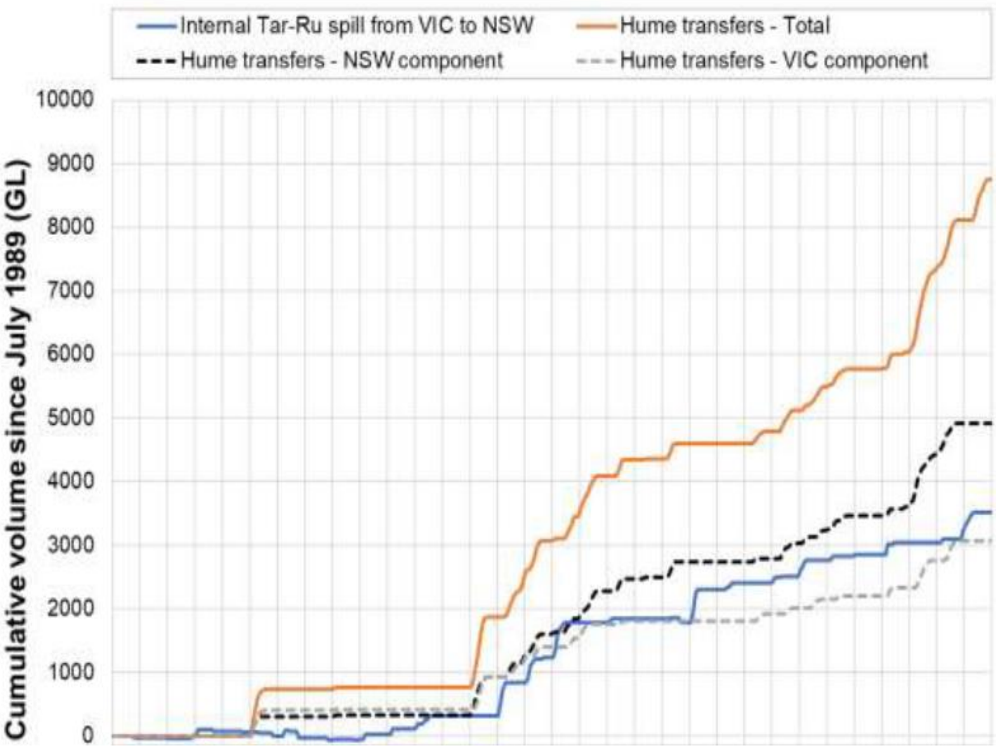

Figure 16. *Internal spills from Victoria to NSW share of Tar-Ru since July 1989*[73]

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
Any opportunity to shift transfers through the Barmah-Millewa Reach from the summer period to earlier in the season would better align with the ecologically tolerable flows in the reach. Earlier transfers reduce the risk of potential overbank flows to the Barmah Forest during the summer. In the flow ranges potentially available, this could be considered a marginally positive change to the flow regime.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
Any opportunity to shift transfers from the summer period to earlier in the season would generally better align with the ecological flows within the River Murray, outside of the reach. In the flow ranges potentially available, this could be considered a marginally positive change to the flow regime.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
Any shift in timing for transfers from Lake Hume to Tar-Ru (Lake Victoria) would not change the sediment load entering the Barmah-Millewa Reach, and therefore would not be expected to change the risk to sediment accumulation within the reach, unless transfers could be delivered at the same time as overbank events.

MCA6: risk to environmental outcomes through the Southern Connected Basin
There are no physical works associated with the implementation of this option. Accordingly, outside of the change in flow regime (considered in MCA3 and MCA4), there are no further impacts or benefits expected for environmental outcomes in the Basin.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
This option may provide a minor benefit to river operators in managing delivery shortfalls. If Tar-Ru is filled earlier in the season, deliveries that otherwise would have been provided downstream of Tar-Ru may be available to be re-allocated to meet a spike in demand in Sunraysia, with Tar-Ru drawn down to meet the downstream demand temporarily. Therefore, there is potential that an early transfer may support delivery shortfalls, by means of substitution.

[73] *Ibid.*

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
During the years where there is an opportunity to shift transfers out of the January – April period into winter/spring, based on the recent historic record, there would be around 750 ML/day of additional capacity available in the Barmah-Millewa Reach during the summer months which would have otherwise been used for transfers. Based on the recent historic record, this opportunity would have been available around 3 in every 20 years. For the purposes of assessing this option (compared with other options which would be available every year), the annualised average additional capacity is taken to be around 100 ML/day over a 10-year period.

There is low confidence in the consistent availability of this capacity, noting that the opportunity for earlier transfers is highly dependent on system and seasonal conditions, which in recent historic records have only prevailed around 1 to 2 in every 10 years.

MCA9: social impacts
This option requires no physical works to occur and therefore there are no impacts on private landholders. There are no changes expected for local social or recreational activities.

Summary of MCA outcomes
Table 10 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 10. Multi-criteria assessment outcomes for the Tar-Ru (Lake Victoria) drivers project option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	-20	-2.5
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	-10	-1.3
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	10	0.5
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	10	2.5
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	10	2.5
Social risk	**MCA9** – Risk of social impacts	0	0.0
	TOTAL WEIGHTED SCORING		2.3

Option assessment part 3: qualitative assessment

This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- While the initial assessment has indicated that this option may only be applicable relatively infrequently (e.g., 1 or 2 years in 10), it is likely that dry years in which Tar-Ru fails to fill from tributary inflows are years that would also see high summer irrigation demands. Under these circumstances, early transfers and improved reserves in Tar-Ru at the start of the summer peak demand period would provide an important boost to system resilience and flexibility. Adequate reserves in Tar-Ru support meeting full deliveries to South Australia and reduce risks of shortfalls downstream of the Barmah-Millewa Reach.
- Under climate change scenarios, tributary inflows to the River Murray are expected to decline. The circumstances wherein this option could be beneficial may be more frequently applicable in future conditions. The ability to take a risk-based approach and identify opportunities to transfer water to Tar-Ru to better meet peak demands is likely to be an important boost to the ability of the system to respond to and adapt to climate change.
- Management of transfers to Tar-Ru is already a fundamental component of existing system operations, so this option should be able to be effectively incorporated into system operations.
- Applying a risk-based approach to transfer decisions may involve some additional analysis and effort for system operators. However, the implementation of improved planning tools for river operations (which are currently under development for the River Murray system) should reduce the effort required to undertake the necessary analysis.
- The Tar-Ru operating levels have been designed to minimise adverse effects on First Nation (Barkindji / Maraura) cultural heritage. Management of Tar-Ru must continue to meet the objectives and outcomes sought in the Aboriginal Heritage Impact Permit (current and successors) and the Tar-Ru (Lake Victoria) Operating Strategy. Any investigations and proposals for changed management arrangements for Tar-Ru must proceed in partnership with the Barkindji / Maraura peoples. This should occur through existing partnership arrangements and protocols in a transparent and sensitive manner.

Option assessment part 4: financial cost

The scoping study report assumed that the cost to implement the project would be in the vicinity of $500k to $1.0 M. This assumes that the next stages of the project are progressed by 1 - 2 full-time equivalents (FTEs) from the MDBA and Basin States. There would not be any change to operational costs because of this option.

Assessment summary

Table 11 summarises the key outcomes for this option based on the assessment.

Table 11. Assessment summary of the Tar-Ru (Lake Victoria) drivers project option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	100 ML/day[1]
Confidence that option is accessible	Low
Part 1: Implementation readiness	**4 years**
Part 2: MCA scoring	
Water availability	-3.8
Environmental conditions	1.0
Delivery risk	5.0
River communities and Traditional Owners	0.0
Total MCA score	**2.3**
Part 3: Qualitative assessment of non-scored elements	!
Part 4: Cost effectiveness	
Capital cost	$1.0 M
Operational cost (50 years)	-
Total cost (capital + operational) / bypass capacity	**$10k / ML / 100-day capacity**

[1]: based on the recent historic record, the opportunity for this option to be implemented would have occurred around 1 to 2 years in 10 and provided around 400 – 1,000 ML/day of additional capacity over the summer period. For the purposes of comparing this option with other options that are available every year, the contribution to mitigating system shortfall events has been annualised.

3.5 Option 4A.1– MIL Options – Optimised escapes [no works option]

Description of the option

Murray Irrigation Limited (MIL) own and operate a 2,700km network of irrigation water supply channels diverting water from the River Murray. The main channel in the network, the Mulwala Canal, diverts water from the River Murray at Lake Mulwala, supplying the channel system network across the Southern Riverina Plain before outfalling into Edward-Kolety, Niemur, Wakool, Murray Rivers, and Billabong Creek through escapes. Since the automation of the MIL irrigation network, the system operates more efficiently, meaning that there is reliably spare capacity within the network.

MIL has agreements in place to use the escapes for the delivery of environmental water on behalf of NSW Department of Planning and Environment (DPE), in coordination with the Commonwealth Environmental Water Holder. This option proposes a similar approach be taken to use the escapes for the delivery of water to bypass the Barmah-Millewa Reach. There are two options being considered:

- Option 4A.1 – No works: accessing the available capacity at escapes which are already automated and metered and would require no upgrade works. There are eight escapes which meet this criterion and can be considered for delivering additional flows.
- Option 4A.B – Works required: undertaking targeted works to increase the capacity and install automation and metering. The works involve replacing manually operated escapes with automated (metered) regulators, maximising the available channel capacity.

Further detail on the description of this option is available in the BMFS: MIL Options Investigation Report[74].

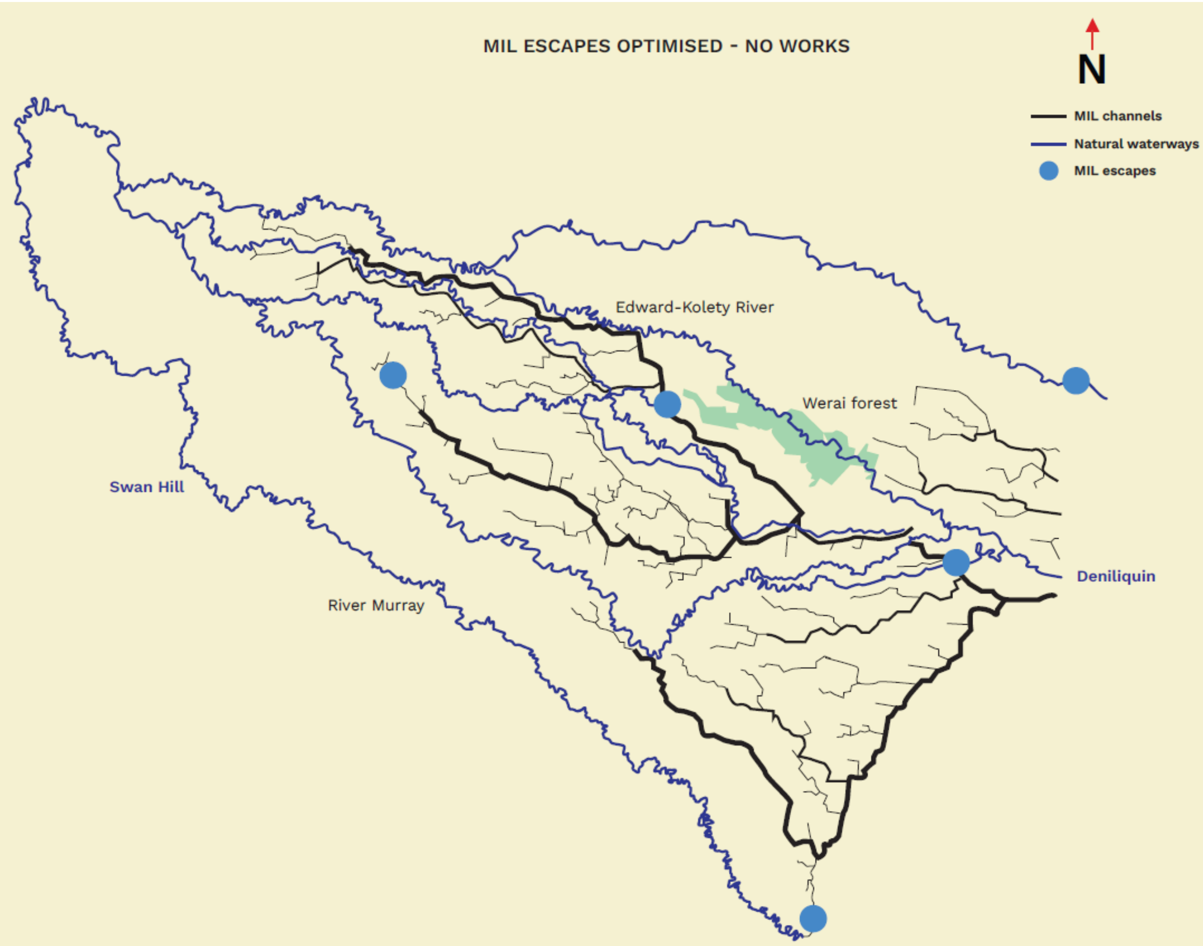

Figure 17. *Map of the MIL channel escapes and receiving waterways (no works option)*

[74] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Scoping and flow capacity

The *No Works* option requires no capital works to be performed.

The option includes eight escapes which are all currently automated and are used for the delivery of environmental water or operational water on behalf of DPE or WaterNSW respectively. The use of the escapes for environmental watering events tends to currently occur during the spring months.

The engineering assessment determined that the MIL channel network and eight escapes have the capacity to deliver an additional 1,605 ML/day during summer. These flows would be in addition to existing system commitments.

The limit on deliverable ecologically tolerable flow capacities is based on the lower of the available ecologically tolerable flow capacity and the escape capacity. This represents the volume of water that:

a. is ecologically tolerable in the context of current (existing) flows within the channel.
b. can be delivered within the proposed escape capacity.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the outfalls. This assessment considered tolerable baseflow and fresh deliveries across the summer and winter/spring seasons. Over the summer period, the average daily flow was determined as 665 ML/day. Water can be released into river systems as an ecologically acceptable release through five of the eight escapes as identified in Table 12. For three of the escapes, the receiving waterways were determined to already be at or exceeding an ecologically recommendable flow regime, and as such, no additional flows were recommended.

More detail around each of the escapes, the maximum available capacity, and the adopted tolerable flow capacities (including how they have been derived) is available in the BMFS: MIL Options Investigation Report[75].

Table 12. The escapes which could be used for bypass flows with no works required

Escape name	MIL channel & escape available capacity (no works required)	Receiving waterway	Ecologically tolerable release – seasonal average in summer (ML/day)
Wakool Main Escape	500	Wakool River	108
Southern Escape	70	Neimur / Wakool Rivers	70
Mallan W221/4 Escape	15	Niemur River	-
Mallan W149 Escape	70	Niemur River	-
Northern Niemur Escape	300	Niemur River	288
Mascotte Escape	300	Niemur River	-
Billabong Escape	250	Billabong Creek	96
Perricoota Escape	100	River Murray	100
TOTAL	1,605 ML/day		662 ML/day ***665 ML/day adopted***

[75] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Option assessment part 1: implementation readiness

The five escapes in this option have been chosen primarily because no works are required, the additional flows are ecologically tolerable, and can be implemented within shorter timeframes.

As no works are required, the implementation timeframe will be driven by agreement timeframes between MIL and the MDBA for the use of the escapes to bypass flows. There are existing agreements in place for third-party deliveries of a similar purpose, therefore negotiations should be relatively straight forward, with the escapes able to be used within the year.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water

The five escapes could be used to deliver an ecologically tolerable median delivery of 665 ML/d. Over the 100-day summer period from January to April, this equates to a tolerable median delivery of 67 GL.

Water transferred through the MIL system for the purposes of bypassing the Barmah-Millewa Reach (i.e., any water that is not MIL shareholder water) is assumed to attract a conveyance loss of approximately 10% when the network is delivering > 200,000 ML/day. If there were no other deliveries (or < 100,000 ML/day) the loss allowance is likely to be closer to 17%. As such, a conveyance loss of 17% of the first 100,000 ML transferred, 13% for transfer volumes between 100,000 ML and 200,000 ML, and 10% for any additional transfers (pers. comm. MIL, August 2022) is expected. These figures may be subject to refinement and negotiation in future; however, they represent current advice.

Depending on when the additional deliveries occur relative to existing non-MIL shareholder deliveries, the conveyance loss over summer for an additional 67 GL delivery is estimated to range from 7-11 GL per year.

In estimating the increase in whole-of-system conveyance losses attributable to this bypass option, it has been assumed that conveyance losses in permanent waterways are not significantly altered by reducing daily flows in the River Murray channel through the Barmah-Millewa Reach and/or increasing daily flows in the permanent waterways of the Edward-Wakool system. This is because the major contributors to conveyance losses from these permanent waterways (seepage and evaporation) are not expected to materially change in response to daily flow variations, provided that flows remain within-channel.

There are also likely to be additional losses in the receiving waterways used to bypass water around the Barmah-Millewa Reach during the wetting-up phase if these waterways are not already being used to distribute consumptive or environmental water deliveries. Through discussions with DPE and based on its experiences in managing environmental water events, a loss of 30 ML/km has been assumed for wetting up natural waterways for the purpose of delivering bypass water. This is an average estimate from DPE that will vary in practice for individual waterways and for different antecedent conditions.

The total length of escape channels for this option is 18.6 km and the total length of creek until permanent rivers are reached is 60.9 km. If in any given year only the escape channels need to be wetted up, then an additional 0.6 GL of losses would be incurred. If both the escape channels and associated rivers/creeks need to be wetted up, then an additional 2.4 GL of losses would be incurred. These losses are only expected to occur in drier years at times when deliveries via the MIL have not been made in the season to date.

When these two types of losses (wetting up plus delivery) are combined, the aggregated loss is estimated to range from 7-14 GL/yr. Relative to the conveyance losses of 178 GL along the River Murray via the Barmah-Millewa Reach (to the Wakool Junction), these losses of 7-14 GL/yr represent an incremental loss of 4-8% relative to existing conveyance losses.

As such, this has been categorised as a small increase in losses expected, resulting in a multi-criteria analysis score of -10.

Table 13. Range of expected additional losses over summer (Jan – Apr) for Option 4A.1

Assumed loss (%)	Assumed loss for 67 GL transfer (GL/yr)
17%	11.3
13%	8.7
10%	6.7
Reach length that may require wetting up (km)	**Assumed loss if wetting up required (GL/yr)**
18.6 km of escape channels	0.6
60.9 km of creeks	1.8
TOTAL loss (GL/yr):	**7 – 14 GL/yr**

MCA2: change in State water shares
There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
This option is expected to substantially contribute to managing the environmental risk as a result of the flow regime in the Barmah-Millewa Reach.

The option allows relatively significant flows to be delivered through the MIL channel system, which in turn will reduce pressure on the Barmah-Millewa Reach, reducing instances of inappropriate forest inundation and promote drying of wetlands within the forest. The option will also enable managers to restore short-term variations in flow, which influence ecosystem functions including patterns of productivity, nutrient and organic matter cycling. Use of the option would also have potential to reduce erosion rates in the Barmah-Millewa Reach.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
The flows delivered to natural receiving waterways are all expected to be below bank full. This will avoid unseasonal watering of floodplain and forest vegetation communities. The increased flows are likely to lead to improved water quality and increases in available habitat and opportunities for native fish movement.

Flows would be delivered as 'pulses' rather than as consistently high flows.

The option would consolidate a shift of some of these stream systems from ephemeral waterways to perennial waterways. This is consistent with the objectives of the documented environmental water requirements of these waterways. Accordingly, this option provides some (low to moderate) improvement opportunities for environmental outcomes in waterways outside of the Barmah-Millewa Reach.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would be expected to reduce the flow volumes being delivered through the Barmah-Millewa Reach, in turn providing a minor beneficial outcome for sediment dynamics in the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option does not involve any construction works or result in any changes to environmental conditions, outside of those already considered as part of changes to the environmental flow regimes assessed in MCA3 and MCA4.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
Using this option would allow on average around 665 ML/day of additional bypass flows to be delivered, as measured at the escapes. This accounts for delivering the water through the escapes in 'pulses' and takes into consideration the ecological and geomorphic considerations of the receiving waterways.

The volume returned to the River Murray would be lower, noting the conveyance losses associated with using the creeks, as discussed in MCA1.

The MIL system provides a consistently reliable means of transferring and delivering water. Accordingly, there is a high confidence this option would be consistently available for contributing to the flow objectives of the BMFS.

MCA9: social impacts
This option does not require any physical works to be undertaken. The infrastructure would be operated within its current capacity. Flow deliveries would be managed in-bank and not affect access. It is expected that some flows in the creeks may have positive environmental outcomes and therefore be reasonably received by local communities. Accordingly, there are no social impacts expected as a result of this option.

Summary of MCA outcomes
Table 14 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 14. Multi-criteria assessment outcomes for the MIL optimised escapes (no works) option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	MCA1 – Change in system water (e.g. arising from conveyance and evaporative losses)	-10	-1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	MCA3 – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	20	1.0
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	10	0.5
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	10	0.5
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	MCA7 – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	MCA9 – Risk of social impacts	0	0.0
	TOTAL WEIGHTED SCORING		5.8

Option assessment part 3: qualitative assessment
This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides increased capacity equivalent to approx. 7% of the current Barmah-Millewa Reach summer capacity to address system shortfall and opportunities to improve the flexibility of system operations.
- By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide opportunity for a more flow variability through the reach.
- Additional flow monitoring in the natural waterways would be recommended to understand conveyance loss behaviour and travel time for operational purposes.
- This option relies on access to surplus capacity in the MIL network. In dry seasons with high NSW General Security water availability, there may be some limitations on spare capacity available in the MIL system over peak summer periods, which may limit the ability of this option to regularly support improved resilience of overall system operations.
- Climate change is however likely to reduce inflows to the system, which will have flow on impacts of reducing available water determination for NSW General Security entitlements. It is possible that surplus capacity will be available more often in the future than it has been historically. The option does offer useful additional flexibility in years when access is possible.

- Barmah-Millewa bypass flows are already regularly delivered via the Mulwala Canal and the Edward Escape into the Edward-Kolety River at Deniliquin, so suitable water accounting arrangements are already available. It is likely that the discharge points from this option back to the river system would require approval by the Ministerial Council as a recognised outfall for water accounting under the provisions of clause 108 of the MDB Agreement. However, this is achievable.
- There may be a need to give consideration to compliance actions needed to protect bypassed water from extraction once it is discharged to natural waterways and prior to it reaching the River Murray.
- Depending on the nature of the charging arrangements adopted and given that there are no works required, this option offers potential for low initial cost and scalable ongoing costs if need for/usage of the bypass varies over time.

Option assessment part 4: financial cost

A capital cost allowance of $100,000 has been made, assuming that there would be some overhead and administration for the MDBA to coordinate and negotiate additional delivery of bypass water through the MIL system. There is also a current delivery charge for the transfer of water through the MIL network. Assuming this mechanism continues it is likely that this would be a volumetric charge based on the volume of total water delivered. This charge would be subject to negotiation between MIL and MDBA. However, if this was based on other similar agreements, it is assumed that the charge may range from $4-5 per megalitre delivered. There has been no discussion with MIL or MDBA about the reliability of this assumption.

Assuming the tolerable average summer bypass flow rate of 665 ML/day is accessed across the 100 days of summer (allowing for ‘pulses’ to be delivered, rather than constant high-flow delivery all summer), this equates to around 67 GL being delivered annually, for a delivery charge of around $250 - $350k (in 2022 dollars). Based on an annual average delivery charge of around $300k, the operational cost for implementing this option has been calculated at around $4.1 million, as assessed over a 50-year period using a 7.0% discount rate.

Assessment summary

Table 15 summarises the key outcomes for this option based on the assessment.

Table 15. Assessment summary of the MIL optimised escapes (no works) option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	665 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	< 1 year
Part 2: MCA scoring	
Water availability	-1.3
Environmental conditions	2.0
Delivery risk	5.0
River communities and Traditional Owners	0.0
Total MCA score	**5.8**
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$0.1 M
Operational cost (50 years)	$4.1 M
Total cost (capital + operational) / bypass capacity	**$6.3k / ML / 100-day capacity**

3.6 Option 4A.2 – MIL Options – Optimised escapes [upgrade works option]

Description of the option

The *Works Required* option investigates whether there is an opportunity to undertake upgrade works at the 20 priority MIL escapes to deliver higher bypass flows. The upgrade works generally involve automating the escape regulators and increasing the capacity of receiving channels and waterways. Further detail on the description of this option is available in the BMFS: MIL Options Investigation Report[76].

Scoping and flow capacity

The *Works Required* option considers upgrading escapes with unused upstream capacity, which could then be used to deliver additional bypass flows.

The engineering assessment determined that the MIL channel network and escapes could be upgraded to deliver an additional 3,355 ML/day during summer. These flows would be in addition to existing system commitments.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the outfalls. This assessment considered tolerable baseflow and fresh deliveries across the summer and winter/spring seasons. Over the summer period, the average daily flow was determined as 960 ML/day. Water can be released into river systems as an ecologically acceptable release through ten of the twenty escapes as identified in Figure 18.

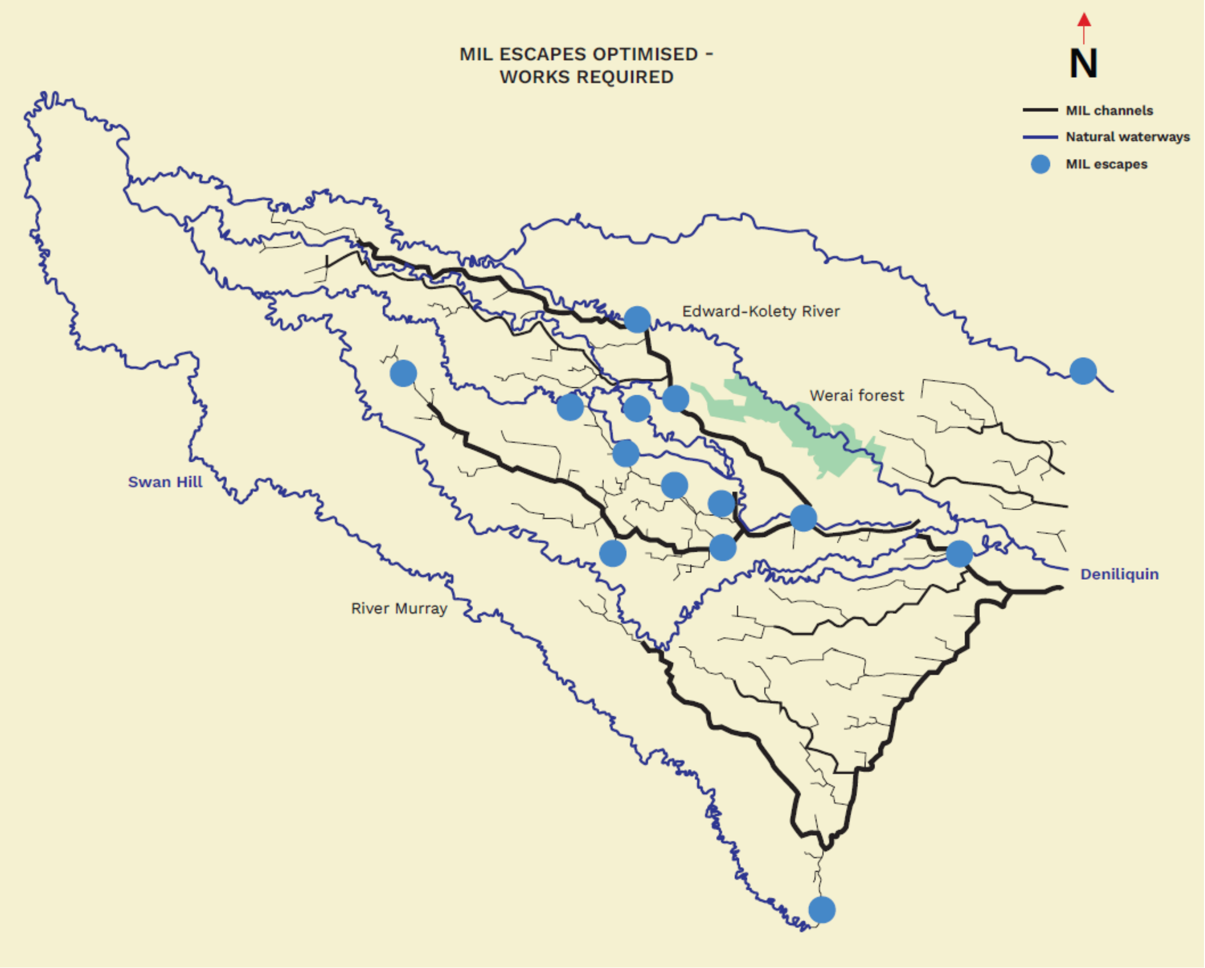

Figure 18. *Map of the MIL channel escapes and receiving waterways (works required option)*

[76] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Eight outfalls would need to be upgraded and six outfalls could provide additional flows with no additional works required. There is no capacity in downstream waterways from six of the outfalls and thus no works would be undertaken on these outfalls.

More detail around each of the escapes, the maximum available capacity, and the adopted tolerable flow capacities (including how they have been derived) is available in the BMFS: MIL Options Investigation Report[77].

Table 16 summarises the escapes proposed to be used under this option.

Table 16. The escapes which could be used for bypass flows, with works required

Escape name	Existing capacity (ML/day)	Upgraded capacity (ML/day)	Receiving waterway	Ecologically tolerable release – seasonal average in summer (ML/day)	Ecologically tolerable release – maximum peak in summer (ML/day)	Works required on escape based on ecologically tolerable flows
Wakool Main Escape	500	700	Wakool River	136	647	Upgrade works
Southern Town Escape	50	250	Wakool River	183	250	Upgrade works
Southern 27 Escape	15	50	Wakool River	-	50	Upgrade works
Southern Escape	70	70	Niemur / Wakool Rivers	24	70	No works required
Mallan Escape Frasers	50	330	Niemur River	-	-	No capacity in waterways
Mallan W149	70	70	Niemur River	-	-	No capacity in waterways
Mallan W186A	15	100	Niemur River	-	-	No capacity in waterways
Northern Escape W190	20	160	Niemur River	-	-	No capacity in waterways
Mallan W211 Escape	15	125	Niemur River	-	-	No capacity in waterways
Mallan W221/4 Escape	15	90	Niemur River	-	-	No capacity in waterways
Niemur Escape	300	300	Niemur River	280	300	No works required
Mascotte Escape	300	300	Niemur River	-	20	No works required
Northern 4 Escape	15	20	Niemur River	15	20	Upgrade works
Jimaringle 1 Escape	15	40	Niemur River	40	40	Upgrade works
Jimaringle 3 Escape	10	20	Niemur River	-	20	Upgrade works
Jimaringle 11 Escape	20	20	Niemur River	20	20	No works required
Jimaringle Escape	20	60	Edward-Kolety River	-	60	Upgrade works
Northern Branch Channel	30	300	Niemur River	60	300	Upgrade works
Billabong Escape	250	250	Billabong River	96	110	No works required
Perricoota Escape	100	100	River Murray	100	100	No works required
TOTAL	**1,880**	**3,355**		**954 (960 adopted)**		

[77] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Option assessment part 1: implementation readiness
This option requires works to several escapes and associated downstream works to transfer the larger flows. These works would be best managed as a single capital works program to be delivered over winter shutdown periods.

The implementation timeframe for these works would be around 2 years from project inception, which includes the planning, design and construction of the works and engagement with impacted downstream landowners.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water
This option is similar to the *No Works* option, but with a higher delivery capacity and longer length of river and channel used to bypass water around the Barmah-Millewa Reach.

When the works are implemented, over the 100-day summer period from January to April, a tolerable median delivery of 96 GL could be delivered.

Depending on when the additional deliveries occur relative to existing non-MIL shareholder deliveries, the conveyance loss over summer is estimated to range from 10 - 16 GL/yr.

The total length of escape channels for this option is 27.5 km and the total length of creek until permanent rivers are reached is 148.2 km. If in any given year only the escape channels need to be wetted up, then an additional 1 GL of losses would be incurred. If both the escape channels and associated rivers/creeks need to be wetted up, then an additional 4 GL of losses would be incurred. These losses are only expected to occur in drier years at times when deliveries via the MIL have not been made in the season to date, prior to Barmah-Millewa Reach bypass deliveries being made.

When these two types of losses (wetting up plus delivery) are combined, the aggregated loss is estimated to range from 10 - 21 GL/yr. Relative to the conveyance losses of 178 GL along the River Murray via the Barmah-Millewa Reach (to the Wakool Junction), these losses of 10-21 GL/yr represent an incremental loss of 6-12% relative to existing conveyance losses.

As such, this has been categorised as a small increase in losses expected, with a multi-criteria analysis score of -10.

Table 17. Range of expected additional losses over summer (Jan – Apr) for Option 4A.2

Assumed loss (%)	Assumed loss for 96 GL transfer (GL/yr)
17%	16.3
13%	12.5
10%	9.6
Reach length that may require wetting up (km)	Assumed loss if wetting up required (GL/yr)
27.5 km of escape channels	0.8
148.2 km of creeks	4.4
TOTAL loss (GL/yr):	10 – 21 GL/yr

MCA2: change in State water shares
There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
This option is expected to provide a notable decrease in the environmental risk as a result of the flow regime in the Barmah-Millewa Reach. The option allows significant flows to be delivered through the MIL channel system, which in turn will reduce pressure on the Barmah-Millewa Reach, reducing instances of unseasonal forest inundation and promote drying of wetlands within the forest. The option will also enable managers to restore short-term variations in flow through the Barmah-Millewa Reach, which influence ecosystem functions including patterns of productivity, nutrient and organic matter cycling.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
The flows delivered to natural receiving waterways are all expected to be below bankfull. This will avoid unseasonal watering of vegetation communities. The increased flows are likely to lead to improved water quality and increases in available habitat and opportunities for native fish movement.

Flows would be delivered as 'pulses' rather than as consistently high flows.

This option delivers water to several creeks and rivers from multiple escapes. Accordingly, this option provides significant opportunities for environmental outcomes in waterways outside of the Barmah-Millewa Reach.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would be expected to reduce the flow volumes being delivered through the Barmah-Millewa Reach, in turn providing a moderately beneficial outcome for sediment dynamics in the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves construction works to upgrade escapes, channels, and infrastructure in the downstream creeks and rivers to support the delivery of additional bypass flows. Any environmental impacts associated with these works are expected to be manageable as part of usual site inspection, design, approvals, and construction management practices. Accordingly, there are no changes to environmental conditions expected, outside of those already considered as part of changes to the environmental flow regimes assessed in MCA3 and MCA4.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
Using this option would allow on average around 960 ML/day of additional bypass flows to be delivered, as measured at the escapes. This accounts for delivering the water through the escapes in 'pulses', comprising combinations of base flows and freshes with freshes.

The volume returned to the River Murray would be lower, noting the conveyance losses associated with using the creeks, as discussed in MCA1.

The MIL system provides a consistently reliably means of transferring and delivering water. Accordingly, there is a high confidence this option would be consistently available for contributing to the flow objectives of the BMFS.

MCA9: social impacts
Works to increase the escape capacities would involve construction activities on approximately 12 private properties, with all works occurring being enlargement to existing private crossings. Discussions with MIL and DPE suggest landholders are generally supportive of works that will provide additional water to adjacent creeks and rivers.

Accordingly, the social outcomes from this option are considered neutral.

Summary of MCA outcomes

Table 18 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 18. Multi-criteria assessment outcomes for the MIL Optimised Escapes (upgrade works) option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	-10	-1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	20	1.0
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	20	1.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	10	0.5
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	**MCA9** – Risk of social impacts	0	0.0
	TOTAL WEIGHTED SCORING		**6.3**

Option assessment part 3: qualitative assessment

This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides increased capacity equivalent to approx. 11% of the current Barmah-Millewa Reach summer capacity to address system shortfall and opportunities to improve the flexibility of system operations.
- By taking pressure off flows through the Barmah-Millewa Reach, this option would provide a notable opportunity for more flow variability through the reach.
- Additional flow monitoring in the natural waterways would be recommended to understand conveyance loss behaviour and travel time for operational purposes.
- This option relies on access to surplus capacity in the MIL network. In dry seasons with high NSW General Security water availability, there may be some limitations on spare capacity available in the MIL system over peak summer periods, which may limit the ability of this options to regularly support improved resilience of overall system operations.
- Climate change is however likely to reduce inflows to the system, which will have flow on impacts of reducing available water determination for General Security. It is possible that surplus capacity will be available more often in future that has been the case historically. The option does offer useful additional flexibility in years when access is possible.
- Barmah-Millewa bypass flows are already regularly delivered via the Mulwala Canal and the Edward Escape into the Edward-Kolety River at Deniliquin, so suitable water accounting arrangements are already available. It is likely that the discharge points from this option back to the river system would require approval by the Ministerial Council as a recognised outfall for water accounting under the provisions of clause 108 of the MDB Agreement. However, this is achievable.
- There may be a need to give consideration to compliance actions needed to protect bypassed water from extraction once it is discharged to natural waterways and prior to it reaching the River Murray.

Option assessment part 4: financial cost

A cost estimate to implement the option has been detailed as part of the MIL options report.

Assuming the tolerable median summer bypass flow rate of 960 ML/day is accessed across the 100 days of summer (allowing for 'pulses' to be delivered, rather than constant high-flow delivery all summer), this equates to around 96 GL being delivered annually for a delivery charge of around $385 - $480k (in 2022 dollars). Based on an annual average delivery charge of around $435k, the operational cost for implementing this option has been calculated at around $10.4 million, as assessed over a 50-year period using a 7.0% discount rate.

Table 19. MIL Optimised Escapes (upgrade works) option cost estimate summary

Item	Works Type	Total ($)
1	**Infrastructure costs**	**9,784,000**
1.1	201480 - Wakool main Escape	285,000
1.2	212821 - Southern 2 Escape	625,000
1.3	213543 - Southern 27 Escape	455,000
1.4	214426 - Southern Escape	-
1.5	411334 - Niemur Escape	-
1.6	214391 - Northern 4 Escape	200,000
1.7	213307 - Jimaringle Escape	135,000
1.8	214948 - Jimaringle 11 Escape	20,000
1.9	213343 - Jimaringle 3 Escape	902,000
1.10	211842 - Jimaringle 1 Escape	312,000
1.11	214261 - Mascotte Escape	-
1.12	410527 - Mallan W221/4 Escape	-
1.13	214040 - Mallan W211 Escape	-
1.14	213305 - Mallan W186A Escape	-
1.15	214427 - Mallan W149 Escape	-
1.16	212222 - Mallan Escape Frasers	-
1.17	212574 - Northern Branch Channel	350,000
1.18	212575 - Northern Escape W190	-
1.19	207049 - Billabong Escape	-
1.20	211609 - Perricoota Escape	-
1.21	River system infrastructure (Wakool River, Cockrans & Jimaringle, Yallakool structures)	6,500,000
2	**Program management, survey, design, approvals, overheads**	**3,424,400**
2.1	Program management - Low complexity - 15% of infrastructure costs	1,956,800
2.2	Survey and design - Low complexity - 5% of infrastructure costs	489,200
2.3	Regulatory approvals including offsets - Low complexity - 10% of infrastructure costs	978,400
3	**Contingency**	**5,283,360**
	Total capital cost	**18,491,760**
4	**Operations and maintenance (NPV, assessed over 50 years)**	**10,403,488**

Assessment summary

Table 20 summarises the key outcomes for this option based on the assessment.

Table 20. Assessment summary of the MIL optimised escapes (upgrade works) option

Assessment category	Assessment outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	960 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	2 years
Part 2: MCA scoring	
Water availability	-1.3
Environmental conditions	2.5
Delivery risk	5.0
River communities and Traditional Owners	0.0
Total MCA score	6.3
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$18.5 M
Operational cost (50 years)	$10.4 M
Total cost (capital + operational) / bypass capacity	$60k / ML / 100-day capacity

3.7 Option 4B– MIL Options – Perricoota Escape Works

Description of the option

The Perricoota Escape outfalls water from the Deniboota canal to the River Murray via a 10km escape channel (see **Figure 19**). The existing design capacity of the Perricoota escape is 150 ML/day. During the summer months, around 100 ML/day of this capacity is currently available for delivering bypass flows. This option explores undertaking upgrade works to the Deniboota Canal and the Perricoota escape to support bypass flows of up to 300 ML/day (i.e., an increase of 200 ML/day from the current available capacity). Further detail on the description of this option is available in the BMFS: MIL Options Investigation Report[78].

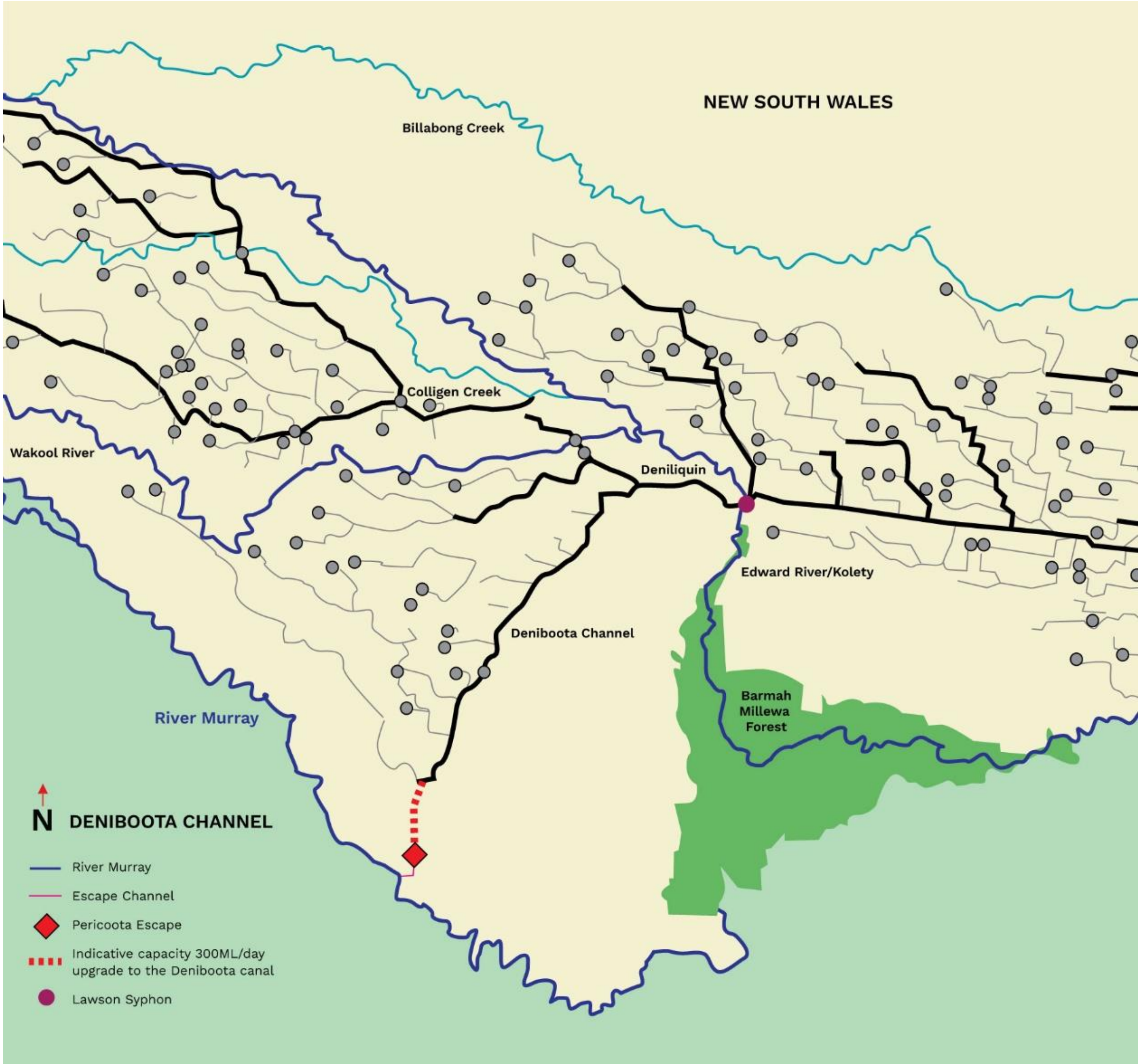

Figure 19. *Map of the Perricoota Escape and Deniboota Canal location relative to the Barmah-Millewa Forest*

[78] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Scoping and flow capacity

Increasing the escape capacity to support bypass flows of 300 ML/day (i.e., an increase of 200 ML/day from what can currently be achieved) would require works to approximately 10km of the Deniboota channel and associated infrastructure.

For the purposes of assessing this option, it is considered that the upgrade works would provide the capacity to deliver an additional 200 ML/day through the Deniboota Canal.

MIL have previously undertaken a desktop study, which investigated options to widen the existing Deniboota Canal to accommodate flows of 500, 1,000 and 1,500 ML/day. Based on preliminary engineering assessments and discussions with MIL operational staff, the Deniboota Canal under gravity would struggle during high River Murray summer flows to deliver more than 300 ML/day. Flows above this during a high river would break out from the escape channel into the Perricoota Forest, increasing losses and slowing delivery.

Option assessment part 1: implementation readiness

The upgrade of the Perricoota Escape could be performed in a single winter period, assuming productivity rate of 100-150m day per work crew, and assuming 3 work crews, with total construction length of 10km.

This option will most likely take 2 years from project inception to plan, design, obtain statutory approvals, and construct, including customer engagement.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water

The additional capacity of the Perricoota Escape and Deniboota Canal provided by works for this option is 200 ML/d over a 10 km reach of channel. Assuming the additional capacity can provide a tolerable median additional delivery volume equal to the additional capacity, over the 100-day summer period from January to April, this equates to a tolerable median delivery of 20 GL.

Depending on when the additional deliveries occur relative to existing non-MIL shareholder deliveries, the conveyance loss over summer is estimated to range from 2-3 GL/yr.

The length of channel with works for this option is 10 km. If in any given year only this section of channel needs to be wetted up (i.e., assuming any upstream channels and creeks are already wet), then an additional 0.3 GL of losses would be incurred. These losses are only expected to occur in drier years at times when deliveries via the MIL have not been made in the season to date, prior to Barmah-Millewa Reach bypass deliveries being made.

When these two types of losses (wetting up plus delivery) are combined, the aggregated loss is estimated to range from 2-4 GL/yr. Relative to the conveyance losses of 178 GL along the River Murray via the Barmah-Millewa Reach (to the Wakool Junction), these losses of 2-4 GL/yr represent an incremental loss of 1-2% relative to existing conveyance losses.

As such, this has been categorised as no or very small change expected, with a multi-criteria analysis score of 0.

Table 21. Range of expected additional losses over summer (Jan – Apr) for Option 4B

Assumed loss (%)	Assumed loss for 20 GL transfer (GL/yr)
17%	3.4
13%	2.6
10%	2.0
Reach length that may require wetting up (km)	Assumed loss if wetting up required (GL/yr)
10 km of channel	0.3
TOTAL loss (GL/yr):	2 – 4 GL/yr

MCA2: change in State water shares
There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
This option will provide a small decrease in risk for the environmental flow regime, as the bypass volumes and additional flexibility available through the option is relatively minor.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
The capacity to deliver relatively minor flows around the Barmah-Millewa Reach will provide a very small (negligible) outcome for the environmental flow regime in the River Murray during summer downstream of the reach.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would only marginally reduce flow volumes and therefore the potential for sediment accumulation in the Barmah-Millewa Reach. This would not be expected to result in any material change.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves construction in previously disturbed footprints. Therefore, there are no adverse or positive environmental outcomes expected through implementing the option, outside of those already considered as part of changes to the environmental flow regimes assessed in MCA3 and MCA4.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
This option would contribute a minor increase in system capacity by allowing an additional 200 ML/day to be delivered through the connected system.

As discussed, the ability to deliver the bypass flows through the Deniboota Canal are subject to the height of the River Murray and the hydraulic head difference. At higher River Murray flows, the outfall capacity is expected to be significantly lower than design flow. Accordingly, there is a low confidence in the availability of additional capacity, depending on River Murray operations at the time of the bypass.

MCA9: social impact
There are approximately 12 landowners (MIL customers) that will be impacted by the upgrade works. The channel runs through a floodplain and the enlargement of the Deniboota Canal may cause concerns that the new infrastructure may impact on current flood and drainage lines.

Accordingly, this option is considered to have low to medium social impact, which should be explored further should any subsequent investigations be undertaken.

Summary of MCA outcomes
Table 22 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 22. Multi-criteria assessment outcomes for the MIL – Perricoota Escape option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	0	0.0
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	10	2.5
Social risk	**MCA9** – Risk of social impacts	-10	-0.5
	TOTAL WEIGHTED SCORING		**2.5**

Option assessment part 3: qualitative assessment
This option offers some limited potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides some limited increased capacity to address system shortfall and opportunities to improve the flexibility of system operations.
- By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide a slight opportunity for more flow variability through the reach.
- This option relies on access to surplus capacity in the MIL network. Based on the relatively modest flow rates for this option and assessment of available capacity in the MIL system, it is expected that this option will be available in virtually all years, making it a reliable opportunity for operations planning.
- Barmah-Millewa bypass flows are already regularly delivered via the Mulwala Canal and the Edward Escape into the Edward-Kolety River at Deniliquin, so suitable water accounting arrangements are already available.

Option assessment part 4: financial cost
A cost estimate to implement the option has been detailed as part of the MIL options report. A summary of the expected capital and operations and maintenance costs (in net present value) is provided in **Table 23** below.

There will be a delivery charge for the transfer of water through the MIL irrigation network. It is likely the delivery charge will be a volumetric based charge based on the total water delivered. The delivery charge would be subject to negotiations between MIL and the MDBA. For the purposes of this assessment and based on other similar agreements, it is assumed that the volumetric charge may range from $4 – 5 per ML delivered. Assuming the existing available capacity of 200 ML/day is accessed for 100 days each summer, this equates to around 20,000 ML being delivered annually, for a delivery charge of around $80k - $100k (in 2022 dollars).

Operation and maintenance costs (including delivery charge) have been calculated in present annual value as a % of the capital cost. The O&M has then been assessed over a 50-year period using a 7.0% discount rate.

Table 23 Perricoota Escape works cost estimate summary

Item	Works Type	Total ($)
1	**Infrastructure costs**	**12,095,000**
1.1	Channel works	2,800,000
1.2	Meter outlets	420,000
1.3	Regulators	1,700,000
1.4	Road crossings and structures	7,175,000
2	**Program management, survey, design, approvals, overheads**	**4,497,750**
2.1	Program management - High complexity - 20% of infrastructure costs	2,419,000
2.2	Survey and design - High complexity - 10% of infrastructure costs	1,209,500
2.3	Regulatory approvals including offsets - High complexity - 15% of infrastructure costs	1,814,250
3	**Contingency**	**7,015,100**
3.1	40% of infrastructure, program management, survey, design, approval and overhead	7,015,100
	Total capital cost	**24,552,850**
4	**Operations and maintenance (NPV, assessed over 50 years)**	**7,881,013**
4.1	Additional maintenance and renewal costs as a result of upgrade works	6,776,953
4.2	Delivery charge (200 ML/day for 100 days per year)	1,104,060

Assessment summary

Table 24 summarises the key outcomes for this option based on the assessment.

Table 24. Assessment summary of the MIL – Perricoota Escape option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	200 ML/day
Confidence that option is accessible	Low
Part 1: Implementation readiness	**2 years**
Part 2: MCA scoring	
Water availability	0.0
Environmental conditions	0.5
Delivery risk	2.5
River communities and Traditional Owners	-0.5
Total MCA score	**2.5**
Part 3: Qualitative assessment of non-scored elements	!
Part 4: Cost effectiveness	
Capital cost	$24.5 M
Operational cost (50 years)	$7.9 M
Total cost (capital + operational) / bypass capacity	**$162k / ML / 100-day capacity**

3.8 Option 4C– MIL Options – Mulwala Canal Expansion

Description of the option

This option involves an extension of the Mulwala Canal from its current termination point at the Wakool Escape on the Wakool River to the Wakool Main Channel (see **Figure 20**). Further detail on the description of this option is available in the BMFS: MIL Options Investigation Report[79].

Figure 20. *Map of the Mulwala Canal and Yallakool Creek location relative to the Barmah-Millewa Forest*

[79] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: MIL Options Investigation.*

Scoping and flow capacity

The current delivery arrangement for the Wakool Irrigation District involves supplying water via the Edward-Kolety River, which is then diverted at Stevens Weir. Stevens Weir creates a weir pool which allows water to be diverted down the Colligen and Yallakool Creeks and the Wakool River. Colligen Creek is the main supply to MIL's Wakool Irrigation District via the Wakool Main Canal.

This option proposes the construction of a new channel section to connect the Mulwala Canal to the Wakool Main Canal. This channel would then be used to supply some of the Wakool Main Canal demands, as opposed to using the Edward-Kolety River. Accordingly, this would provide surplus capacity in the Edward-Kolety River upstream of Stevens Weir.

The existing infrastructure upstream of the proposed channel extension has an existing surplus capacity of 1,000 ML/day. Key upstream infrastructure includes the Mulwala Canal, Lawson Syphon, Woolshed and Carew Regulators and Wakool River Syphon. Any works to these existing assets would be prohibitively expensive and unviable. Accordingly, the new canal capacity would be confined to supplying 1,000 ML/day.

Through discussions with WaterNSW and our ecological assessment, there is a capacity constraint on the Edward-Kolety River downstream of Steven's Weir of 2,700 ML/day. This constraint recognises the risk of unseasonal inundation of the Werai Forest. The Edward-Kolety River below Stevens Weir is already at capacity during summer, including consideration of current bypass flows which are delivered. Accordingly, there is no opportunity to deliver additional bypass flows via the Edward-Kolety River.

Given this constraint on the Edward-Kolety River, the full extension of the canal to the Wakool Main Canal would provide no benefit from a water resource perspective, given any bypass water delivered in the Edward-Kolety River would still need to be diverted at Stevens Weir to avoid exceeding the downstream capacity constraints. There would be environmental outcomes from this extension however, as the Edward-Kolety River runs close to bank full for extended periods over summer to deliver demands downstream.

The partial extension of the Mulwala Canal could provide some water resource outcomes by extending the Mulwala Canal to the Yallakool Creek and using this as a route for delivering bypass flows.

There is approximately 1,000 ML/day of spare capacity during summer in the Mulwala Canal up to its current termination point at the Wakool River. Therefore, the canal extension options include:

- Partial Extension Option: a pipeline to discharge into the Yallakool Creek (6.3km)
- Full Extension Option: a 1,000 ML/Day channel to discharge to the Wakool Main Channel (7.9km)

The partial extension option (Yallakool extension) would provide a water resource benefit by supporting the delivery of bypass flows. The full extension option (Mulwala Canal – Wakool Main Canal connection) would provide no water resource benefit, due to the constraint in delivering any additional flows to the Edward-Kolety River downstream of Stevens Weir.

Accordingly, the partial extension of the Mulwala Canal to the Yallakool Creek has been used for the basis of the options assessment for the purposes of the Barmah-Millewa Feasibility Study.

The engineering assessment determined that sufficient capacity was available in the system to install a 200 ML/day gravity pipeline to deliver flows into the Yallakool Creek system. This would require the installation of dual 1500mm diameter concrete pipes for a length of 6.3km.

The ecological flows assessment was undertaken to determine an ecologically tolerable flow regime in the natural waterways and to identify any limitations for additional releases from the pipeline extension. The ecological assessment confirmed that the ecologically tolerable flow should be restricted to an average of around 185 ML/day due to capacity constraints in the Wakool River. However, expecting that some of this available capacity is taken by optimising the current escapes (Option 4A), the additional capacity available for this option reduces to around 38 ML/day.

Option assessment part 1: implementation readiness

The piped extension of the Mulwala Canal can be constructed in season as the channel has previously been decommissioned and will not impact on irrigation deliveries.

Design, customer engagement and approvals are estimated to take around 12 months. These activities are expected to be of a low complexity, noting that the proposed pipeline would follow the alignment of the decommissioned Mulwala Canal. Easements are still in place. Construction can be undertaken outside the shutdown period and would take approximately half a year, with 3 works crews completing 15-20 metres day.

This option will most likely take 2 years from project inception to plan, design, secure statutory approvals, and construct, including customer engagement.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water

The additional capacity of the Mulwala Canal extension is 38 ML/d using a 10 km pipeline. Over the 100-day summer period from January to April, this equates to a pipeline delivery volume of 4 GL.

Pipeline losses are typically lower than channel losses, due to zero evaporative losses and lower leakage. Pipeline losses over a 10 km section of pipeline are likely to be negligible and have been assumed to be zero for the purposes of this assessment.

Channel delivery losses would however still apply to the additional water transferred through the MIL, prior to reaching the Mulwala Canal Expansion and beyond the pipeline outfall into Yallakool Creek. Depending on when the additional deliveries occur relative to existing non-MIL shareholder deliveries, the conveyance loss over summer is estimated to range from 0.5 - 1 GL/yr.

Relative to the conveyance losses of 178 GL along the River Murray via the Barmah-Millewa Reach, these losses of 0.5 - 1 GL/yr represent an incremental loss of <1% relative to existing conveyance losses.

As such, this has been categorised as no or very small change expected, with a multi-criteria analysis score of 0.

Table 25. Range of expected additional losses over summer (Jan – Apr) for Option 4C

Assumed loss (%)	Assumed loss for 4 GL transfer (GL/yr)
17%	0.7
13%	0.5
10%	0.4
Reach length that may require wetting up (km)	Assumed loss if wetting up required (GL/yr)
10 km of channel	0.0
TOTAL loss (GL/yr):	0.5 – 1

MCA2: change in State water shares

There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach

This option will provide a small decrease in risk for the environmental flow regime, as the bypass volumes and additional flexibility available through the option is relatively minor.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach

The Yallakool Creek has a large channel with spare capacity to enable it to accommodate additional flows without increasing environmental risks and potentially providing improvements in water quality, fish habitat and opportunities for native fish movement.

This is not considered to provide any significant change in environmental risk outside of the reach.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would only marginally reduce flow volumes and therefore the potential for sediment accumulation in the Barmah-Millewa Reach. This would not be expected to result in any material change.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves construction in previously disturbed footprints. Therefore, there are no adverse or positive environmental outcomes expected through implementing the option, outside of those already considered as part of changes to the environmental flow regimes assessed in MCA3 and MCA4.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
This option would contribute a minor increase in system capacity by allowing an additional 200 ML/day to be delivered through the connected system.

This option would be utilising existing spare capacity in the Mulwala Canal and would use dedicated infrastructure to deliver water to the Yallakool Creek. Accordingly, there is a high confidence that this option would be reliably available to deliver bypass flows.

MCA9: social impact
There are three MIL customers that will be impacted by the Mulwala Canal extension. Given the canal has been decommissioned and the landowners have reconfigured their properties based on the channel no longer being there, it is likely the landholders will not be in favour of the extension. To mitigate this risk to some extent, the extension is proposed to involve a buried pipeline.

Landholders downstream and adjacent to the Yallakool Creek are expected to be likely to support this extension as it will improve the health of the creek.

There is both a minor negative and minor positive social impact for this option; however, has been assessed as being slightly negative, because of the direct impact on landholders with the reinstatement of irrigation infrastructure across their properties.

Summary of MCA outcomes
Table 26 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 26. Multi-criteria assessment outcomes for the MIL – Mulwala Canal Expansion option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	MCA1 – Change in system water (e.g. arising from conveyance and evaporative losses)	0	0.0
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	MCA3 – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	MCA7 – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	10	2.5
Social risk	MCA9 – Risk of social impacts	-10	-0.5
	TOTAL WEIGHTED SCORING		2.5

Option assessment part 3: qualitative assessment

This option offers limited potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides limited increased capacity to address system shortfall and opportunities to improve the flexibility of system operations.
- By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide a slight opportunity for a more flow variability through the reach.
- This option relies on access to surplus capacity in the MIL network. Based on the relatively modest flow rates for this option and assessment of available capacity in the MIL system, it is expected that this option will be available in virtually all years, making it a reliable opportunity for forward operations planning.
- Barmah-Millewa bypass flows are already regularly delivered via the Mulwala Canal and the Edward Escape into the Edward-Kolety River at Deniliquin, so suitable water accounting arrangements are already available. It is likely that the discharge points from this option back to the river system would require approval by the Ministerial Council as a recognised outfall for water accounting under the provisions of clause 108 of the MDB Agreement. However, this is achievable.
- There may be a need to give consideration to compliance actions needed to protect bypassed water from extraction once it is outfalled into natural waterways and prior to it reaching the River Murray, and additional flow monitoring in the natural waterways to understand loss behaviour and travel time for operational purposes.

Option assessment part 4: financial cost

A cost estimate to implement the option has been detailed as part of the MIL options report. A summary of the expected capital and operations and maintenance costs (in net present value) is provided in Table 27 below.

There will be a delivery charge for the transfer of water through the MIL irrigation network. It is likely the delivery charge will be a volumetric based charge based on the total water delivered. The delivery charge would be subject to negotiations between MIL and the MDBA. For the purposes of this assessment and based on other similar agreements, it is assumed that the volumetric charge may range from $4 – 5 per ML delivered.

Assuming the existing available capacity of 38 ML/day is accessed for 100 days each summer, this equates to around 3,800 ML being delivered annually, for a delivery charge of around $15k - $20k (in 2022 dollars).

Asset maintenance and renewal costs have been calculated in present annual value as a % of the capital cost. Delivery charge is an estimate only and subject to negotiation. The O&M has then been assessed over a 50-year period using a 7.0% discount rate.

Table 27. Mulwala Canal expansion works cost estimate summary

Item	Works Type	Total ($)
1	**Infrastructure works**	**21,160,000**
1.1	Mulwala channel extension – dual 1,500mm diameter pipeline	20,160,000
1.2	Mulwala channel extension – pipeline offtake – construct new	250,000
1.3	Roads, bridges, structures	750,000
2	**Program management, survey, design, approvals, and overheads**	**6,348,000**
2.1	Program management – low complexity – 15% of infrastructure costs	3,174,000
2.2	Survey and design – low complexity – 5% of infrastructure costs	1,058,000
2.3	Regulatory approvals including offsets – low complexity - 10% of infrastructure costs	2,116,000
3	**Contingency**	**11,003,200**
3.1	40% of infrastructure, program management, survey, design, approval and overhead costs	11,003,200
	Total capital cost	**38,511,200**
4	**Operations and maintenance (NPV, assessed over 50 years)**	**10,839,437**
4.1	Additional maintenance cost as a result of upgrade works - 2% of capital costs	10,629,666
4.2	Delivery charge (38 ML/day for 100 days per year)	209,771

Assessment summary

Table 28 summarises the key outcomes for this option based on the assessment.

Table 28. Assessment summary of the MIL – Mulwala Canal Expansion option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	38 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	**2 years**
Part 2: MCA scoring	
Water availability	0.0
Environmental conditions	0.5
Delivery risk	2.5
River communities and Traditional Owners	-0.5
Total MCA score	**2.5**
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$38.5 M
Operational cost (50 years)	$10.8 M
Total cost (capital + operational) / bypass capacity	**$1,299k / ML / 100-day capacity**

3.9 Option 5A – Victorian Options – Enhanced use of the VMMS

Description of the option

The Victorian Mid-Murray Storages (VMMS) consist of four storages: Lake Boga, Lake Charm, Kangaroo Lake and Ghow Swamp. For the purposes of this study, Ghow Swamp has not been included, recognising its existing role in supplying Victorian entitlements and local irrigator demands, and ongoing effects to improve outcomes for social, cultural, and environmental values at the site.

The VMMS are 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 (TIA), the four lakes have been equipped with regulating structures and are incorporated into the irrigation system.

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. Water can be supplied from Lake Boga, Kangaroo Lake, and Lake Charm for River Murray demand, with Ghow Swamp managed for supplying irrigation demands and minimising releases from upper storages for the TIA.

For the purposes of the BMFS, this option considers the enhanced use of the Lake Boga, Kangaroo Lake, and Lake Charm storages to support the project objectives. Further detail on the description of this option is available in the BMFS: Victorian Options Investigation Report[80].

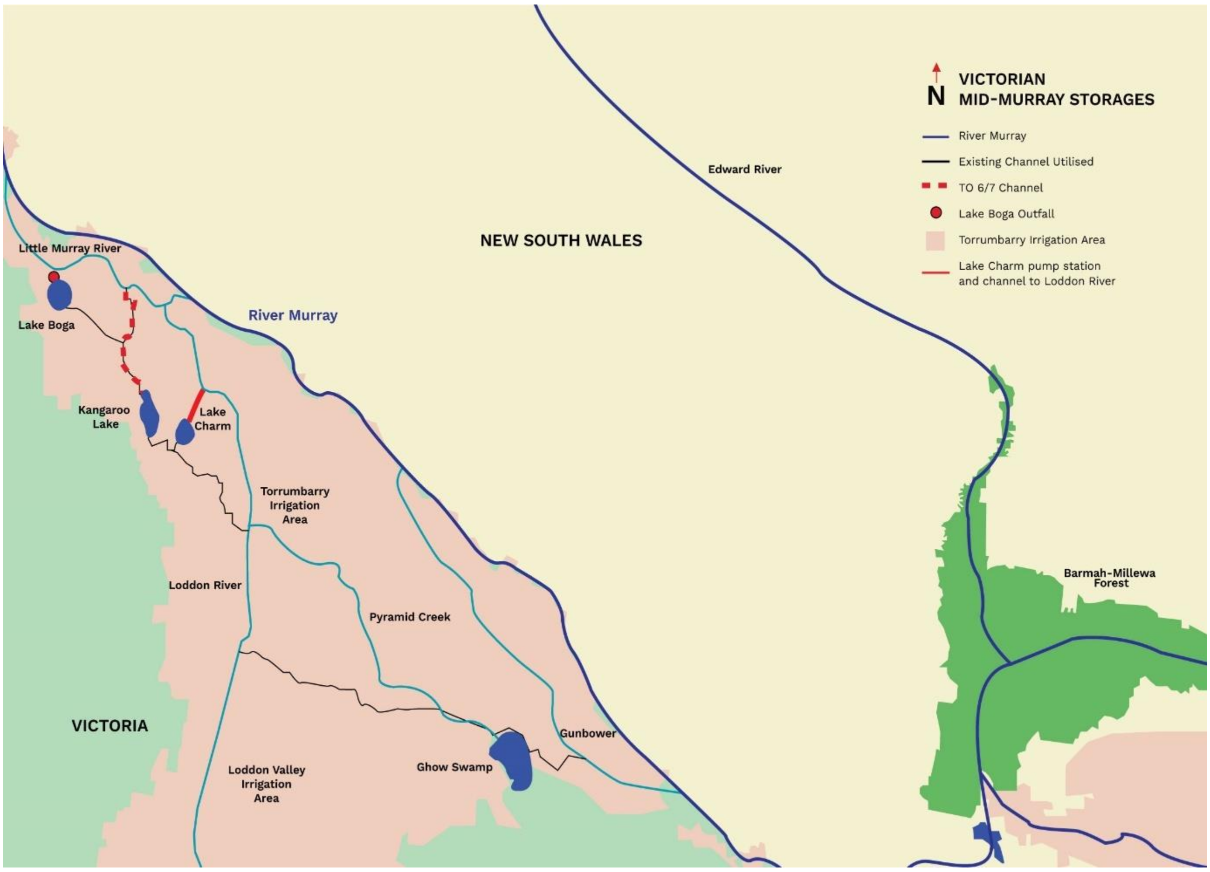

Figure 21. *Location of the Victorian Mid-Murray Storages relative to the Barmah-Millewa Reach*

[80] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation.*

There are several factors which currently limit the use of the VMMS, which are discussed in more detail in the Victorian options report[81]. One of these key factors is that the available discharge capacity from the storages is less than the normal operational discharge which can be achieved (see **Table 29**).

Table 29. Active storage capacity and maximum design discharge for the Victorian mid-Murray storages[82]

VMMS Storage	Available Active Storage Capacity (ML)	Maximum design discharge (ML/day)	Normal Operational Discharge (ML/day)
Lake Boga	20,907 ML	0 – 1,000	200 – 500
Kangaroo Lake	7,840 ML	1,000 (flood releases) 650 (operational)	Up to 610*
Lake Charm	3,590 ML	150 (pumps)	150
Ghow Swamp	-	-	-
TOTAL			950 – 1,250 ML/day

* discharge rates from Kangaroo Lake are likely to be limited to around 360 ML/day based on Ramsar criteria, subject to further assessment

Scoping and flow capacity

The feasibility study engineering review for the VMMS focussed on investigations and works that may be considered to reinstate and enhance the discharge rates from the storages, including:

- **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 or system shortfalls (**Table 30**).

[81] *Ibid.*
[82] GMW (2022), *Victorian Mid-Murray Storages 2022/2023 Annual Operating Plan, June 2022.*

Table 30. Active storage capacity and proposed discharge for the enhanced Victorian mid-Murray storages[83]

VMMS Storage	Available Active Storage Capacity (ML)	Assumed discharge capacity available (for 10 days)
Lake Boga	20,907	500
Kangaroo Lake	7,840 ML	360
Lake Charm	3,590 ML	150
Ghow Swamp	-	
TOTAL	Approx. 30,000 ML	~ 1,000 ML/day

Option assessment part 1: implementation timeframe

Enhancing the use of the Victorian Mid-Murray Storages will require a detailed review of the current and future operating practices, consultation with Victorian entitlement holders about the proposed changes, the identification and undertaking of requisite operational modelling and changes in operating procedures, investigation of social, cultural, and environmental values resulting from the operational changes, and communications with the public.

The enhanced use also requires targeted engineering investigations, to confirm the scope of works required to reinstate and potentially improve the discharge capacity. The infrastructure works which could be undertaken to support higher and more regular discharge flows are relatively minor in nature. A capital works program could be expected to be completed within 1 - 2 years of funding being initiated, including time for the investigation and design.

The VMMS are already available and used for the purposes of supporting lower Murray demands. Increasing the frequency and extent of this use could be achieved in a relatively short time (i.e., within 2 years). Any change to the operation of the VMMS would need to include consideration of cultural values and ongoing discussions with Traditional Owners regarding the operation of Ghow Swamp.

In summary, the enhanced use of the mid-Murray storages could feasibly be delivered within 2 years.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water

The losses associated with operation of the Victorian Mid-Murray Storages are accounted for in two parts:

1. a fixed distribution loss and
2. net evaporation from the Victorian Mid-Murray Storages.

The storages are typically operated to relatively high levels over the summer period (see **Figure 22**, **Figure 23** and **Figure 24**). Enhancing the use of these storages would likely result in more water being released to the River Murray more regularly over summer, thus reducing storage volumes compared with current practice. Within the range of operations being contemplated, this change in water surface area would only be marginally different to current operations.

Additionally, in the circumstance of Menindee Lakes being unavailable as a shared resource and dry climatic conditions, the enhanced availability of the VMMS may allow river operators to release water more efficiently from Lake Hume, potentially allowing the system to be run with slightly lower losses.

Therefore, enhancing the use of the storages is expected to result in a small reduction in net evaporation losses.

[83] Alluvium (2022), *Op. Cit.*

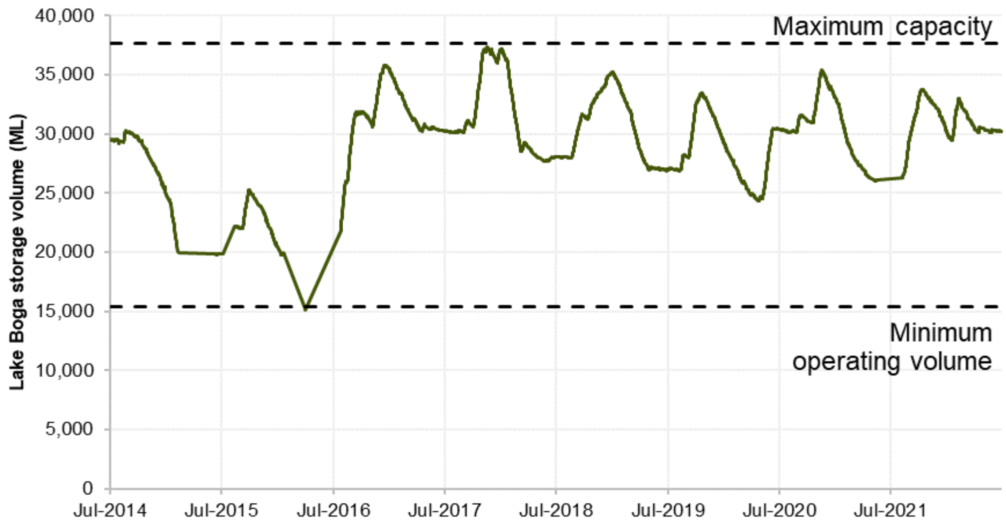

Figure 22. *Historic storage levels at Lake Boga from 2014 - 2021*

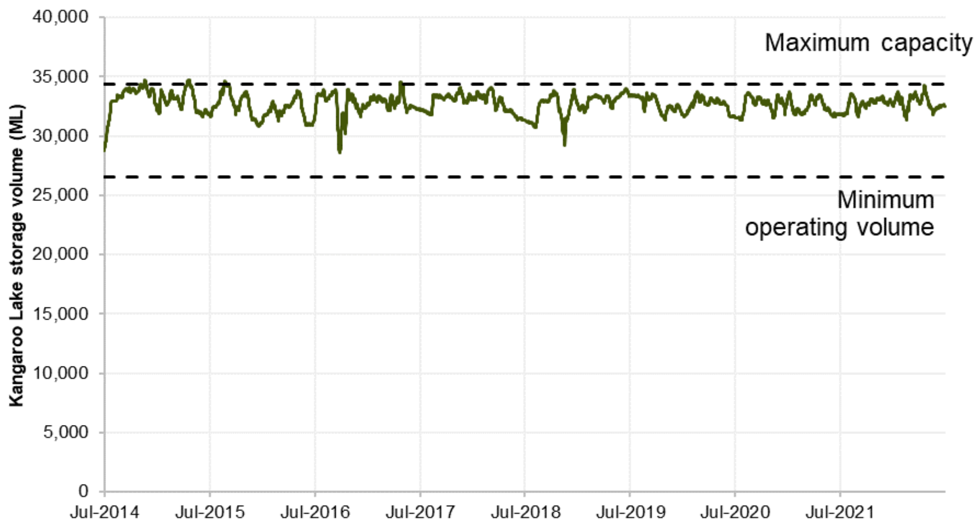

Figure 23. *Historic storage levels at Kangaroo Lake from 2014 – 2021*

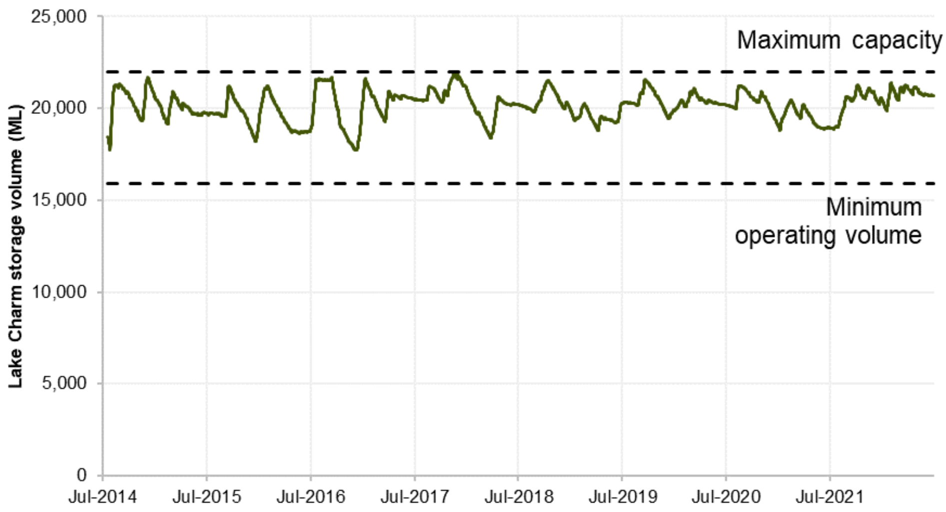

Figure 24. *Historic storage levels at Lake Charm from 2014 – 2021*

MCA2: change in State water shares

The primary purpose of the VMMS is to capture and store Victorian tributary inflows from the Goulburn, and particularly unregulated inflows from the Broken system which occur following the decommissioning of Lake Mokoan. This purpose will need to be continued in the future.

If the enhanced use of the VMMS also includes options for transfer of water from Lake Hume in years when tributary inflows are not sufficient to fill the storages, detailed water accounting arrangements may need to be developed to cover these arrangements.

If transfers were made from Lake Hume to the VMMS for the purposes of supporting a potential delivery shortfall, it is expected that this would only occur during dry seasons when tributary inflows are low, and forecasts are expecting continually dry conditions. Accordingly, it would be expected that there would be a low risk of lost opportunity for harvesting unregulated flows. This assumption should be tested with river operators and entitlement holders in planning any changes to the operational arrangements for the VMMS.

In summary, the increased use of the VMMS is not likely to change State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach

The VMMS would be filled through inflows to Ghow Swamp during winter/spring, either by capturing of unregulated Victorian tributary flows (following the decommissioning of Lake Mokoan on the Broken system) or through transfers from Lake Hume. Any transfers from Lake Hume at this time of the year would be ecologically tolerable within the Barmah-Millewa Reach.

Additionally, in years when Menindee Lakes is unavailable as a shared resource, if river operators could rely on a flow from the VMMS during a heat wave to help with managing a potential spike in demand, this option should allow releases from Lake Hume to be managed more efficiently, resulting in a reduction in flows through the Barmah-Millewa Reach. This would be very significant, even if it is only in some years.

Thus, this option is considered to provide a positive change to environmental flow regime through the Barmah-Millewa Reach.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach

There are two considerations for this option – filling of the storages and discharging the summer-autumn release flows.

1. ***Fill the storages slowly through winter**:* it is considered ecologically tolerable to send winter-spring flows down Pyramid Creek to the storages. The delivery of water to the lakes via Pyramid Creek could be aligned with winter / spring fresh environmental flow requirement for the creek. The impact on the lakes is to be confirmed and will be informed by acceptable rate of filling and maximum acceptable change in depth. Vegetation and birds that inhabit the lakes will respond positively to additional water in the spring period.
2. ***Discharging flows from the lakes in summer-autumn***: any potential impact on the lakes would be controlled by ensuring the lakes are operated within an acceptable rate of discharge and the maximum acceptable change in depth. The impact on the Loddon River and Little Murray River that will be used to deliver water to the River Murray is to be confirmed, however it is expected to be tolerable, and align with summer fresh flow requirements for these systems, provided there are no overbank flows. With regard to water quality, water discharged from Lake Charm to the Loddon River can be moderately saline and its impact on water quality in the Loddon River and River Murray may be neutral to negative. The salinity levels in Lake Charm would be expected to decrease with continued use and additional inflows. There are river flow triggers which limit the use of the outfall channel to periods when any salinity impacts fall within the range of tolerable salinity levels in the received waterways. These triggers assist to mitigate this potential risk to adverse ecological outcomes.

Additional flow releases from the mid-Murray storages are likely to be short duration and contained within the existing channel and not be associated with the dominant lower Murray erosion mechanism associated with sustained flows and constant rates and elevation. Flow releases would be managed to avoid adverse outcomes associated with increased salinity levels in the receiving waterways.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would not change the volume of flow delivered through the Barmah-Millewa Reach, and therefore would not be expected to change sediment accumulation potential in the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
Kangaroo Lake and Lark Charm are part of the Kerang Wetlands Ramsar site. The storages are already operated by GMW as part of current practices. The proposed changes in inflow rate, outflow rate, and water depths should be planned in accordance with the accepted characteristics. On the basis that the storages are operated within the acceptable tolerances, no increase in environmental risks are expected.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
The VMMS can be operated to provide a high flow over a short period, which could supply peak flows in the lower Murray with limited notice. This would assist river operators in managing potential delivery shortfall events. This operation would require high volumes to be delivered from each of the storages for a short period.

Assuming that the proposed works are undertaken and successful in returning the design discharge volumes, Lake Boga could sustain a flow of 500 ML/day over this period. Kangaroo Lake may be able to provide up to 360 ML/day, depending on demand on the TO 6/7 channel. Lake Charm may be able to provide 150 ML/day. In total, an average of around 1,000 ML/day or 10 GL volume may be provided over a 10-day period.

This represents an upper bound limit, subject to:

- operations being able to be managed within the acceptable rates of rise and fall as prescribed for the Kerang Lakes Ramsar site.
- salinity levels and the ability to discharge from Lake Charm and Lake Boga.
- capacity in the TO 6/7 channel being available.
- the ability to re-instate the discharge capacity on Lake Boga.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
The VMMS could be operated to provide a sustained lower flow over a longer period, which could provide additional system capacity for supplying the Lower Murray demands. This would assist river operators with managing potential system shortfall events.

The value of operating the storages in this manner is likely to be substantially lower than operating the storages to manage potential delivery shortfalls, with larger discharges over short periods.

For means of assessing this option against other bypass options, if the storages were operated in this manner, it 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 for 100-days.

MCA9: social impacts
Although the primary purpose of the VMMS storages is to capture, store, and release water for entitlement holders, it is recognised that the lakes have high recreational value and are popular destinations for active pursuits.

The use of the VMMS would typically require the lakes to be drawn down relatively quickly (if supporting a potential delivery shortfall event), likely over the summer period. Affected social activities could include fishing, regattas, and swimming events (Lake Boga) and water skiing (Lake Charm and Kangaroo Lake). The enhanced use of the storages to supply Murray shortfalls would need to consider these social values and how communication is managed with the local community and lake users.

It is noted that some of the recreational opportunities within the lakes were created or enhanced through the VMMS scheme in the first instance. Regardless, it is expected that the social impact through the enhanced use of the mid-Murray storages would be low to moderate.

Summary of MCA outcomes
Table 31 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 31. Multi-criteria assessment outcomes for the Victorian Mid-Murray Storages enhancement option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	10	1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	20	5.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	10	2.5
Social risk	**MCA9** – Risk of social impacts	-10	-0.5
	TOTAL WEIGHTED SCORING		**8.8**

Option assessment part 3: qualitative assessment
This option offers potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- The VMMS releases enter the River Murray at Swan Hill, which represents the most upstream extent of current major nut and vine plantings. It is well placed to command current and potential future developments in the region.
- This is likely to be of increased benefit under climate change, offering the ability to respond quickly to changes in demands arising from the increasingly frequent extreme weather conditions forecast to occur under climate change scenarios. This recognises that the travel time from the VMMS to Mildura Weir is around 7 days, compared to the travel time from Hume to Mildura Weir of around 21 days.
- Additional storage in this region will particularly help to offset operational risk during periods when Menindee Lakes are not available as a shared resource under MDBA control.
- Improved outlet capacity from the VMMS may offer some limited opportunities to supplement environmental water deliveries to help achieve peak flow targets downstream of Swan Hill, noting that this would only be desirable in periods when refilling of the VMMS prior to summer peak demand periods was possible.
- If the enhanced use of the VMMS also includes options for transfer of water from Lake Hume in years when tributary inflows are not sufficient to fill the storages, detailed water accounting arrangements may need to be developed to cover these arrangements

Option assessment part 4: financial cost
A cost estimate to implement the option has been detailed as part of the Victorian options report. A summary of the expected capital and operations and maintenance costs (in net present value) is provided in **Table 32** below. 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. 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.

Table 32. Victorian Mid-Murray Storages Cost Estimate Summary

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	**Infrastructure costs**				**2,833,421**
1.1	Lake Boga regulating structure (1000ML/day)				1,300,000
1.2	Lake Boga channel de-silting and re-profiling				656,053
1.3	Lake Boga outfall sandbar removal				290,000
1.4	TO6/7 channel targeted re-profiling				437,368
1.5	Lake Charm outfall discharge structure				150,000
2	**Investigations and operational arrangements**				**300,000**
2.1	Enhanced operational arrangements - GMW Operators				200,000
2.2	Salinity Management				100,000
3	**Program Management, survey, design, approvals, and overheads**				**920,862**
3.1	Program management and overheads				425,013
3.2	Survey, design and approvals				495,849
4	**Contingency**				**1,621,713**
	Total capital cost				**5,675,996**
5	**Operations and maintenance (NPV, assessed over 50 years)**				**2,429,206**
5.1	Additional maintenance and renewal costs as a result of upgrade works				1,566,660
5.2	Additional operational management of the storages				862,547

Assessment summary

Table 33 summarises the key outcomes for this option based on the assessment.

Table 33. Assessment summary of the Victorian mid-Murray storages option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	10 GL over 10 days
Contribution to mitigating system shortfall events	300 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	**2 years**
Part 2: MCA scoring	
Water availability	1.3
Environmental conditions	0.5
Delivery risk	7.5
River communities and Traditional Owners	-0.5
Total MCA score	**8.8**
Part 3: Qualitative assessment of non-scored elements	!
Part 4: Cost effectiveness	
Capital cost	$5.7M
Operational cost (50 years)	$2.4 M
Total cost (capital + operational) / bypass capacity	**$27k / ML / 100-day capacity**

3.10 Option 5B – Victorian Options – Murray Valley Irrigation Area Outfalls Enhancement

Description of the option and flow capacity

There are four existing outfalls from the Murray Valley Irrigation Area (MVIA) which discharge directly into the highly regulated reaches of the Lower Broken Creek (reaches 3 and 4). These four outfalls are the subject of investigation for potential increases in capacity. The characteristics of the outfalls was provided by the Goulburn-Murray Water (GMW) East Distribution team.

Table 34. Characteristics of the existing MVIA outfalls

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 River Murray)
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**	

For these four outfalls, GMW advised that the current capacity was generally limited by the size of the outfall infrastructure. If the infrastructure were upsized, there would generally be available capacity in the upstream channels to supply the additional flows, based on current irrigation demand patterns over the summer period. **Figure 25** below shows the location of the four targeted outfalls. Further detail on the description of this option is available in the BMFS: Victorian Options Investigation Report[84].

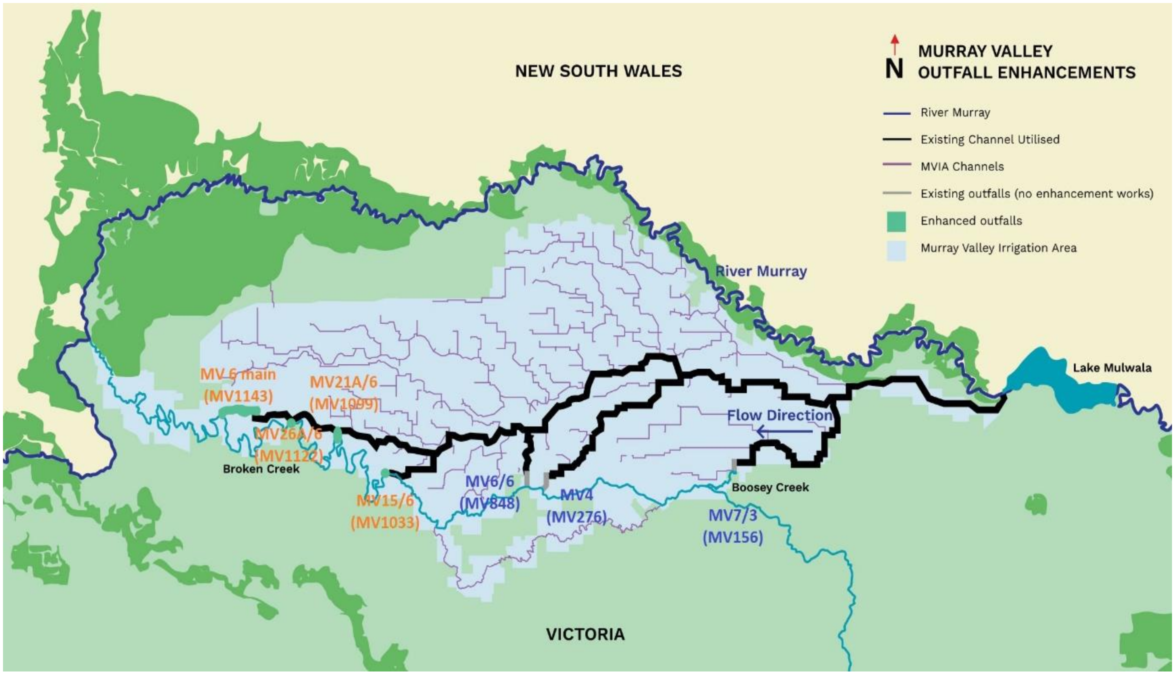

Figure 25. *Location of the existing outfalls from the MVIA into the lower Broken Creek*

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[84] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation.*

Scoping and flow capacity

The engineering investigations focussed on the four existing outfalls which discharge into reaches 3 and 4 of the Lower Broken Creek. These studies investigated the additional capacity which could be achieved by infrastructure upgrades on the outfalls without needing to increase the capacity of any upstream infrastructure. The infrastructure for each outfall was reviewed and a high-level scope of upgrades derived. 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 tolerable alternate means, such as the Rochester 14 bypass option considered in this study.

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. **Table 35** summarises the existing capacity, potential increase, and proposed works for each of the MVIA outfalls.

Table 35. 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)	

Scoping & Assessment Part 1: Implementation Readiness

Without any works, there is an existing bypass capacity of 180 ML/day. This existing capacity is currently utilised by the MDBA when GMW has available capacity within the irrigation system. During the 2021-22 water year, this capacity was essentially fully utilised over the summer months.

The works to upgrade the outfall capacity could be delivered within 1 – 2 years of project initiation.

Any additional delivery of River Murray bypass water would require the equivalent reduction in Goulburn IVT commitments being delivered through the Lower Broken Creek, to avoid ecologically unacceptable changes in the flow regime for the creek. The Goulburn IVT commitments would need an alternate means of being supplied to the River Murray, such as the Rochester 14 channel option being considered in this study. Changing the means of delivering the Goulburn IVT commitments, which require policy consideration and approval requirements, which are understood to be significant. Accordingly, to allow appropriate timeframes for designing and constructing the Rochester bypass channel and to effect any necessary policy changes needed for the delivery of the IVT commitments, it is expected that using such an alternate arrangement could take around five years to achieve.

Accordingly:

- The current arrangement can continue without delay.
- The proposed enhanced arrangement could be implemented within 5 years, subject to an alternate means of delivering Goulburn IVT being available.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water (including conveyance losses)

The additional capacity of the four Murray Valley outfalls to lower Broken Creek is 110 ML/d. Over the 100-day summer period from January to April, this equates to a delivery volume of 11 GL.

GMW apply a loss provision of 10% to water supplied from the GMID to the Lower Broken Creek via these outfalls. The same loss rate would be applied to additional deliveries. The conveyance loss over summer for this option is therefore estimated to be 1.1 GL/yr.

Relative to the conveyance losses of 86 GL along the River Murray via the Barmah-Millewa Reach (to the Broken Creek confluence), these losses of 1.1 GL/yr represent an incremental loss of 1% relative to existing conveyance losses. As such, this has been categorised as no or very small change expected, with a multi-criteria analysis score of 0.

MCA2: change in State water shares

There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach

If implemented, this option would allow an additional 110 ML/day to be delivered through the MVIA rather than the Barmah-Millewa Reach over the summer period. This option will provide a small decrease in risk as magnitude of flows through the reach will be relatively minor.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach

If implemented, this option would not alter the flow regime in Lower Broken Creek, as any alternate delivery of Goulburn IVT commitments in the creek would be replaced by an equivalent increase in bypass flows. While there would be additional flexibility and potential variability in flows, assuming that the additional capacity is used to consistently deliver bypass flows, there is no change to the risk of preferred environmental flow regimes outside of the Reach.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach

This option would only marginally reduce flow volumes and therefore the potential for sediment accumulation in the Barmah-Millewa Reach. This would not be expected to result in any material change.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves minor construction works in locations with previous disturbance. Therefore, there are no adverse or positive environmental outcomes expected through implementing the option, outside of those already considered as part of changes to the environmental flow regimes assessed in MCA3 and MCA4.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
This option would contribute a relatively small increase in system capacity. Whilst this additional capacity would assist river operators and help to offset the ongoing reduction in the reach, relative to other options being considered, this option provides a relatively low contribution to managing shortfall events.

There is a low confidence that this additional capacity would be achievable and consistently available, noting the reliance on the Lower Broken Creek flow regime and IVT deliveries.

MCA9: social impacts
Works to increase the outfall capacities would involve construction activities on a very limited number (< 10) of private properties, with most work occurring within existing easement and areas of previous disturbance. The works would not be constructing any new channel sections not already in place and therefore the risk of changing any overland flow paths is considered negligible. Accordingly, the social outcomes from this option are considered neutral.

Summary of MCA outcomes
Table 36 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 36. Multi-criteria assessment outcomes for the Murray Valley Outfall Enhancement option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	0	0.0
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	0	0.0
Social risk	**MCA9** – Risk of social impacts	0	0.0
	TOTAL WEIGHTED SCORING		**0.5**

Option assessment part 3: qualitative assessment
This option offers limited potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides limited capacity to address system shortfall and has limited capability to improve the flexibility of system operations. By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide a slight opportunity for a more flow variability through the reach.
- This option relies on access to surplus capacity in the Murray Valley Irrigation Area network. In dry seasons with high water availability, there may be limited spare capacity available in the MVIA over peak summer periods, which limits the ability of this options to regularly support improved resilience of overall system operations. It does, however, offer some additional flexibility in years when access is possible.
- This supply route is currently regularly used for transfers around the reach, so suitable water accounting arrangements are already available.

Option assessment part 4: financial cost
A cost estimate to implement the option has been detailed as part of the Victorian options report.

A summary of the expected capital and operations and maintenance costs (in net present value) is provided in **Table 37** below.

Table 37 Murray Valley outfalls cost estimate summary

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	**Infrastructure cost**				**1,188,700**
1.1	MV 6 main outfall (MV 1143				493,900
1.2	MV 26A/6 outfall (MV 1122, 'Flanners')				148,000
1.3	MV 21A/6 outfall (MV 1099, 'Jewells')				248,800
1.4	MV 15/6 outfall (MV 1033)				298,000
2	**Program Management, survey, design, approvals, and overheads**				**242,685**
2.1	Program management and overheads				178,305
2.2	Survey, design, and approvals				118,870
3	**Contingency**				**594,350**
	Total capital cost				**2,080,225**
4	**Operations and maintenance (NPV, assessed over 50 years)**				**1,355,985**
4.1	Additional maintenance and renewal costs as a result of upgrade works				574,173
4.2	GMID Infrastructure Use Fee (based on delivering 110 ML/day over 100 days)				781,812

Assessment Summary

Table 38 summarises the key outcomes for this option based on the assessment.

Table 38. Assessment summary of the Murray Valley irrigation outfalls option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	Nil
Contribution to mitigating system shortfall events	+ 110 ML/day
Confidence that flow capacity is achievable	Low
Part 1: Implementation readiness	**5 years**
Part 2: MCA scoring	
Water availability	0.0
Environmental conditions	0.5
Delivery risk	0.0
River communities and Traditional Owners	0.0
Total MCA score	**0.5**
Part 3: Qualitative assessment of non-scored elements	
Part 4: Cost effectiveness	
Capital cost	$2.1M
Operational cost (50 years)	$1.4M
Total cost (capital + operational) / bypass capacity	**$31k / ML / 100-day capacity**

* additional capacity subject to equivalent reduction of IVT deliveries in the Lower Broken Creek

3.11 Option 5C – Victorian Options – Barmah bypass gravity channel

Description of the option

This option considers constructing a 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 several existing channels in this area which are used by GMW to supply customers in the Murray Valley Irrigation Area (MVIA). Constructing a large channel along the alignment of an existing channel would likely be more practical than a new alignment. This recognises that the existing MVIA channels occupy a significant area of land already, and as such there would be less impact on adjacent landholders.

None of the existing channels in the MVIA discharge directly to the River Murray. There are several channels in the MVIA which discharge to the Lower Broken Creek, which in turn reconnects to the River Murray. The enhanced use of these outfalls is considered as a separate option in this report.

Of the existing channels in the MVIA, the MV 5 and MV 9/6 channels are closest to the River Murray. Both channels have a similar length between their location and the River Murray (around 15km), have similar design capacities, and are around 100km in channel length from the Yarrawonga Main Channel (YMC) offtake structure to the end of the channel. For the purposes of this exercise, the MV 5 alignment was selected as the indicative alignment for investigation. 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 link to the River Murray, which generally follows the road alignment (Figure 26). Further detail on the description of this option is available in the BMFS: Victorian Options Investigation Report[85].

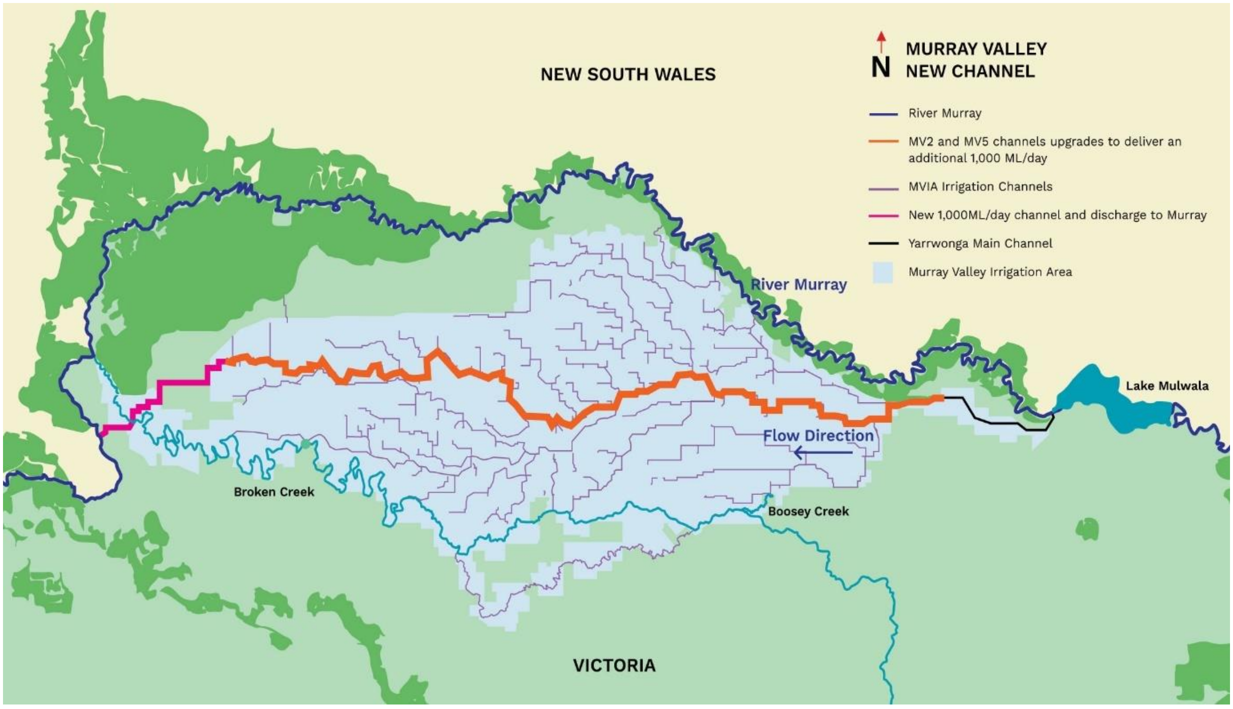


Figure 26. *Location and concept map for the Barmah-Millewa bypass gravity channel*

[85] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation.*

Scoping and flow capacity

The preliminary engineering review completed to support this option for the feasibility study is detailed in the Victorian options report[86]. Initial investigations and consultation with Goulburn-Murray Water (GMW) indicated that, based on demand in recent years and long-term trends in the GMID, there is significant available capacity in the Yarrawonga Main Channel (YMC) and MV 2 channels. These are large channels with significant infrastructure. Accordingly, for the purpose of this feasibility study, the flow rate for this bypass option was determined by utilising this available spare capacity. The assumption that this available capacity would be accessed for the purpose of this option should be explored in more detail and confirmed if this option proceeds to the next stage of development.

GMW provided capacity and flow data for the MV 1B regulator, which is on the YMC. 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. 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, a target flow of 1,000 ML/day was adopted for this option.

The indicative design capacity required to support the current customer demands and to supply an additional 1,000 ML/day through the YMC, MV 2 and MV 5 channels was determined by reviewing the current system capacity and recent demand patterns. Maximum average daily demands over summer were used as a basis for the current requirements, with 1,000 ML/day additional capacity required.

The indicative scope of work required to achieve this are provided in **Table 39.**

Table 39. 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

[86] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation*

Scoping & Assessment Part 1: Implementation Timeframe

This option contemplates the replacement of approximately 70km of channel with a significantly increased capacity as well as the construction of approximately 20km of large channel. 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 and other structures.

Construction of the project would require the channels to be shut down while works are undertaken. The MV 2 and 5 channels supply hundreds of customers on the main channels and spurs. Accordingly, most of the work would need to be undertaken during the 12-week winter maintenance shutdown periods.

Due to the scale of the upgrades required, it is expected that approximately five shutdown periods would be required to complete the full project. Allowing for 2-3 years in planning and 3-5 years in delivery, this accounts for a delivery timeframe of around 5-8 years from project inception.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water (including conveyance losses)

The additional capacity to be provided by this option is 1,000 ML/d along 70 km of existing channel and 20 km of new channel. Over the 100-day summer period from January to April, this equates to a delivery volume of 100 GL.

GMW apply a loss provision of 10% to water supplied from the GMID. The same loss rate would be applied to these additional deliveries.

The conveyance loss over summer for this option is therefore estimated to be 10 GL/yr. Relative to the conveyance losses of 86 GL along the River Murray via the Barmah-Millewa Reach (to the Broken Creek confluence), these losses of 10 GL/yr represent an incremental loss of 12% relative to existing conveyance losses.

As such, this has been categorised as a small increase in losses expected, with a multi-criteria analysis score of -10.

MCA2: change in State water shares

There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach

This option is expected to provide a significant decrease in the environmental risk as a result of the flow regime in the Barmah-Millewa Reach.

The option allows significant flows to be delivered through the bypass channel, which in turn will reduce pressure on the Barmah-Millewa Reach, reducing instances of inappropriate forest inundation and promote drying of wetlands within the forest. The option will also enable managers to restore short-term variations in flow, which influence ecosystem functions including patterns of productivity, nutrient and organic matter cycling.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach

The option provides limited ability to deliver environmental flow regimes outside of the Barmah-Millewa Reach, as the option returns flows back to the River Murray near the Barmah township.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach

This option would be expected to reduce the flow volumes being delivered through the Barmah-Millewa Reach, in turn providing a minor beneficial outcome for sediment dynamics in the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option requires the construction of a siphon under the Lower Broken Creek and a major discharge structure on the banks of the River Murray. These works have significant ecological considerations which will need to be addressed through the project development, ecological investigations, and regulatory approval applications.

Construction in these environmentally sensitive areas presents a significant risk which would need to be managed.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
Due to the travel time between Lake Hume to the lower Murray and using this route, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
This option would provide a substantial contribution to mitigating system shortfalls by increasing the capacity to transfer water from Lake Hume to the lower Murray by up to 1,000 ML/day.

This option would involve a purpose-built channel being constructed, and therefore there is a high confidence that the option would be consistently and reliably available for supporting the BMFS objectives.

MCA9: social impact
An assessment has been undertaken to estimate the number of private properties impacted by the Barmah bypass gravity channel upgrade construction footprint. The primary data source used in the assessment is the Victorian Land Use Information System (VLUIS) 2016/17 dataset created by the Department of Economic Development, Jobs, Transport, and Resources. This dataset identifies individual cadastral parcels and properties with information on land tenure and land use.

A GIS analysis have been undertaken using a notional alignment for the MV channel and an assumed 80 m construction footprint parallel to the channel alignment. The notional alignment and construction footprint was overlaid on the land use data to identify impacted properties. Public land and water authority held land was excluded from the analysis.

A summary dataset was then produced containing a list of the number of properties by land use type. In total it is estimated that 175 properties will be impacted by the construction footprint of the Barmah bypass channel as shown in Table 40.

Table 40. Approximate number of properties impacted by the construction of the Barmah bypass gravity channel option

Land Use Description	Number of properties affected
Bulk Grain Storage (structures)	1
Detached Home	4
Domestic Livestock Grazing	4
General Cropping (generally more than 20 ha plantings)	3
Government School	1
Gravel/Stone	1
Horse Stud / Training Facilities/Stables	3
Livestock Production – Beef Cattle	14
Livestock Production – Dairy Cattle	53
Livestock Production – Sheep	14
Mixed Farming and Grazing	1
Mixed farming and grazing (generally more than 20 ha)	4
Native Vegetation	1
Orchards, Groves and Plantations	8
Piggery	1
Residential Land	1
Residential Rural / Rural Lifestyle (0.4 to 20 Hectares)	30
Sand	1
Specialised Cropping	22
Transport – Road Systems	1
Vacant Residential Rural / Rural Lifestyle (0.4 to 20 Hectares)	6
Vineyard	1
TOTAL	175

The Barmah bypass gravity channel option involves constructing a larger channel along the existing alignment of the MVIA channels with an approximate 19km section of new channel required to allow discharge to the River Murray. The construction of above-ground channel banks to support this section of new channel may affect localised overland flow paths. This would need to be appropriately considered in next stages of development.

The channel extension may provide an opportunity for new customers to access the channel system, for D&S services as an example.

Considering the above, the social impact of this option is considered significant in the short-term and moderate in the longer term, noting that landholders would be fully compensated for the expanded infrastructure footprints on their property. These matters would be key considerations if this option were to proceed to further investigation.

Summary of MCA outcomes

Table 41 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 41. Multi-criteria assessment outcomes for the Barmah bypass channel option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	**MCA1** – Change in system water (e.g. arising from conveyance and evaporative losses)	-10	-1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	**MCA3** – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	20	1.0
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	0	0.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	10	0.5
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	-20	-1.0
Delivery risk	**MCA7** – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	**MCA9** – Risk of social impacts	-10	-0.5
	TOTAL WEIGHTED SCORING		**3.8**

Option assessment part 3: qualitative assessment

This option offers significant potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides limited capacity to address delivery shortfall and has limited capability to improve the flexibility of system operations. By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide a slight opportunity for a more flow variability through the reach.
- MVIA infrastructure is currently regularly used for transfers around the Barmah-Millewa Reach, so suitable water accounting arrangements are already available.
- It is likely that the discharge point from this option back the River Murray would require approval by the Ministerial Council as a recognised outfall for water accounting under the provisions of clause 108 of the MDB Agreement. However, this is achievable.

Option assessment part 4: financial cost

A cost estimate to implement the option has been detailed as part of the Victorian options report. A summary of the expected capital and operations and maintenance costs (in net present value) is provided in **Table 42** below.

Table 42. 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
1.2	Meter outlets				6,000,186
1.3	Regulators				86,600,000
1.4	Road crossings & structures				106,000,000
2	**Program Management, survey, design, approvals, and overheads**				**133,377,699**
2.1	Program management and overheads				59,278,977
2.2	Survey, design, and approvals				74,098,722
3	**Contingency**				**171,909,034**
	Total capital cost				**601,681,620**
4	**O&M (NPV, assessed over 50 years)**				**173,180,492**
4.1	Additional maintenance and renewal costs as a result of upgrade works				166,073,108
4.2	GMID Infrastructure Use Fee (based on delivering 1,000 ML/day over 100 days				7,107,384

Assessment summary

Table 43 summarises the key outcomes for this option based on the assessment.

Table 43. Assessment summary of the Barmah bypass gravity channel option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	1,000 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	**5 - 8 years**
Part 2: MCA scoring	
Water availability	-1.3
Environmental conditions	0.5
Delivery risk	5.0
River communities and Traditional Owners	-0.5
Total MCA score	**3.8**
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$602M
Operational cost (50 years)	$173M
Total cost (capital + operational) / bypass capacity	$775k / ML / 100-day capacity

3.12 Option 5D – Victorian Options – Rochester 14 bypass channel

Description of the option

This option considers creating an alternative delivery pathway for the delivery of Goulburn commitments to the River Murray. This alternate pathway could be used during summer, when pressure on the Barmah-Millewa Reach is greatest and there is the highest risk of delivery shortfalls in the lower Murray (i.e., over summer).

An upgraded channel along the alignment of the existing Rochester 14 (RO 14) alignment has been selected as a potential option for assessment as:

- there is existing infrastructure and capacity available to deliver high volumes of water from storages to the channel offtake.
- the RO 14 channel provides one of the shortest routes available in the GMID between major backbone channels, such as the Western Waranga Channel (WWC), and the River Murray (approximately 25km).
- there are existing channels and easements in place for a majority of the length between the offtake and the River Murray, meaning that works to increase the channel capacity would have significantly less impact on landholders than constructing an entirely new channel or extending another channel.

Figure 27 shows the location of the proposed Rochester 14 bypass channel relative to the Waranga Basin and the Western Waranga Channel (labelled as Waranga Main Channel).

Further detail on the description of this option is available in the BMFS: Victorian Options Investigation Report[87].

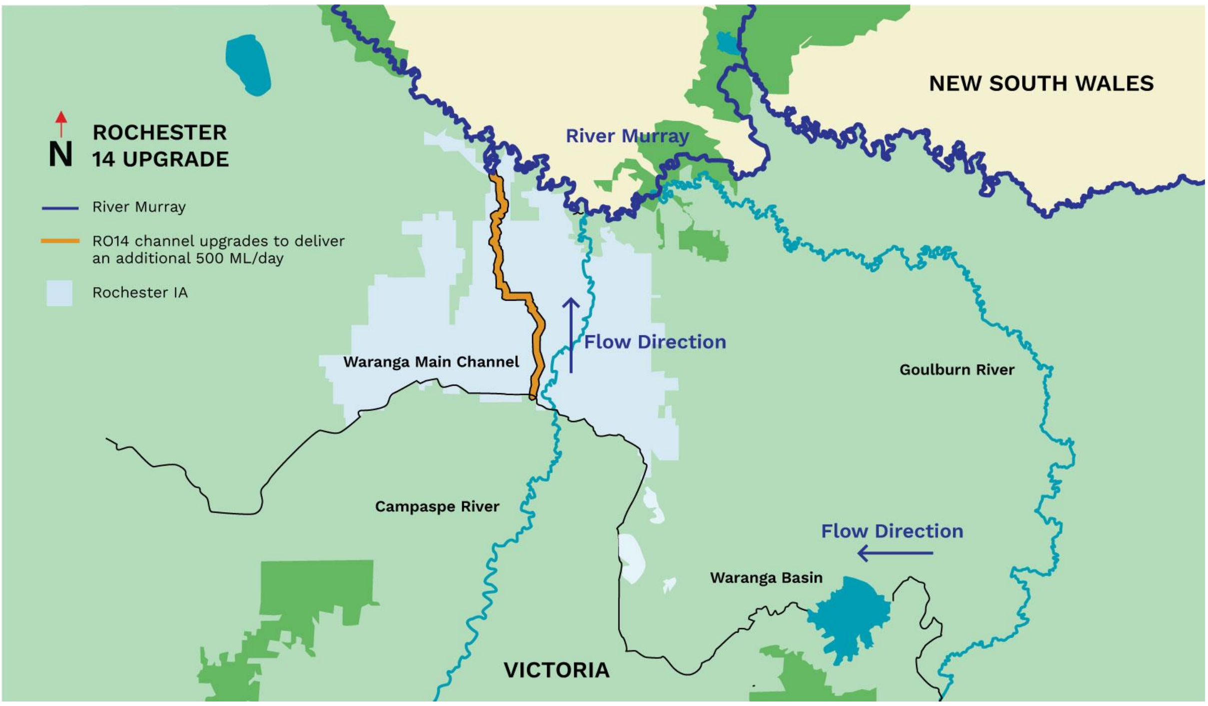


Figure 27. *Location of the Waranga Basin, Western Waranga Channel, and the proposed bypass channel.*

[87] Alluvium (2022), *Barmah-Millewa Feasibility Study – Technical Report: Victorian Options Investigation.*

Scoping and flow capacity

Initial investigations and consultation with Goulburn-Murray Water (GMW) indicated that the opportunity to deliver additional flows to the River Murray using this option would be limited by the capacity of existing structures on the WWC and existing system demands.

GMW provided capacity and flow data for all structures on the WWC between Waranga Basin and the RO 14 offtake channel, including the Campaspe River siphon and five regulators.

Analysis of the demand patterns during the 2021-22 water year over summer indicates that there is spare capacity in the system which could reliably provide for delivering an additional 500 ML/day flows for this option.

The indicative design capacity required to support the current customer demands and to supply an additional 500 ML/day through the RO 14 system was determined by reviewing the current system capacity and recent demand patterns. Maximum average daily demands over summer were used as a basis for the current requirements, with 500 ML/day additional capacity required.

This analysis determined that, generally, the upper ~11km of the channel would need to deliver an additional 350–400 ML/day, ~16km to deliver an additional 400-450 ML/day, and the pipeline would need to be replaced with a channel which can deliver 500-535ML/day.

Increasing the capacity to achieve these additional flows requires all existing channel on the RO 14 main to be re-constructed, the pipeline to be replaced with a channel, and all existing structures re-configured or installed as new. The indicative scope of work required to achieve this are provided in **Table 44.**

Table 44. Indicative quantities of work required to increase the RO14 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

The engineering and ecological investigations have determined that:

- The capacity to deliver flows to the River Murray through the RO 14 option would be limited by the existing capacity of infrastructure on the WWC and the existing demand patterns. Based on preliminary analysis, it is likely that a consistent flow of around 500 ML/day could be delivered over summer.
- There are no significant risks in ecological flow tolerances associated with this option. Transfers between Lake Eildon and Waranga Basin are required to deliver these flows, however, these would be achievable within current and accepted ecological flow tolerances on the mid-Goulburn.

For the purposes of the option assessment, it is assumed that 500 ML/day can be delivered using this option. The option would provide this capacity throughout the irrigation season.

Scoping & Assessment Part 1: Implementation Timeframe
This option contemplates the replacement of approximately 40km of channel and pipeline with a channel of significantly increased capacity. This would require almost every asset on the existing channel and pipeline to be replaced or relocated, including approximately 124 irrigation outlets, 129 D&S services, 42 regulators and 42 bridges and other structures.

Construction of the project would require the channel to be shutdown while works are undertaken. The RO14 channel supplies a significant number of customers on the main channel and spurs. Accordingly, most of the work would need to be undertaken during the 12-week winter maintenance shutdown periods.

Due to the scale of the upgrades required, it is expected that approximately three shutdown periods would be required to complete the full project. Allowing for two years in planning and three years in delivery, this accounts for a delivery timeframe of around 5 years from project inception.

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water (including conveyance losses)
The additional capacity to be provided by this option is 500 ML/d along an upgraded channel from the Waranga Western Channel at Rochester to the River Murray, ~25 km to the north. Over the 100-day summer period from January to April, this equates to a delivery volume of 50 GL.

GMW apply a loss provision of 10% to water supplied from the GMID. The same loss rate would be applied to these additional deliveries.

The conveyance loss over summer for this option is therefore estimated to be 5 GL/yr. Relative to the conveyance losses of 104 GL along the River Murray via the Barmah-Millewa Reach (to downstream of the Campaspe River), these losses of 5 GL/yr represent an incremental loss of < 5% relative to existing conveyance losses.

As such, this has been categorised as a small increase in losses expected, with a multi-criteria analysis score of -10.

MCA2: change in State water shares
There would be no change to harvesting abilities, the capability to store and release water, or change in the probability (or frequency) of spills. Therefore, this arrangement would not affect any State water shares.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
This option is expected to provide a significant decrease in the environmental risk as a result of the flow regime in the Barmah-Millewa Reach.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
This option provides an opportunity to deliver Goulburn IVT commitments to the River Murray through an alternate route rather than using the lower Goulburn River, the Lower Broken Creek and the Campaspe River.

This option seeks to concentrate IVT deliveries in the summer period which would assist in managing shortfall risks. In turn, this option would likely result in increased flow volumes being delivered through the mid-Goulburn over summer, depending on the use of Waranga Basin. Initial advice is that this would be ecologically tolerable, noting that summer flows in the mid-Goulburn in recent historical period are significantly lower than previous.

Accordingly, this option provides a significant opportunity to reduce pressure on natural carriers, which will result in a relatively significant decrease in risk to the preferred environmental flow regime in these reaches.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option does not alter the flow regime or sediment transport capacity of the Barmah-Millewa Reach and therefore has no impact on the risks to sediment accumulation within the Barmah-Millewa Reach compared to base case conditions.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option involves construction of a major discharge structure on the banks of the River Murray, an ecologically sensitive area. This presents some minor risk to ecological harm.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
For this option to respond to a potential delivery shortfall event in the lower Murray, water would need to be transferred from the Waranga Basin to the River Murray via the WWC and RO 14 channel, then via the River Murray near Echuca to the lower Murray.

The travel time from Torrumbarry to the Mildura Weir is more than 10 days[88]. Accordingly, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
Moderate contribution to mitigating system shortfalls. Allowing Goulburn IVT contributions to the Murray to be concentrated by up to 500 ML/day additional over summer would allow an additional 500 ML/day to be delivered to the lower Murray through the connected system.

This option would involve a purpose-built channel being constructed, and therefore there is a high confidence that the option would be consistently and reliably available for supporting the BMFS objectives.

MCA9: social impact
An assessment has been undertaken to estimate the number of private properties impacted by the RO 14 channel upgrade construction footprint. The primary data source used in the assessment is the Victorian Land Use Information System (VLUIS) 2016/17 dataset created by the Department of Economic Development, Jobs, Transport, and Resources. This dataset identifies individual cadastral parcels and properties with information on land tenure and land use.

A GIS analysis have been undertaken using a notional alignment for the RO 14 channel and an assumed 70 m construction footprint parallel to the channel alignment. The notional alignment and construction footprint was overlaid on the land use data to identify impacted properties. Public land and water authority held land was excluded from the analysis.

A summary dataset was then produced containing a list of the number of properties by land use type. In total it is estimated that 88 properties will be impacted by the construction footprint of the RO 14 channel upgrade as shown in Table 45.

Table 45. Approximate number of properties impacted by the construction of the RO 14 option

Land Use Description	Number of properties affected
Domestic Livestock Grazing	2
Fire Station Facility	2
General Cropping (generally more than 20 ha plantings)	30
Livestock Production - Beef Cattle	2
Livestock Production - Dairy Cattle	14
Livestock Production - Sheep	2
Mixed Farming and Grazing	3
Mixed farming and grazing (generally more than 20 ha)	2
Residential Rural / Rural Lifestyle (0.4 to 20 Hectares)	31
Specialised Cropping	2
TOTAL	88

[88] MDBA (2016), *Source Model for the Murray and Lower Darling System. Technical Report No. 2015/03, Version 2.*

The RO 14 option involves constructing a larger channel along the existing alignment of the channel and the previous alignment of the channel where a pipeline is now installed. The only section of new channel proposed is a 0.75km section linking the end of the alignment to the River Murray. Accordingly, it is not expected that constructing this option would have an adverse effect on localised overland flow paths.

However, the replacement of a relatively new pumped pipeline will have a potentially adverse impact on affected landholders. The need for replacing the pump station and pipeline should be investigated as part of any subsequent stages in developing this option.

Considering the above, the social impact of this option is considered significant, based on the high number of affected local landholders and the social perception of replacing newly constructed infrastructure (pump station and pipeline). These matters would be key considerations if this option were to proceed to further investigation.

Summary of MCA outcomes
Table 46 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 46. Multi-criteria assessment outcomes

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	MCA1 – Change in system water (e.g. arising from conveyance and evaporative losses)	-10	-1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	0	0.0
Environmental condition	MCA3 – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	20	1.0
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	20	1.0
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	0	0.0
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	-10	-0.5
Delivery risk	MCA7 – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	MCA9 – Risk of social impacts	-20	-1.0
	TOTAL WEIGHTED SCORING		4.3

Option assessment part 3: qualitative assessment

This option offers some potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- This option provides limited capacity to address delivery shortfall and has limited capability to improve the flexibility of system operations. By taking some pressure off flows through the Barmah-Millewa Reach, this option would provide a slight opportunity for a more flow variability through the reach.
- Suitable water accounting arrangements are already available for delivery of IVT and for outfalls from channel systems.
- It is likely that the discharge point from this option back the River Murray would require approval by the Ministerial Council as a recognised outfall for water accounting under the provisions of clause 108 of the MDB Agreement. However, this is achievable.

Option assessment part 4: financial cost

A cost estimate to implement the option has been detailed as part of the Victorian options report. A summary of the expected capital and operations and maintenance costs (in net present value) is provided in **Table 47** below.

Table 47. Rochester 14 bypass channel cost estimate summary

Item	Asset Type	Qty	Rate	UoM	Total ($)
1	**Infrastructure cost**				**87,452,880**
1.1	Channel works				29,533,880
1.2	Meter outlets				6,054,000
1.3	Regulators				25,990,000
1.4	Road crossings & structures				25,000,000
1.5	Land transactions				875,000
2	**Program Management, survey, design, approvals, and overheads**				**30,683,487**
2.1	Program management and overheads				15,304,254
2.2	Survey, design, and approvals				15,304,254
3	**Contingency**				**47,224,555**
	Total capital cost				**165,285,943**
4	**O&M (NPV, assessed over 50 years)**				**49,286,834**
4.1	Additional maintenance and renewal costs as a result of upgrade works				45,733,142
4.2	GMID Infrastructure Use Fee (based on delivering 500 ML/day over 100 days)				3,553,692

Assessment summary

Table 48 summarises the key outcomes for this option based on the assessment.

Table 48. Assessment summary of the Rochester 14 bypass channel option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	500 ML/day
Confidence that option is accessible	High
Part 1: Implementation readiness	**5 years**
Part 2: MCA scoring	
Water availability	-1.3
Environmental conditions	1.5
Delivery risk	5.0
River communities and Traditional Owners	-1.0
Total MCA score	**4.2**
Part 3: Qualitative assessment of non-scored elements	✓
Part 4: Cost effectiveness	
Capital cost	$165 M
Operational cost (50 years)	$49 M
Total cost (capital + operational) / bypass capacity	**$430k / ML / 100-day capacity**

3.13 Option 6 – Snowy Transfers

Description of the option

This option proposes the use of the Snowy Hydro system to transfer some River Murray releases that would normally be delivered upstream of Hume Dam instead to the Murrumbidgee River for delivery back to the River Murray, near Euston. Using this option would reduce the need to supply regulated water through the capacity restricted Barmah-Millewa Reach. Murrumbidgee releases from the Snowy Hydro system can either be made via the Tumut River or the Upper Murrumbidgee River, as shown in **Figure 28**.

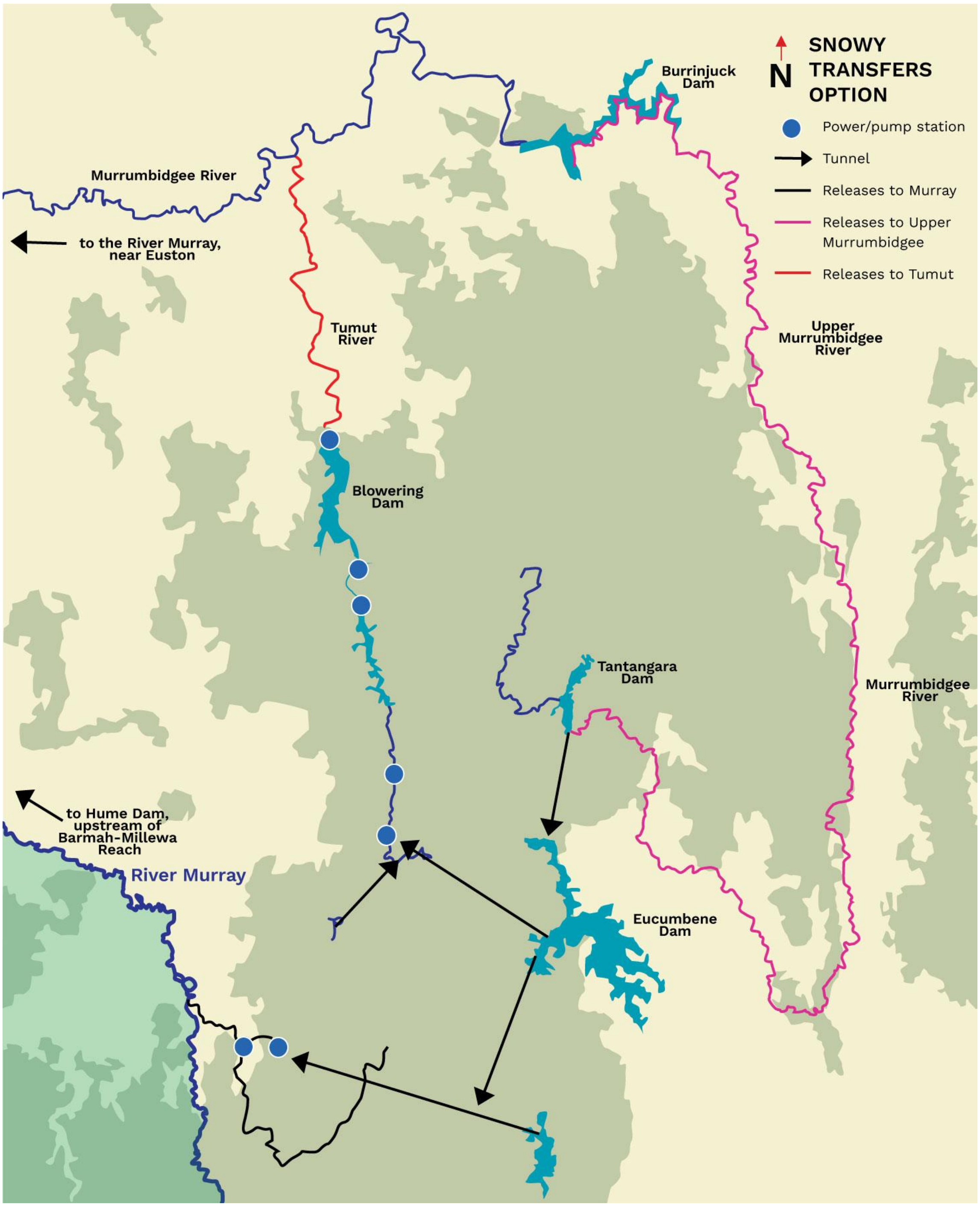


Figure 28. *Key features of the Snowy Scheme, with the routes for releases to the Murray, the Upper Murrumbidgee, and the Tumur River highlighted*

Snowy Scheme
The Snowy Scheme is a hydroelectric generation scheme located in the upper catchments of the Murray, Murrumbidgee and Snowy Rivers. The scheme harvests water from the upper catchments into dams and generates electricity by releasing water through power turbines into the Murray and Murrumbidgee Rivers or tributaries of these rivers.

The scheme is divided into two power generation systems:

- Snowy-Murray Development, which generates power from flows primarily released into the Murray catchment; and
- Snowy-Tumut Development, which releases flows into the Murrumbidgee catchment.

In both developments releases from the Snowy Scheme into the catchments are re-regulated in headworks and accounted for as water inflows to become a resource to supply downstream demands.

It is physically possible to release water from the Snowy Scheme directly from Tantangara Dam into the upper Murrumbidgee River where water could be re-regulated in Burrinjuck Dam. However, Tantangara Dam has no power generation capability, and therefore making releases from the storage directly into the Murrumbidgee River would reduce power generation from the scheme.

Snowy Water Licence
The Snowy Scheme is operated by Snowy Hydro Limited (SHL). Snowy Hydro is a Commonwealth government business enterprise under the Corporations Act and operates on a strictly commercial basis[89].

The Corporation is subject to NSW state legislation including the Snowy Hydro Corporatisation Act and the Snowy Water Licence. The Snowy Water Licence sets out the rights and obligations on Snowy Hydro Limited for the collection, storage and release of water within the Snowy Scheme's area of operation.

Required Annual Releases
Flow releases to the catchments from the Snowy Scheme are governed by the Snowy Water Licence issued to SHL by the NSW Government. The licence obliges SHL to supply annual water release targets - Required Annual Release (RAR) - for each of the Murray and Murrumbidgee catchments. RARs are nominally set at 1,062 GL per year in the River Murray and 1,026 GL in the Murrumbidgee.

Inter-valley connections within the Snowy Scheme
Lake Eucumbene, the largest storage in the Snowy Scheme, and Tantangara Reservoir store water for both the Snowy-Murray and Snowy-Tumut Developments and are physically interlinked through tunnels, as illustrated in Figure 28.

This physical connection allows Snowy Scheme RARs to be varied by increasing the annual RAR to one catchment (or valley) and undertaking a corresponding reduction in the RAR to the other valley, thus facilitating inter-valley transfers between the Murray and Murrumbidgee. These inter-valley transfers are possible in either direction.

Inter-valley transfers
A mechanism exists in the Snowy Water Licence to undertake inter-valley transfers between the Murray and Murrumbidgee systems. Clause 9 of Schedule 4 to the Snowy Water Licence sets out a process for inter-valley water transfers including:

- Cl 9.2 - the NSW Minister may request the Water Consultation and Liaison Committee[90] to consider a transfer.

[89] https://www.snowyhydro.com.au/about/our-company
[90] Constituted under the Snowy Water Inquiry Outcomes Implementation Deed, this is the primary forum for operational consultation between Snowy Hydro Limited and NSW, Victoria, and the MDBA.

- **Cl 9.3** – the Water Consultation and Liaison Committee must be given reasonable opportunity to consider a proposal.
- **Cl 9.4** – Snowy Hydro Limited must operate the scheme to effect the transfer, unless it cannot be done for operational or practical reasons.

The Snowy Water Licence requires that variations to the water release requirements can only be made without the agreement of Snowy Hydro Limited following determinations by separate independent experts on the "water management and resource impacts", and the financial impact upon Snowy Hydro Limited, and payment of any compensation to Snowy Hydro Limited for the financial impact. This mechanism is infrequently used and it was not envisaged that there would be standing arrangements in one direction (Murray to Murrumbidgee for this feasibility investigation) applying each year.

Snowy Scheme Annual Water Operating Plan

Snowy Hydro prepares an annual water operating plan for the scheme before the commencement of each year which provides certainty for SHL in terms of its obligations to release water. The operating plan sets out:

- the target RAR for the coming water year and the range of forecast water releases on a quarterly basis. SHL operates to ensure the RAR is met by 30 April each year.
- the volumes of inter-valley transfers. This means the volume of inter-valley transfer for the upcoming water year in the River Murray (June -May) would be expected to be set in February and remain unchanged during the course of the year.

Aside from the quarterly forecasts of water releases, SHL does not have specific requirements regarding the pattern or timing of RAR releases during the water year. The corporation operates to maximise electricity generation opportunities while meeting its water release obligations.

Murray-Darling Basin Agreement

The Murray-Darling Basin Agreement (the Agreement) between the basin states and the Commonwealth government includes:

- provisions for accounting of inflows from tributary rivers (including the Murrumbidgee River) to the River Murray, and
- a schedule (Schedule F) that sets out agreed arrangements for sharing water from the Snowy Scheme.

The Agreement requires flows from the Murrumbidgee River into the River Murray to be accounted as a NSW resource. An intervalley transfer from the Murray to Murrumbidgee with delivery back into the Murray would need to be accounted as a shared resource, similarly to inflows into the River Murray from the Snowy Scheme.

Regulated Murrumbidgee Water Sharing Plan

Murray releases transferred to the Murrumbidgee would come under the jurisdiction of the NSW Water Management Act, Regulated Murrumbidgee Water Sharing Plan. The water sharing plan for the Murrumbidgee regulated river water source (the regulated WSP) includes Burrinjuck and Blowering Dams, and the Murrumbidgee and Tumut Rivers below the dams, and sets requirements for the management of the water captured and released by the dams.

There is currently no provision in the regulated WSP to recognise additional water released from the Snowy-Tumut development as a result of a transfer from the Murray development, and current arrangements would result in Murray inter-valley transfers being allocated to water access licences as set out in the regulated WSP.

Flow capacity

Annual intervalley transfer volume
The volume of inter-valley Murray to Murrumbidgee transfer required would vary from year to year, based on several inter-linked factors that include water availability, climatic conditions, tributary inflows downstream of the Barmah-Millewa Reach, and specific operational requirements such as transfers to Tar-Ru (Lake Victoria).

Initial investigations suggest that an annual intervalley transfer of 50 GL/yr (nominally 500 ML/day delivered over 100 days) would provide River Murray system river operators with a useful buffer to manage potential system shortfalls.

The following factors will likely influence the assessment of the overall feasibility and relative benefits and costs of different levels of intervalley transfer:

- Increased risks of Tumut River flooding, community, and environmental impacts.
- Increased risks of lower Murrumbidgee River environmental impacts.
- Snowy Hydro costs from foregone or changed electricity generation.

Tumut River Impacts
The Snowy-Tumut development releases water into Blowering Dam which is the largest of the two main storages supplying the Murrumbidgee regulated river system. Blowering Dam releases flows into the Tumut River, a tributary of the Murrumbidgee River (see Figure 28 for reference).

A factor to be considered in using the Tumut route to deliver Murray to Murrumbidgee inter-valley transfers is deliverability constraints in the Tumut River downstream of Blowering Dam. When most of the available water in the Murrumbidgee regulated river system is held in Blowering Dam (including assured releases from the Snowy Scheme), there can be difficulties delivering a high enough proportion of the available water through the Tumut River before the end of the summer irrigation season. This deliverability issue has, at times, required restrictions on the proportion of the water available that can be delivered by the end of the summer irrigation season.

Existing regulated flow releases from Blowering to the Tumut River also impact on the environmental values of the river and there has been landholder and community concern over the impacts of river regulation on public amenity, flooding, and recreation. Long periods of operating at channel capacity have caused erosion and water logging of nearby land, affected flow paths over time, and the rock-lining and other management measures have decreased the aesthetic value of the Tumut River.

Additional flows from Snowy Hydro inter-valley transfers delivered during the summer irrigation period would likely exacerbate capacity issues and Tumut River unless the delivery of transferred water was delayed or limited to avoid impacts to water delivery in the Murrumbidgee Valley. Whilst transfers may not increase flow-related impacts to the Tumut River back to past levels, it is likely to raise concerns from the local community.

Lower Murrumbidgee River Impacts
As with other regulated rivers in the Murray-Darling Basin, flow regulation has altered the natural flow regime in the Murrumbidgee River, increasing summer and autumn flows and decreasing average flows in winter and spring. The lower Murrumbidgee River floodplain, below Maude Weir to the confluence of the River Murray, is a key environmental asset within the Murray-Darling Basin.

Murray to Murrumbidgee inter-valley transfers will increase flows in the regulated Murrumbidgee River system, leading to higher-than-normal flows in the lower reaches. Environmentally damaging unseasonal summer flows in the lower reaches would potentially occur more often, and in conjunction with inter-valley transfers for water trade.

The potential impact of a long-term increase in summer flows in the lower Murrumbidgee River would need to be considered further. At present, it is not clear whether an increase in flows in the lower Murrumbidgee River of 500 ML/day (as proposed above) would result in increased environmental impacts, and whether these would be within tolerable limits.

Snowy Hydro Cost Impacts
The Snowy Water Licence requires that variations to the water release requirements can only be made without the agreement of Snowy Hydro Limited following determinations by separate independent experts on the "water management and resource impacts", and the financial impact upon Snowy Hydro Limited, and payment of any compensation to Snowy Hydro Limited for the financial impact.

The primary financial impact of intervalley transfers on Snowy Hydro arise from the location, timing and volume of releases, and the resultant opportunities that Snowy Hydro gains or losses in terms of revenue from electricity generation. The scale of potential costs from intervalley transfers is difficult to assess, noting the variables above. The involvement of Snowy Hydro Limited would be required to quantify the costs under a range of potential supply and volume scenarios.

From publicly available data it is known that:

- the Snowy Scheme generates a similar amount of energy per gigalitre via either the Snowy-Murray or Snowy-Tumut developments;
- hydroelectric plants like the Snowy Scheme typically operate as flexible or peaking plants, which tend to increase their output when market prices are high and reduce output when prices are low. Snowy Hydro has considerable discretion around the pattern and timing of RAR releases during the water year and if this flexibility was reduced by intervalley transfer obligations, it could impact the opportunity cost of the transfer;
- the Snowy-Murray development generates energy into the Victorian sector of the National Electricity Market (NEM), and the Snowy-Tumut development generates energy into the NSW sector of the NEM. Price differentials in the markets could impact on the opportunity costs of intervalley transfers; and
- if Murray to Murrumbidgee intervalley water were to be released from Tantangara dam to the Upper Murrumbidgee River, Snowy Hydro would completely forgo power generation for the water released, impacting the cost of the transfer.

From first principles, it would be reasonable to presume that higher volumes of intervalley transfer and higher degrees of flexibility required around the timing of releases would impact the revenue of the Corporation.

Arrangements to alter the long-term balance of releases from the Snowy-Murray to the Snowy-Tumut development may potentially also result in some internal transition costs relating to forward contracts, and other operational and maintenance arrangements over time.

Notice and flexibility
It is unlikely that the volume of Murray to Murrumbidgee inter-valley transfer required could be accurately estimated prior to the commencement of any water year. The volume of water required would increase and decrease through the year in response to the factors such as demand, tributary inflows, seasonal climate, etc.

The Snowy Water Licence requires that an annual water operating plan is prepared before the commencement of each year (the water year for the Snowy Scheme is May to April). To provide certainty for Snowy Hydro Limited, release requirements for each year are generally set at this time. Setting a volume of Murray to Murrumbidgee transfer at the beginning of each water year would require the MDBA to forecast the coming year's water availability. Forecasts early before the start of a water year would have significant uncertainty.

It may be possible to agree with Snowy Hydro to set an approximate volume of transfer or even to have water transferred on-demand during water year. Either of these arrangements would be more disruptive to Snowy Hydro Limited's electricity generation planning and commercial arrangements, and therefore likely to generate greater opportunity costs.

One possible arrangement that may prove practical is for the inter-valley transfer volume to be sourced from Murrumbidgee reserves and then paid back in the following year from inter-valley transfers. This arrangement would provide certainty to Snowy Hydro at beginning of the year around the volume of water to be transferred. This approach would need to be explored in more detail with WaterNSW to understand its feasibility and potential impacts on Murrumbidgee water users.

Scope

Options assessment and concept proposal
An initial options assessment would need to be undertaken to identify a preferred approach to inter-valley transfers, including confirming the likely volumes and callout flexibility, as well as identifying other institutional and administrative arrangements that would be required for implementation of the proposal. The preferred approach would then need to be further developed into a concept proposal and costing for discussion with key stakeholders.

Presentation to government stakeholders
The concept proposal would be presented to government stakeholders to gain an understanding of their appetite to support the proposal. Governmental support will be key to securing the funding for further developing the project and stakeholder support for negotiations with Snowy Hydro.

Preliminary negotiations with Snowy Hydro
The option would require agreement with SHL to make inter-valley transfers. It is anticipated that the MDBA and WaterNSW (on behalf of the joint venture) would enter negotiation with Snowy Hydro to determine the terms of agreement and the likely range of opportunity costs.

Water resource management and operational assessment
Broader consultation with Basin government agencies would be undertaken to identify the changes required to water management institutional, administrative, and operational arrangements, assess impacts and quantify responsibilities, costs, and timelines.

Business case preparation
Preparation of the business case for the proposed inter-valley transfer program for consideration by the Basin governments. The business case would set out the benefits and costs of the program and seek funding for its implementation.

Development of detailed arrangements
Based on agreed outcomes and approval of the business case, preparation of detailed agreements, administrative arrangements, and necessary statutory changes to implement the inter-valley transfer program.

Execution of agreements and program implementation
Approval and execution of agreements with Snowy Hydro. Implementation of all necessary statutory, administrative, and operational arrangements.

Option assessment part 1: implementation readiness

The key steps in developing and implementing this option are detailed in **Table 49** below. The infrastructure to support this option is existing and readily available. The timeframes to implement this option therefore could be relatively short, dependent entirely on the time required to obtain support and endorsement of the option from key Government stakeholders and Snowy Hydro.

Table 49. Expected key activities and timing for the Snowy option

No.	Activity	Description	Indicative Timeframe
1	Options assessment and concept proposal	An initial options assessment would need to be undertaken to identify a preferred approach to inter-valley transfers, including confirming the likely volumes and callout flexibility, as well as identifying other institutional and administrative arrangements that would be required for implementation of the proposal. This would likely include hydrological modelling of the system and initial consultation with affected stakeholders, including Snowy Hydro, Government agencies, and Murrumbidgee entitlement holders. The preferred approach would then be to be further developed into a concept proposal and costing for discussion with key stakeholders. The development of this concept proposal would leverage the work completed to date.	6 - 12 months
2	Presentation to Government stakeholders	The concept proposal would be presented to government stakeholders to gain an understanding of their appetite to support the proposal. Governmental support will be key to securing the funding for further developing the project and stakeholder support for negotiations with Snowy Hydro. This would require advice from Basin Officials Committee and consideration by the Ministerial Council.	6 – 12 months
3	Preliminary negotiations with Snowy Hydro	The option would require agreement with SHL to make inter-valley transfers. It is anticipated that the MDBA and WaterNSW would enter negotiation with Snowy Hydro to determine the terms of agreement and the likely range of opportunity costs.	6 - 12 months
4	Water resource management and operational assessment	Broader consultation with Basin government agencies would be undertaken to identify the changes required to water management institutional, administrative, and operational arrangements, assess impacts, and quantify responsibilities, costs, and timelines.	Concurrent with activity 3
5	Business case preparation	Preparation of the business case for the proposed inter-valley transfer program for consideration by the Basin governments. This would include detailed consultation and engagement with entitlement holders on the Murrumbidgee. Preliminary terms and conditions for the agreements would be developed and agreed in-principle by the relevant parties. The business case would set out the benefits and costs of the program and seek funding for its implementation. The business case would likely need some form of public consultation prior to consideration by the joint venture.	9 – 12 months
6	Development of detailed agreements	Based on agreed outcomes and approval of the business case, preparation of detailed agreements, administrative arrangements, and necessary statutory changes to implement the inter-valley transfer program. Depending on the requirements detailed through the above stages, the MDB Agreement may require revision.	3 – 6 months
7	Execution of agreements and program implementation	Approval and execution of agreements with Snowy Hydro. Implementation of all necessary statutory, administrative, and operational arrangements.	3 – 6 months
		TOTAL	**3 – 5 years**

Option assessment part 2: multi-criteria assessment against project objectives

MCA1: change in system water
For the purposes of this option assessment, the additional capacity to be provided by this option is assumed to be 500 ML/d of transfers from the Murrumbidgee River to the River Murray, with the transfers returning to the River Murray near Euston. Over the 100-day summer period from January to April, this equates to a delivery volume of 50 GL.

For environmental water deliveries through the lower Murrumbidgee, it is understood that a 14% deduction is taken to cover losses. Assuming that this same loss rate would be applied to these additional deliveries, the conveyance loss over summer for this option is therefore estimated to be 7 GL/yr. Relative to the conveyance losses of 200 GL along the River Murray via the Barmah-Millewa Reach (to the Murrumbidgee River confluence, notionally represented by the losses to Wakool Junction), these losses of 7 GL/yr represent an incremental loss of 4% relative to existing conveyance losses.

As such, this has been categorised as a small increase in losses expected, resulting in a multi-criteria analysis score of -10.

MCA2: change in State water shares
As noted in the project description, this option has the potential to give raise to a range of complex water sharing issues. Potential mitigations have been identified for most of the significant issues, but development of these mitigations will require detailed assessment and analysis to ensure there are no unintended consequences.

A key water sharing consideration is the increase in transfers through the Snowy-Tumut development will put more water into Murrumbidgee storages. There is potential that increasing transfers into these storages may lead to increased spill risks in some situations. This may impact water availability for Murrumbidgee entitlement holders, or if the spill is attributed to the Murray bypass component of water in store may reduce Murray water availability if that water can't be re-regulated or used downstream in the Murray.

While the risk of spills in the Murrumbidgee increases, there may be some decrease in the risk of spills in the Murray. There are complexities to this which would need to be further analysed.

If this option is only taken up in dry years, it may somewhat reduce the risk of large transfers into high storages, however if water is delivered to the Murray from Murrumbidgee reserves and then paid back in a subsequent year, the spill risk might be higher. This will need further detailed analysis.

MCA3: risk to preferred environmental flow regime through the Barmah-Millewa Reach
There will be a moderate decrease in risk to the preferred environmental flow regime in the Barmah-Millewa Reach as it will reduce pressure on reach in summer-autumn and possible unseasonal flooding in forest.

MCA4: risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach
There will be an increased risk to the preferred environmental flow regime in the Tumut River and the lower Murrumbidgee Rivers due to increased flows during the summer months. Quantifying this increased risk would require further investigation if this option were to proceed to future stages of development, however, for this assessment, it is assessed as having minor to moderate increase in risk.

MCA5: risk to sediment accumulation in the Barmah-Millewa Reach
This option would be expected to reduce the flow volumes being delivered through the Barmah-Millewa Reach, in turn providing a minor beneficial outcome for sediment transport into the reach.

MCA6: risk to environmental outcomes through the Southern Connected Basin
This option is unlikely to create any additional opportunity for enhanced environmental flow deliveries within the River Murray or to provide better environmental outcomes elsewhere through the SCB. Therefore, the outcomes are expected to be neutral.

MCA7: ability to enhance or maintain capacity to deliver peak demand delivery ('delivery shortfalls')
For this option to respond to a potential delivery shortfall event in the lower Murray, water would need to be transferred from the Blowering Dam in the upper Murrumbidgee to the River Murray.

The travel time would be longer than from Lake Hume. Accordingly, this option would not contribute to the ability for river operators to manage a potential delivery shortfall event.

MCA8: ability to enhance or maintain capacity to deliver demand throughout the season ('system shortfalls')
This option would provide a significant contribution for buffering capacity and mitigating system shortfalls. If delivery in the system is constrained at the Barmah-Millewa Reach, this option would allow an additional 500 ML/day (or more, by negotiation) to be delivered to the lower Murray through the connected system. This would be particularly of benefit for supporting Tar-Ru filling targets.

This option uses existing infrastructure and waterways which would be reliably available and leverages existing institutional arrangements. Access to the option is dependent on ongoing agreement from SHL to undertake the inter-valley transfer, which would need to be re-negotiated periodically. Additionally, the cost viability of using the option may change year-to-year depending on a range of considerations. Therefore, there is a medium confidence that the option would be available in any given year to support the BMFS objectives.

MCA9: social impact
It is expected that stakeholders may not support the delivery of higher unseasonal flows in the Tumut River and the lower Murrumbidgee River. Accordingly, there may be low to moderate social outcomes.

Summary of MCA outcomes
Table 50 provides a summary of the scoring and weighted outcomes for each of the MCA criteria.

Table 50. Multi-criteria assessment outcomes for the Snowy Hydro option

MCA Theme	MCA Criteria	MCA scoring	Weighted scoring
Water resource availability	MCA1 – Change in system water (e.g. arising from conveyance and evaporative losses)	-10	-1.3
	MCA2 – Change in state water shares e.g. arising from changed harvesting opportunity	-10	-1.3
Environmental condition	MCA3 – Risk to preferred environmental flow regimes through the Barmah-Millewa Reach	10	0.5
	MCA4 – Risk to preferred environmental flow regimes outside of the Barmah-Millewa Reach	-10	-0.5
	MCA5 – Risk to sediment accumulation in the Barmah-Millewa Reach	10	0.5
	MCA6 – Risk to environmental outcomes through the Southern Connected Basin	0	0.0
Delivery risk	MCA7 – Ability to enhance or maintain capacity to deliver peak demand delivery	0	0.0
	MCA8 – Ability to enhance or maintain capacity to deliver demand throughout the season	20	5.0
Social risk	MCA9 – Risk of social impacts	-10	-0.5
	TOTAL WEIGHTED SCORING		2.5

Option assessment part 3: qualitative assessment

This option offers some potential for improving the resilience and adaptability of system operations. Key aspects related to resilience and adaptability include:

- While there is no upfront capital cost for infrastructure, this option involves varying a range of complex licences and agreements that have significant financial implications for both water and power sector outcomes. The negotiations involved will therefore be complex and may be lengthy as identified in the discussion on implementation readiness.
- For sub-options involving releases from Tantangara to Burrinjuck Dam, flows will need to travel through unregulated sections of the NSW Murrumbidgee, and through the ACT before entering the regulated river system at Burrinjuck. Some consideration may need to be given to shepherding releases through these unregulated reaches in order to protect them from extraction by other water users. This may require changes to the unregulated Murrumbidgee River Water Sharing Plan and possibly ACT water legislation/regulations, which adds further complexity to establishment of this sub-option.
- Climate change is generating a range of uncertainties in both water and energy markets. Recent events have highlighted current volatility in energy markets, which may make it difficult for the parties to predict volumes and costs for delivering these transfer options in the short to medium term, especially until more stability and certainty is established in the energy market.
- Expansion of the Snowy scheme under the Snowy 2.0 project is also in progress, and it is unclear if this development will impact on the opportunities or costs to transfer Snowy-Murray development resources to the Snowy-Tumut development.
- Water accounting arrangements are not currently in place to cope with routine transfers of the scale that might be required under this option. Implementation of this option will involve development of new water accounting processes to cover accounting for water transfers within the Snowy system, volumes held in Blowering/Burrinjuck including any spill arrangements, and accounting for delivery through the Murrumbidgee including application of any loss provisions etc. The new accounting processes will also need to be incorporated into Snowy business systems, WaterNSW operational management and accounting systems (e.g. CARM river operations system) and incorporated into the River Murray accounts system.
- Management of Snowy transfers via the Murrumbidgee system will involve additional operational complexity for both WaterNSW operators in the Murrumbidgee and MDBA river operators in the Murray system, which may have resourcing implications.
- Given its operational complexity, it is likely that this option will not be able to be activated at short notice in any year. It will need to be factored into annual operations planning for the Snowy system, Murrumbidgee system and the Murray system, which will require collaborative planning and significant lead times.

Option assessment part 4: financial cost

As discussed above, the operational cost to deliver the option is dependent on several variables, including:

- the volume of the inter-valley transfer.
- the flexibility (or lack thereof) of the volume and timing for inter-valley transfers to be delivered in any given year.
- Snowy Hydro's commercial position within the electricity generating market.
- the split of any proposed flows to be delivered through the Tumut and Upper Murrumbidgee systems, noting that delivery through the Upper Murrumbidgee would incur significant cost to compensate foregone power generation.

These variables and the impact on the potential operational cost of this option can only be determined through further investigation of the option and through discussions with SHL.

The up-front cost to implement this option would include MDBA management resources and consultants as required to develop, negotiate, and implement the necessary arrangements. The options assessment and concept proposal may cost around $1 million to develop. The total program may cost in the range of $3 - 5 million to implement, including management and consultancy fees.

Assessment summary

Table 51 summarises the key outcomes for this option based on the assessment.

Table 51. Assessment summary of the Snowy Hydro option

Assessment category	Assessment Outcome
Contribution to BMFS flow objectives	
Contribution to mitigating delivery shortfall events	-
Contribution to mitigating system shortfall events	500 ML/day
Confidence that option is accessible	Medium
Part 1: Implementation readiness	3 - 5 years
Part 2: MCA scoring	
Water availability	-2.5
Environmental conditions	0.5
Delivery risk	5.0
River communities and Traditional Owners	-0.5
Total MCA score	2.5
Part 3: Qualitative assessment of non-scored elements	!
Part 4: Cost effectiveness	
Capital cost	$3 - 5 M
Operational cost (50 years)	To be determined in any future stages
Total cost (capital + operational) / bypass capacity	To be determined in any future stages

3.14 Options assessment outcomes

Assessment summary

The twelve individual options were assessed in four parts:

- **Part 1**: Implementation readiness
- **Part 2**: Multicriteria analysis against (scorable) project objectives
- **Part 3**: Qualitative assessment (non-quantified)
- **Part 4**: Cost effectiveness

This section provides an analysis of this assessment and an interpretation of the results.

This analysis is presented by:

1. reporting on how each individual option performed against each of the individual parts.
2. interpreting the outcomes, including consideration of the non-scored (qualitative) criteria and the confidence that the option will be readily accessible and available for river operators.

A summary of the assessment outcomes is provided in tabular format in **Table 52** on the page over.

Note that, as discussed in more detail in the sections above:

- the operational cost for the Snowy Hydro option is highly variable depending on a range of factors, such as the flexibility for flow deliveries during the water year, the waterway route used for supply (and therefore any lost power generation potential), and other factors. These operational costs require more definition on the proposed operational arrangement and preliminary engagement with SHL before they can be quantified.
- the qualitative considerations (by nature) are not easily represented within tables or graphs. A summary assessment has been included in the table to show whether there are any significant matters identified which require further work. Detail for these considerations is provided in the sections above.

Table 52. Option assessment outcome summary

Assessment category	Unit	Option 1 Riverbank works	Option 2 Sediment Management	Option 3 Tar-Ru transfers	Option 4A.1 MIL escapes (no works)	Option 4A.2 MIL escapes (upgrades)	Option 4B Perricoota	Option 4C Mulwala	Option 5A VMMS	Option 5B MVIA outfalls	Option 5C Bypass channel	Option 5D RO 14 channel	Option 6 Snowy Hydro
Contribution to BMFS flow objectives													
System shortfall contribution	ML/day	500 (avoided loss)	1,000 (avoided loss)	100	665	960	200	38	300	110	1,000	500	500
Delivery shortfall contribution	GL (10 days)	-	-	-	-	-	-	-	10 GL	-	-	-	-
Confidence that option is accessible		Medium	Medium	Low	High	High	Low	High	High	Low	High	High	Medium
Part 1: Implementation readiness	**Years**	1	5	4	1	2	2	2	2	5	8	5	4
Part 2: MCA scoring													
Water availability		0.0	0.0	-3.8	-1.3	-1.3	0.0	0.0	1.3	0.0	-1.3	-1.3	-2.5
Environmental conditions		1.0	1.0	1.0	2.0	2.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5
Delivery risk		5.0	5.0	5.0	5.0	5.0	2.5	2.5	7.5	0.0	5.0	5.0	5.0
River communities and Traditional Owners		0.5	0.0	0.0	0.0	0.0	-0.5	-0.5	-0.5	0.0	-0.5	-1.0	-0.5
Total MCA score	**Weighted**	6.5	6.0	2.3	5.8	6.3	2.5	2.5	8.8	0.5	3.8	4.3	2.5
Part 3: Qualitative considerations	non-scored	✓	!	!	✓	✓	!	✓	!	!	✓	✓	!
Part 4: Cost effectiveness													
Capital cost	$ million	$4.5 m	$14.5 m	$1.0 m	$0.1 m	$18.5m	$24.5 m	$38.5 m	$5.7 m	$2.1 m	$601.7 m	$165.7 m	$5.0 m
Operational cost (PV, 50yr)	$ million	$ -	$110.4 m	$ -	$4.1 m	$10.4 m	$7.9 m	$10.8m	$2.4 m	$1.4 m	$173.2 m	$49.3 m	Variable
Total cost per ML per day (over 100 days)	$/ML/day equivalent	9,000	124,906	10,000	6,376	60,198	162,169	1,298,701	27,017	31,238	774,862	429,955	Variable

Contribution to flow objectives

Figure 29 shows the equivalent bypass capacity provided by each of the individual options. In this chart, options which can provide more than 400 ML/day-100 days of equivalent bypass capacity are coloured in green, and those which are less are coloured in orange.

For the purposes of this assessment, **"Equivalent bypass capacity"** means maintaining or reinstating flow capacity in the summer/autumn months through the Barmah-Millewa Reach, by either bypassing the reach <u>directly</u> (via surrounding channels, waterways, and infrastructure) or <u>indirectly</u> through *time*.

The concept of a summer/autumn 'equivalent bypass' means that water is passed through the Barmah-Millewa Reach in the period of winter/spring to be stored downstream and then *released in summer/autumn* months providing 'equivalent bypass' to a direct bypass in these same months. e.g., 10GL of downstream storage capacity released over 100 days in summer/autumn = 100ML/day of summer /autumn "equivalent bypass".

This allows storage options (such as the VMMS) to be compared with direct bypass options (such as MIL escapes, for example).

This shows that use of MIL escapes (either with or without upgrade works) provides a significant bypass flow equivalent relative to the other options, with the Victorian channel options and Snowy Hydro providing relatively high-capacity options as well.

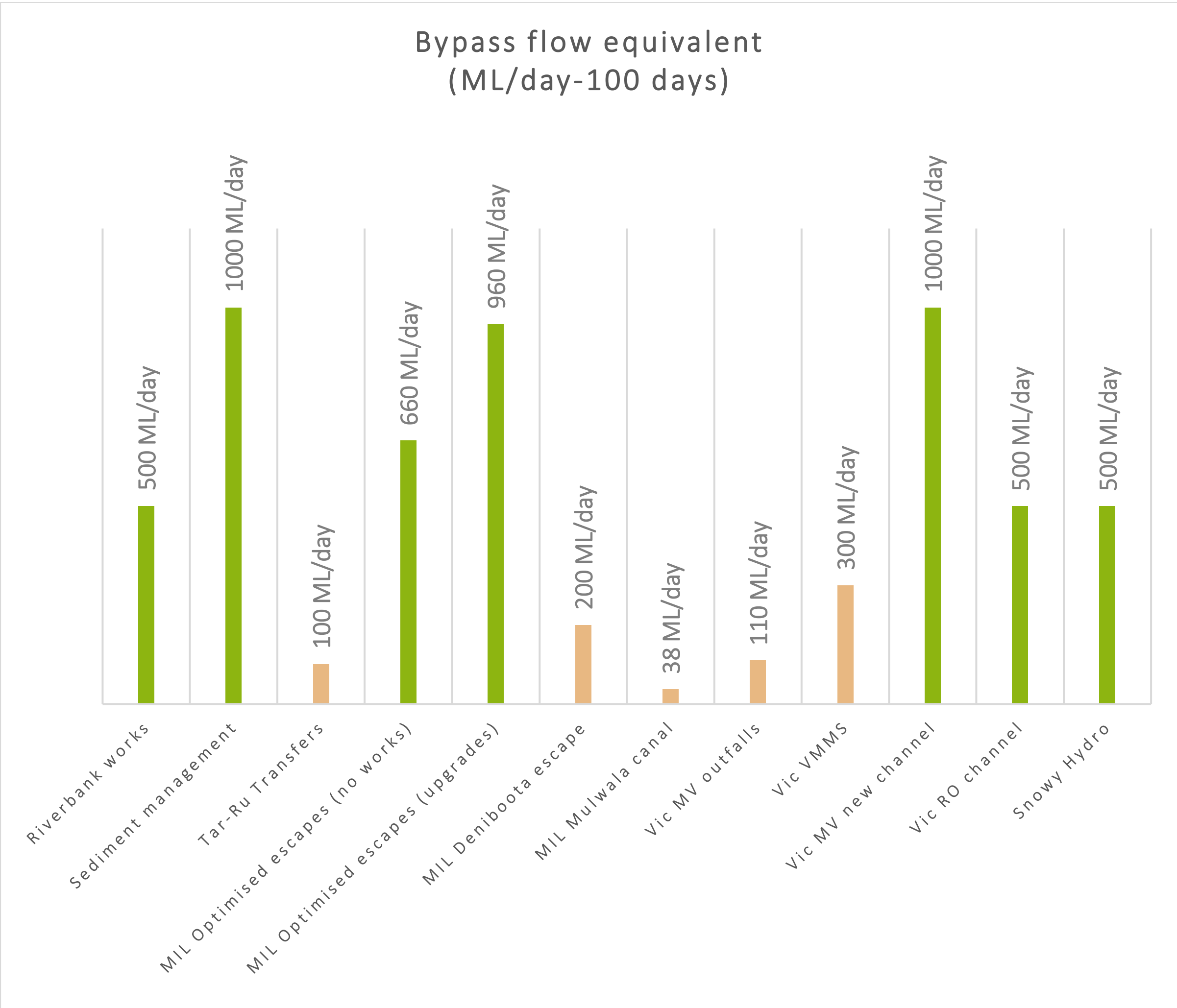


Figure 29. *Bypass flow equivalent (in ML/day-100 days) for each of the individual options*

Part 1: Implementation Readiness
Figure 30 shows the expected timeframe needed to implement each individual option. In this chart, options which can be implemented within 3 years are coloured in green, and those which would take longer coloured in orange.

This shows that:

- there are many options available for implementing in the short-term which could contribute to the project objectives, notably including the use of MIL escapes and the enhanced use of the VMMS.
- the sediment management project could be up to five years to implement. To mitigate the risk of further loss of capacity and adverse impacts within the reach, other options may need to be implemented in the shorter term.
- the options which require the construction of large infrastructure (such as the Victorian channel options) or significant changes to operating practices (such as changing the timing for Tar-Ru transfers or using inter-valley transfers via Snowy Hydro) take a relatively long time to implement.

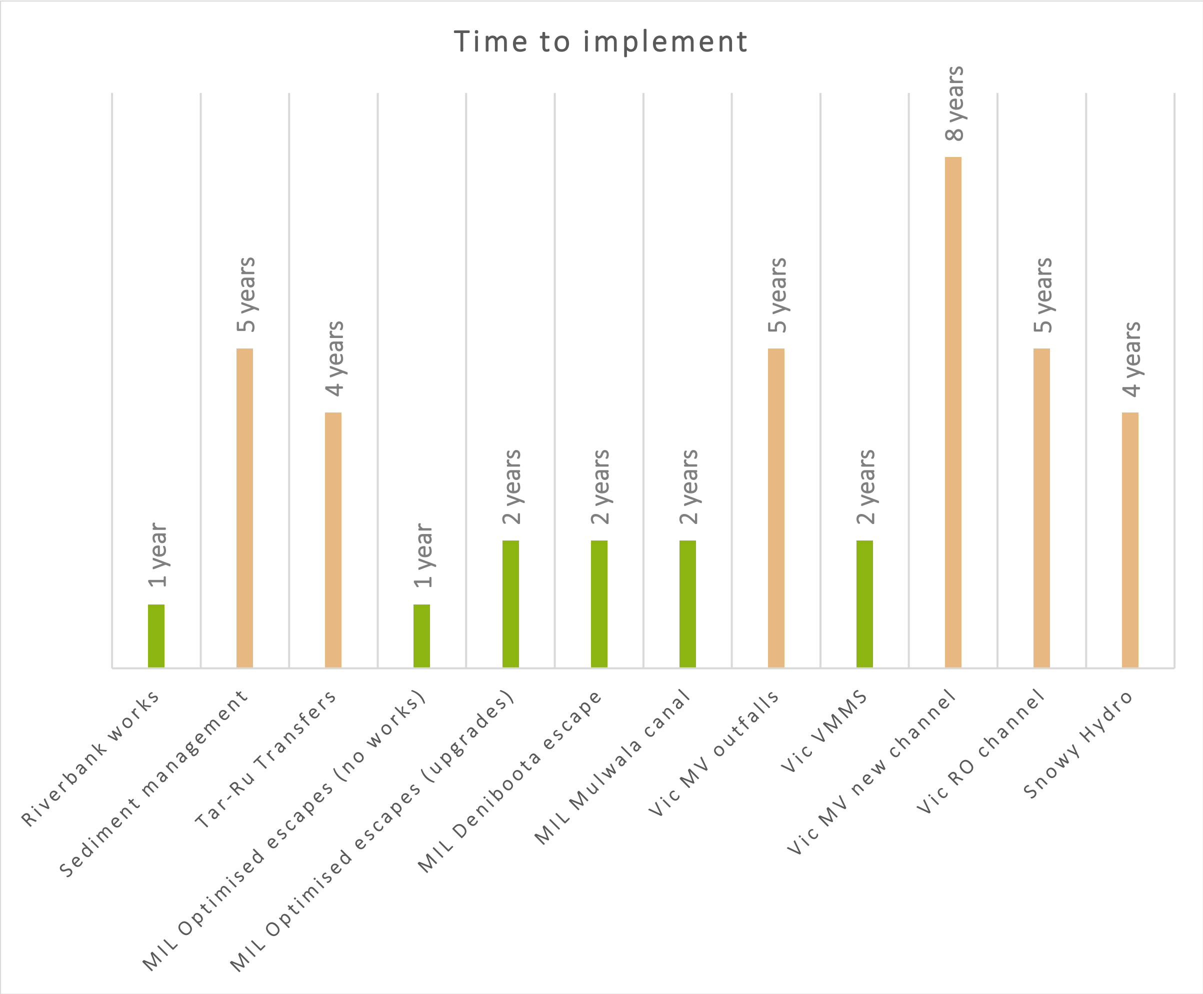


Figure 30. *Time to implement each of the individual options*

Part 2: MCA Scoring

Figure 31 shows how each individual option scored against the multicriteria analysis. In this chart, options which scored greater than 5.0 are coloured in green, and those which scored less than 4.0 are coloured orange.

This figure shows that:

- both options being considered to mitigate against further loss of capacity in the Barmah-Millewa Reach (riverbank works and sediment management) score relatively high on the MCA assessment, noting their contribution to the flow objectives as well as mitigating further risk to environmental, social, and cultural impacts.
- the options which scored poorly on the MCA generally involve risks to changes in system water or State shares (such as Tar-Ru transfers and Snowy Hydro) or contributed relatively minor bypass flows whilst having limited ecological benefits (such as the enhanced use of MV outfalls or the MIL Mulwala Canal option.

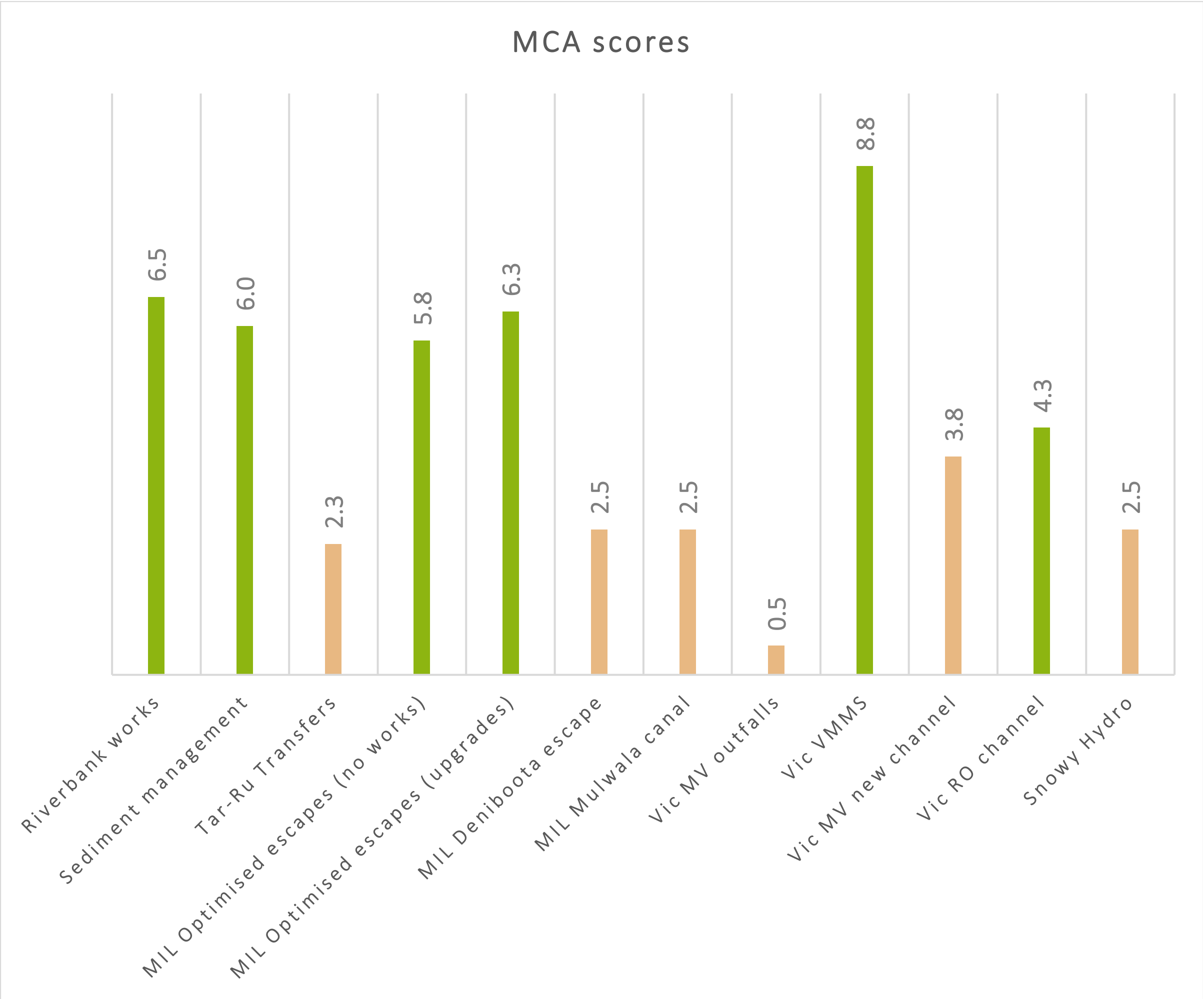


Figure 31. *MCA score outcomes for each of the individual options*

Part 4: Cost effectiveness
Figure 32 shows the relative cost effectiveness per ML of equivalent bypass flow for each option.

This metric has been determined by adding the capital cost and present value of the operational cost (over 50 years), then dividing by the equivalent bypass flow capacity for each option. This metric has been derived to show the relative difference in total cost between options. In this chart, options which are less than $150,000 / ML/day-100 days are coloured green, and those which are higher are coloured orange. This figure shows that:

- options which involve substantial capital works programs (such as the Victorian or MIL channel options) are significantly poorer cost effectiveness than other options.
- options which require minor capital works programs (such as the optimised use of MIL escapes and VMMS) perform relatively well in cost effectiveness.
- options which involve changes to operating practices perform well in cost effectiveness.

Note that the Snowy Hydro option has been excluded from this chart as the operational cost for the option is highly variable and not able to be accurately quantified at this preliminary stage (see option description above for more detail).

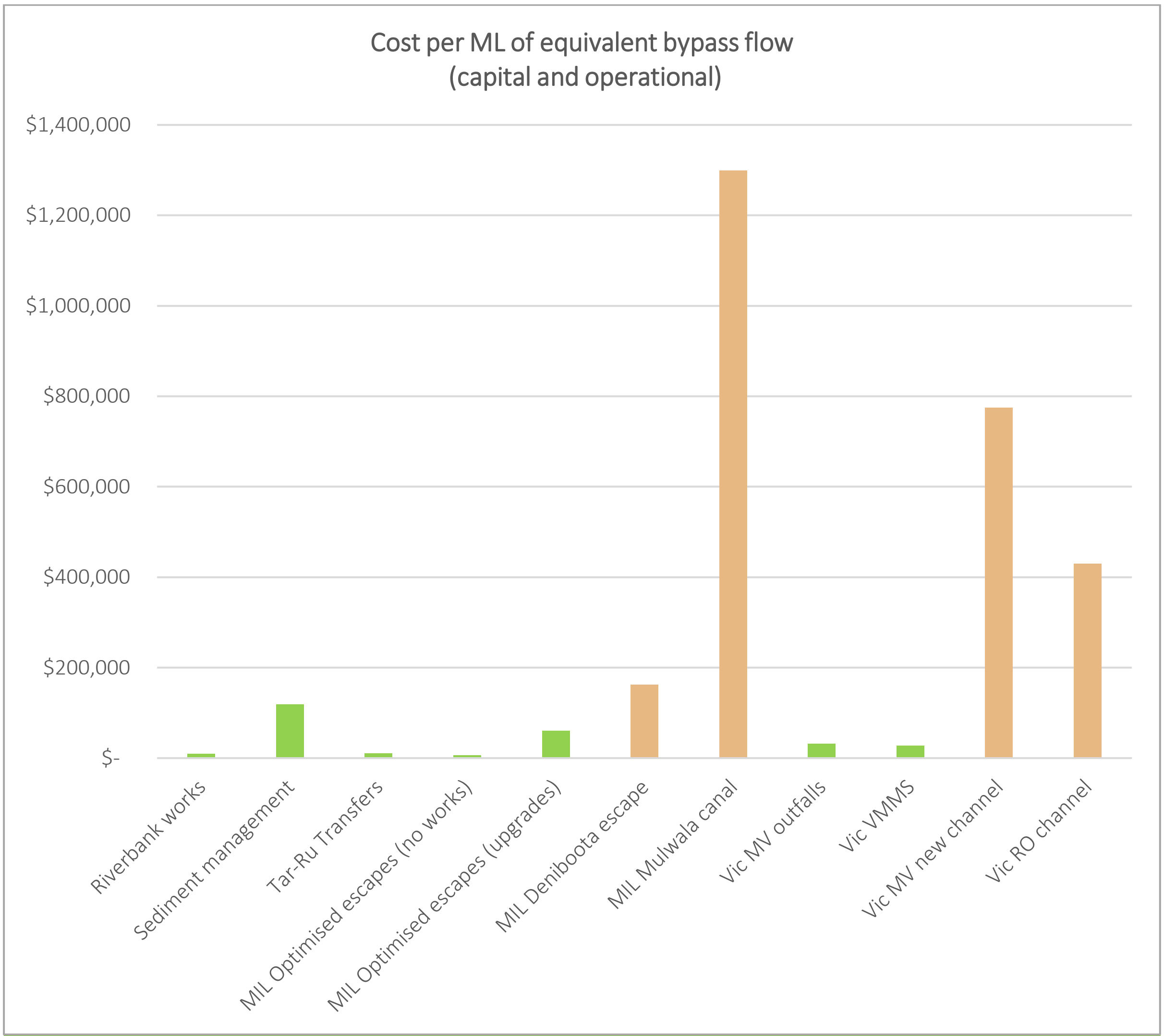


Figure 32. *Cost effectiveness outcomes for each of the individual options*

Flow equivalent and MCA score

The charts above are provided for each of the individual assessment metrics. **Figure 33** combines assessments to plot the performance of each option against bypass flow equivalence and MCA scoring. This chart shows:

- the sediment management, MIL escapes, riverbank works, and Victorian Rochester bypass channel options have relatively high MCA and bypass flow equivalence.
- the Victorian Mid-Murray Storages has a high MCA score, with a relatively lower bypass flow equivalence. Note however that this option would primarily be used to manage potential delivery shortfalls.
- whilst providing relatively high bypass flow capacity, a new Murray Valley bypass channel and Snowy Hydro options scored poorly on the MCA.
- the Mulwala, Perricoota, MVIA outfalls and Tar-Ru options scored poorly on the MCA and have relatively lower flow capacity contributions.

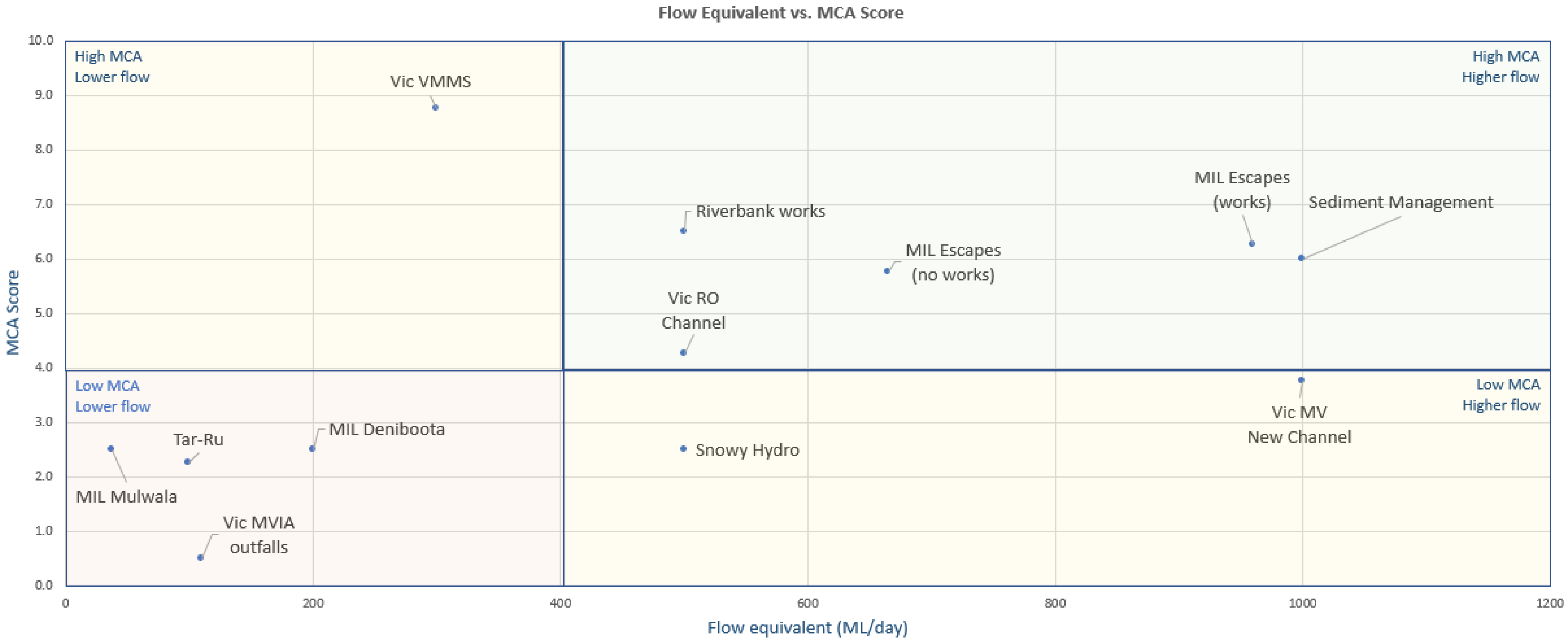


Figure 33. *Plotting the options against the flow equivalence and MCA score criterion*

Assessment and prioritisation

The analysis above shows how the individual options perform against each of the assessment parts. The analysis has been collated in **Table 53** below. An initial priority has been assigned to each individual option, considering:

- if the option has performed well for flow capacity, MCA assessment, and cost effectiveness, it should be highest priority for implementation.
- if the option has only performed well in one or no criteria, it should be of lowest priority.
- time to implement is considered separately in developing suites of options.

Table 53. Initial performance and prioritisation of each option

No.	Option description	Flow capacity	MCA score	Cost	Initial Priority
1	Riverbank works				1
2	Sediment management				1
3	Tar-Ru Transfers				3
4A.1	MIL escapes (no works)				1
4A.2	MIL escapes (upgrades)				1
4B	MIL Perricoota Escape				3
4C	MIL Mulwala Canal				3
5A	Vic VMMS				2
5B	Vic MV outfalls				3
5C	Vic MV new channel				2
5D	Vic RO channel				2
6	Snowy Hydro				3

High Score / Highest Priority
Moderate Score / Secondary Priority
Low Score / Lowest Priority
Unquantifiable at this time

The above assessment does not give any consideration to the qualitative considerations for each option or the time to implement each option. A revised priority has been applied to the options as follows:

- The MV outfalls option has been increased in priority. This recognises that, if the Rochester bypass channel is constructed, the enhanced use of these outfalls would provide opportunities for environmental as well as flow capacity at a relatively low cost. It is recommended that this opportunity be further explored should the Rochester channel be included in any suites.
- The Tar-Ru transfers option has been increased in priority. This recognises that there is an opportunity to coordinate environmental water deliveries during the winter/spring period on top of early transfers. In this circumstance, the risk of foregone harvesting opportunities may be underwritten by the environmental water holders to reduce the risk of third-party impacts on state water shares. This opportunity should be further considered and explored as part of any further development of this option.
- The construction of a new bypass gravity channel has been decreased in priority. This recognises that this option performed exceptionally poorly in the cost effectiveness criteria, and alternate options are available for much less cost which would provide equivalent flow and ecological outcomes.

Table 54. Final prioritisation of options

No.	Option description	Initial Priority	Adopted Priority
1	Riverbank works	1	1
2	Sediment management	1	1
3	Tar-Ru Transfers	3	2
4A.1	MIL escapes (no works)	1	1
4A.2	MIL escapes (upgrades)	1	1
4B	MIL Perricoota Escape	3	3
4C	MIL Mulwala Canal	3	3
5A	Vic VMMS	1	1
5B	Vic MV outfalls	3	2
5C	Vic MV new channel	2	3
5D	Vic RO channel	2	2
6	Snowy Hydro	3	3

4 Combining the options into suites

4.1 Method for developing suites

Purpose

There are numerous objectives of the Barmah-Millewa Feasibility Study (as listed in Section 1.5 of this report). It is expected that no one individual option will be able to adequately address all these objectives. Accordingly, combinations (or 'suites') of options needed to be developed.

The method used for developing the suites generally comprises:

- **Defining the flow options for the suites**: a range of potential targets are defined for maintaining or reinstating the flow capacity of the reach.
- **Determining any requisite options:** there may be some project objectives which can only be met by one option. These options should be identified as they will need to be included in all suites.
- **Key assumptions:** assumptions which underpin the compilation of suites are transparently set out.
- **Compile the suites based on option assessment outcomes:** the assessment of individual options has provided a comprehensive assessment of the relative priorities, key considerations, and timeframe to implement each of the individual options. This information is considered in combining packages (suites) of options for each of the flow scenarios.

Defining the flow scenarios

There are a range of different options which could be considered for maintaining or reinstating the flow capacity in the Barmah-Millewa Reach.

'Do nothing'

This scenario reflects a 'do nothing' scenario. In this scenario, no intervention works or measures are implemented in response to the sand accumulation and the declining flow capacity in the reach.

Suite 1 – maintain current capacity

This scenario reflects undertaking the works required to maintain the current flow capacity through the Barmah-Millewa Reach. In this scenario, intervention works or measures are scoped as required to offset the ongoing decline in the reach associated with the continued sand accumulation, while the sand removal works are further investigated, planned and progressed through approvals processes.

Suites 2 to 4 – reinstate flow capacity

This scenario reflects undertaking the works required to reinstate flow capacity in the River Murray. In this scenario, intervention and bypass works are scoped as required to offset the ongoing decline in the reach and, in addition, restores system capacity by implementing bypass options.

The flow capacity in the Barmah-Millewa Reach has declined from around 11,300 ML/day in the 1980s and 1990s, to around 9,200 ML/day at current (as measured downstream of Yarrawonga Weir). Accordingly, the options to reinstate the flow capacity are:

- **Suite 2.** Reinstatement of around 500ML/day (to 9,700 ML/day) of equivalent bypass capacity
- **Suite 3.** Reinstatement of around 1,000ML/day (to 10,200 ML/day) of equivalent bypass capacity
- **Suite 4.** Reinstatement of around 1,500ML/day (to 10,700 ML/day) of equivalent bypass capacity

Suite 5 – 'Do everything'

This scenario reflects implementing all options under consideration. For the purposes of assessing this option and consistent with the project objectives, the additional capacity (beyond historical capacity) would only be accessed for the delivery of environmental water.

Necessary options

There is a need is to ensure that each of the project objectives can be achieved when compiling the options into suites. The project objectives are set out in **Table 55**.

Table 55. Barmah-Millewa Feasibility Study project objectives

PO#	Project objectives
PO1	Maintain or enhance the ability to meet peak demand downstream of the Barmah-Millewa Reach (managing delivery shortfalls)
PO2	Maintain or enhance the ability to deliver water downstream of the Barmah Millewa Reach throughout the year (managing system shortfalls).
PO3	Provide greater opportunity for more desirable flow regimes to be delivered through the Barmah-Millewa region, including avoided undesirable inundation of the forest
PO4	Reduce the localised environmental impacts associated with the ongoing sedimentation of the river reach (i.e., loss of fish habitat, etc)
PO5	Reduce the risks of bank failure at the Barmah Forest protecting the significant environmental and cultural values of the forest floodplain
PO6	Provide improved ability to deliver environmental water along the River Murray
PO7	Further facilitate the delivery of environmental water into sites within the Edward/Kolety-Wakool system
PO8	Benefits generated by the project will need to be resilient to a range of potential future demand and management scenarios, including with and without constraints relaxation
PO9	Benefits generated by the project will need to be resilient to a range of climatic and water availability conditions.

Table 56 below shows each option considered in this study and whether the option would directly, partially, or not contribute to each of the project objectives.

Table 56. Contribution of options to the BMFS project objectives

Option	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
Option 1 – Riverbank works									
Option 2 – Sediment removal									
Option 3 – Tar-Ru transfers									
Option 4A.1 – MIL – optimised escapes [no works]									
Option 4A.2 – MIL – optimised escapes [upgrades]									
Option 4B – MIL – Perricoota Canal									
Option 4C – MIL – Mulwala Canal									
Option 5A – Vic – Enhanced use of VMMS									
Option 5B – Vic – Enhanced use of MVIA outfalls									
Option 5C – Vic – Barmah bypass channel									
Option 5D – Vic – Rochester bypass channel									
Option 6 – Snowy transfers									
Necessary options	5A			1	2				

Direct or major contribution to project objective	
Minor or indirect contribution to project objective	
No or insignificant contribution to project objective	

Key observations in the context of option assessment and suite development include:

- **Option 1 (riverbank works) will be required as part of any option suites**, to ensure that the project objective of reducing the risk of bank failure at the Barmah-Millewa Forest can be met (PO5). The treatment of the riverbanks through the Barmah-Millewa Reach is the only option available which directly contributes to this objective. While other options may partially contribute to this objective by reducing the potential frequency or duration of bankfull flows being delivered through the reach (and thereby reducing the potential for bank erosion), this option is the only means available to directly protect the riverbanks and the risk of new breakaways forming. This objective is considered an essential (non-negotiable) outcome for this project, noting that riverbank erosion is a key risk within the reach for the environmental health of the forest and the river, sustaining flow capacity in the reach, and responding to social concerns.

- **Option 2 (sediment management) will be required as part of any option suites**, to ensure that the project objective of reducing localised environmental impacts associated with the ongoing sedimentation of the reach is met (PO4). The removal and disposal of sediment from the Barmah-Millewa Reach is the only option available which directly contributes to this objective. While other options may partially contribute to this objective by reducing the flow volumes and therefore sediment volumes entering the reach, the sediment removal option is the only means available to directly reduce the volume of sand accumulating within the reach. This objective is considered an essential (non-negotiable) outcome for this project, on the basis that there is strong evidence that sediment accumulation will continue to occur within the reach (with detrimental outcomes) with associated adverse impacts, unless intervention works are undertaken.

- **Option 5A (enhanced use of the VMMS) will be required as part of any option suites**, to ensure that the project objective of maintaining or enhancing the ability to meet peak demands downstream of the Barmah-Millewa Reach can be met (PO1). Due to its unique position, discharging to the River Murray just upstream of Swan Hill, the enhanced use of the VMMS is the only option assessed which can be used by river operators on short notice to directly respond to a potential delivery shortfall event in the lower Murray. This objective is considered an essential (non-negotiable) outcome for this project, on the basis that shortfall risks in the lower Murray are increasing, and this risk is likely to continue to increase if the capacity of the reach further declines[91]. It is noted that the Snowy Hydro option considers a potentially complementary option of drawing down the Murrumbidgee Weir pools to provide flow to the lower Murray on short notice. This Murrumbidgee Weir Pool option is recommended to be explored in more detail as part of any further development on the Snowy option. If this option proves viable, it could help to mitigate the risk of delivery shortfall, alongside the enhanced VMMS option.

[91] Independent Panel for the Murray-Darling Basin Authority (2020), *Managing delivery risks in the River Murray System – Ensuring a functional system for the future*

Suite development – key assumptions

Key assumptions have been made to enable the development of the suites. These key assumptions are:

1. As discussed above, a 'do nothing' option has been included in the suite of options for comparative purposes.
2. The capacity of the Barmah-Millewa Reach will continue to decline until works commence to remove sand at a rate equal to or greater than its rate of accumulation. Due to the time required to commence works (further studies, approvals, construction) the flow rate will most likely decline in line with the time taken to commence. For example:
    a. **3-year commencement date (2025 start)** equates to an additional 300ML/day loss of capacity, resulting in an expected typical flow rate of *9,000 ML/day* in 2025
    b. **5-year commencement date (2027 start)** equates to an additional 500ML/day loss of capacity, resulting in an expected typical flow rate of *8,800 ML/day* in 2027
    c. **10-year commencement date (2032 start)** equates to an additional 1000ML/d loss of capacity, resulting in an expected typical flow rate of *8,300 ML/day* in 2032

   The **year 2022** is to be the adopted start date for the purposes of assessment and comparison.
3. Further decline of the Barmah-Millewa Reach capacity and its environmental and cultural values is unlikely to be acceptable. As a result, options 1 (riverbank works) and 2 (sediment management) will be required.
4. Options 3 to 6 could serve to either maintain current capacity and/or to reinstate capacity.
5. Options that can be implemented in the short term (1-2 years) are to be included in all suites of options, to offset the short-term continued decline in flow capacity expected because of continued accumulation of sand within the reach.
6. Each suite will be assessed with the assumption that Menindee Lakes are unavailable as a shared resource.
7. Delivery risk is based on current horticultural development through the River Murray System.

Compiling the suites

In compiling options into potential suites, considerations include options which have:

- short term implementation readiness.
- high benefit against the MCA scored objectives.
- positive or manageable outcomes expected by the qualitative assessments.
- a cost-effective solution.

4.2 Suite development

Suites of options have been compiled and are shown in **Table 57** below. The suites of options take into account the project objectives, the necessary options (as described in Section 4.1), the environmental, cultural, social and economic impacts associated with the current condition, and the need to reinstate the flow capacity of the reach to mitigate delivery shortfall risk. The key decisions made in compiling these suites include:

- The riverbank and sediment management options (options 1 and 2) are prioritised as the measures best suited to address the environmental, social, and cultural impacts associated with accelerated bank erosion and accumulation of sand in the riverbed, and to manage the risk of further decline in flow through the reach.
- The enhanced use of the VMMS is the best option available for maintaining or improving the ability for operators to manage delivery shortfall risks. As such, this option has been included in all suites.
- The enhanced use of existing MIL escapes is the best option available for reinstating flow capacity, noting that it also contributes to the project objective of enhancing environmental outcomes in the Edward/Wakool-Kolety system. This option scored positively in all criteria in the option assessment, was identified as the highest priority option for implementation (see Section 3.14) and has a very short timeframe required to implement. As such, this option has been included in all suites.
- Upgrade works to the MIL escapes is the best next option for reinstating further flow capacity and contributes to the broader project objectives.
- The next best option available for reinstating flow capacity is the Rochester 14 bypass channel, the enhanced use of the MVIA outfalls, and early transfers to Tar-Ru. These options were identified as a priority 2 in the option assessment, noting that:
    - The Rochester channel option scored well in the MCA criteria and has a relatively high flow capacity. This option would create an alternate means of delivering Goulburn IVT commitments to the Murray, which in turn provides an opportunity for river operators to manage flows in the lower Goulburn, lower Broken Creek, and Campaspe systems to better align with environmental flow recommendations. Accordingly, this option substantially contributes to a number of the project objectives in addition to managing shortfall risks.
    - If the Rochester channel were constructed, the enhanced use of the MVIA outfalls provides a relatively low-cost opportunity for increasing the system capacity.
    - Early transfers to Tar-Ru scored poorly in the MCA criteria, mostly due to the risk to missed harvesting opportunities and impacts on State water shares. There is a potential opportunity for the environmental water holders to underwrite this risk however, meaning that this option has been increased in priority and included in suites, to promote this option being further developed.
- The next best options available are the Perricoota Escape and Mulwala Canal options. These options scored poorly and should only be considered for high reinstatement suites.
- If the weirs in the lower Murrumbidgee River are further investigated and found to feasibly contribute to mitigating delivery shortfalls, the Snowy option may be considered more feasible, and a higher priority in terms of the options available, subject to resolution of the other considerations for this option as described elsewhere.

Table 57. BMFS suites of options

					Option suites						
					'Do nothing'	Suite 1	Suite 2A MIL only	Suite 2B MIL & Vic	Suite 3	Suite 4	Suite 5
			Annual system capacity (ML/day)	System capacity (rounded, ML/day)	Ongoing decline	Maintain current capacity	Reinstate +500 ML/day	Reinstate +500 ML/day	Reinstate +1,000 ML/day	Reinstate +1,500 ML/day	'Do everything'
Do nothing					-1,500	-1,500	-1,500	-1,500	-1,500	-1,500	-1,500
Implementation timeframe capacity loss						-500	-500	-500	-500	-500	-500
Option 1	1	Riverworks	500	500		500	500	500	500	500	500
Option 2	2	Sediment removal	1,000	1,000		1,000	1,000	1,000	1,000	1,000	1,000
Option 3	3	Tar-Ru	100	100			[1]	[1]	[1]	100	100
Option 4 MIL	4A.1	Existing outlets	665	650		500	650	500	650	650	650
	4A.2	Upgraded outlets	295	350			350		350	350	350
	4B	Perricoota	200	200						200	200
	4C	Mulwala	38	50						50	50
Option 5	5A	VMMS	0[2]	0[2]		Delivery shortfalls[2]	Delivery shortfalls[2]	Delivery shortfalls[2]	Delivery shortfalls[2]	Delivery shortfalls[2]	Delivery shortfalls[2]
	5B	Vic outfalls	110	150						150	150
	5C	Barmah channel	1,000	1,000							1,000
	5D	RO channel	500	500				500	500	500	500
Option 6	6	Snowy	500	500			[3]	[3]	[3]	[3]	500
Change from current					**-1,500**	**0**	**500**	**500**	**1,000**	**1,500**	**3,000**
Bypass capacity					**7,700**	**9,200**	**9,700**	**9,700**	**10,200**	**10,700**	**12,200**

[1]: While the Tar-Ru option is brought into the suite of options relatively later in this assessment, there are potentially significant outcomes in some years at a relatively low cost achievable by implementing this option. Governments may elect to include this option in earlier suites than shown.
[2]: The enhanced use of the Victorian Mid-Murray Storages (VMMS) is most likely to contribute to delivery shortfall events (i.e., by releasing large volumes over a short period) and not relied on for additional system capacity, therefore it has not been assigned a flow in the suites of options. It is important to note that the storages could deliver around 10 GL over a 10-day period to manage potential shortfall events.
[3]: The potential use of weirs in the Lower Murrumbidgee River, to reduce the risk of delivery shortfall in the River Murray, may warrant inclusion of a limited Snowy Transfer option in these suites.

5 Method for assessing the suites of options

5.1 Decision-Making Framework

The Independent Panel for Capacity Project Review (IPCPR) Decision-Making Framework (DMF) has been developed to provide Governments with a transparent and standardised process for making decisions on river operation practices.

The DMF has not been designed to make a decision. Rather, it uses subject matter experts to assess the opportunities and risks of various options using a set of high-level criteria. This information can then be used by decision makers to consider and justify their decisions.

The DMF has been designed to identify multiple options for complex problems within river operations. It is not an exhaustive decision model; however, it can be used as the starting point for an iterative process. The framework is intended to allow trade-offs within and between options to be clearly identified.

This section outlines how the DMF has been applied to assess the relative merits and risks associated with the Suites of Options as part of the BMFS.

5.2 DMF process

The DMF decision-making process generally follows four key steps, including:

1. Describing each option which is being assessed.
2. For each Decision Domain, describing the likely consequential impacts (both positive and negative) for each of the key indicators as relevant to the project using the best available information.
3. For each Decision Domain, assessing the materiality of the likely impacts.
    - Each option is given a consequence and likelihood rating for each key indicator.
    - Commentary is provided to document the factors considered in assigning ratings based on experience, specialist knowledge, and judgement.
    - The risk assignment is determined based on the risk matrix.
4. The decision-making body makes informed trade-off decisions in line with agreed principles.

5.3 Applying the DMF

The DMF involves several components, including:

- **decision domains**, which are the four primary categories of considerations when making decisions regarding river operations.
- **the options for assessment,** which are the alternate options available for decision makers to select between when applying the DMF. These will change between each project and use of the framework.
- **likelihood ratings,** which define how often or likely an impact is expected to occur.
- **consequence ratings**, which define the expected materiality of impact should be event occur.
- **risk assignment,** derived from considering the likelihood and consequence of an impact occurring.

Decision domains

The DMF includes four domains, each with sub-domains for assessment (**Table 58**). Specific objectives have been defined for each of the decision domains. The sub-domains provide key indicators of the expected impact on the objective.

Assessment of each option is completed at the sub-domain level. These assessments are then used to provide a 'summary rating' for each option at the domain level, typically as an 'average' of the sub-domain scores.

Table 58. The decision domains as defined in the DMF

Decision Domain	Objective/s	Sub-domains
Water Resource Availability	To conserve water and minimise losses in order to maximise water available to State water entitlements.	• State water shares • System water resource • Entitlement • South Australian storage right
Environmental condition	To avoid further degradation, manage water quality (including salinity and algal blooms) and where possible, restore priority environmental assets and ecosystem functions. This means operating within ecological tolerances and salinity and water quality targets and, where possible, taking opportunities to improve condition.	• Water quality • Efficiency of eWater • Environmental conditions
Delivery risk	To deliver water to entitlement holders. To deliver all authorised water demand, including South Australian entitlement flow, consumptive and environmental, at the flow rate required for all water users To deliver temporary trade of allocation.	• Environment • Irrigators • Traditional Owners
River communities and Traditional Owners	To have regard for the social, economic, and cultural activities and values of people using the River Murray System. Includes navigation, cultural, and recreational activities.	• River dependent businesses and townships • Riparian landholder impacts • Traditional Owners

5.4 Risk management frameworks

While the DMF has defined the decision domains, the likelihood and consequence ratings need to be defined considering the particulars of each project.

Risk frameworks used by the Victorian[92], South Australian[93] and New South Wales[94] governments were reviewed to support these definitions for this project. This review has found:

- Risk management practices are generally categorised in similar ways by the State Governments.
- The risk management frameworks were all developed using the ISO 31000 – Risk Management Guidelines, which provides a common approach to managing any type of risk and is not industry or sector specific.
- Consequence and likelihood ratings are recommended to be tailored to the individual circumstances of each project or agency.
- Project frameworks typically adopt a low likelihood range for rare and almost certain events. This is intuitive, as 'most' events should be considered possible or likely to occur.
- In the DMF, consequences are evaluated at the sub-domain level. The sub-domains used in the MDBA DMF are specific to the considerations of river operators and are not common risk categories used by other organisations.

In addition, risk registers from various water sector projects which are currently being delivered by various State Governments were reviewed. **Table 59** presents how the likelihood ratings across various projects varied based on the application of the respective agencies risk management framework.

Table 59. Likelihood ratings used for various current government projects

Likelihood rating	Victorian reference project	New South Wales reference project	MDBA Risk Management Framework
Almost certain	80-100%	> 90%	80-100%
Likely	50–79%	50–90%	40–80%
Possible	20–49%	20–50%	20-40%
Unlikely	5–19%	5–20%	10–20%
Rare	0-4%	<5%	0–10%

This review has informed the likelihood and consequence ratings adopted for the Suites of Options assessment.

[92] https://www.dtf.vic.gov.au/planning-budgeting-and-financial-reporting-frameworks/victorian-risk-management-framework-and-insurance-management-policy
[93] https://dhs.sa.gov.au/__data/assets/pdf_file/0008/9782/risk-management-framework.pdf
[94] https://www.treasury.nsw.gov.au/information-public-entities/governance-risk-and-assurance/internal-audit-and-risk-management/risk

5.5 Likelihood ratings

Likelihood ratings describe how often an event or impact is expected to occur. The likelihood rating definitions adopted for the BMFS are provided in **Table 60**.

Table 60. Likelihood ratings applied for the BMFS assessment

Likelihood rating	% chance in any given year of the event occurring[1]	Description
Almost certain	>90%	• The event is expected to occur in most circumstances. • There is a great opportunity, reason or means to occur.
Likely	50-90%	• The event is likely to occur in most circumstances. • There is considerable opportunity, reason or means for the event to occur.
Possible	20-50%	• The event might occur. • There is some opportunity, reason or means to occur.
Unlikely	5-20%	• The event could occur at some time. • There is little opportunity, reason or means to occur.
Rare	< 5%	• Event may occur only in exceptional circumstances.

[1]: assessed over the next 10 years

5.6 Consequence ratings

Consequence ratings describe the expected materiality should an event or impact occur. **Table 61** (on the page over) provides the adopted metrics and definitions used for assigning consequence ratings for the BMFS.

Changes in State water shares have only been considered as impacts (rather than opportunities) and has been based on the worst affected State.

Most consequence criteria have a common scale used for measuring impacts and beneficial outcomes. However, the consequence scale for delivery risks to irrigators uses a different scale for the impact of a further reduction in flow capacity compared with the benefit of restoring flow capacity. As the flow capacity of the Barmah-Millewa Reach declines, the consequence of loss will increase in a non-linear manner. This asymmetrical consequence rating recognises that the disbenefits of further decline in capacity are of greater magnitude than the benefits derived from an equivalent increase in capacity.

Note that the sub-domains relating to cultural water delivery and cultural heritage have not been defined. This recognises that we consider it would not be appropriate for a third-party to attempt to quantify or assess impacts or opportunities for Traditional Owners and cultural heritage, particularly as part of a scored assessment matrix. Initial cultural considerations for this project have been captured through direct engagement with Traditional Owner groups. The views and perspectives heard from the various groups have been captured in a separate report as part of the BMFS.

Preliminary consultation with Traditional Owners has collected initial perspectives on the project and the various options being considered. It is important that decision makers consider these perspectives in addition to this Decision Making Framework scored criteria when determining the next stages and preferred solutions.

Table 61. Consequence ratings applied for the BMFS assessment

Consequence Rating	Water availability				Environmental conditions			Delivery risk			River communities		
	State water shares	System water resources	Entitlements	South Australian storage right	Water quality	Environmental water delivery	Environmental conditions	Environment (shortfalls)	Traditional Owners (shortfalls)	Irrigators (shortfalls)	River-dependent businesses and townships	Landholder & social considerations	Traditional Owner considerations
Metrics	GL change in state water share Based on the worst affected state	GL change in system water in one or a combination of: Losses (conveyance and storage, etc) Harvesting Spills from Hume or other storages	Type and % of allocation change considering the various entitlement classes	Volumes of spills affecting SA storage water right (Lake Hume, Lake Dartmouth, Lake Victoria)	Changes in water quality resulting in events such as blackwater events, fish kills, salinity and/or algal blooms	Change in system operating rules that affect the environmental water holder's ability to use their entitlement	Change in environmental condition caused by construction or operations which impact on matters of environmental significance	Change in system conditions which affects environmental water delivery (typically during the Winter-Spring period)	Not quantified. Please refer to the Traditional Owner Engagement – 'What we heard' report.	Change in system conditions which affects irrigation water delivery (typically during the Summer-Autumn period) through or around the Barmah-Millewa Reach	Impact on income and viability of river dependent businesses including eco-tourism operators and changes to navigation	Change in use of land affecting private landholders and communities, including consideration of cumulative mental health affects	Not quantified. Please refer to the Traditional Owner Engagement – 'What we heard' report.
Catastrophic *International significance* *Basin-scale impacts* *High court action*	100 GL+ change	200 GL+ reduction in system water	10% or greater reduction of allocation for any class of entitlement	100+ GL additional loss of SA storage right	Water quality emergency across the entire River Murray System and major tributaries	Impacts to environmental water delivery across the Murray-Darling Basin	Permanent loss of sites or values of international or national significance	10 GL/day or greater reduction in system capacity		2.0 GL/day or greater reduction in system capacity	Loss of more than 500 river-dependent jobs	Permanent impacts to more than 500 private landholders and/or multiple communities	
Major *National significance* *Major system impacts* *Ministerial action*	50-100 GL change	100-200 GL+ reduction in system water	5% - 10% reduction of allocation for any class of entitlement	50-100 GL additional loss of SA storage right	Water quality emergency through the River Murray and multiple major tributaries	Impacts to environmental water delivery across the River Murray and multiple major tributaries	Permanent loss of sites or values of state significance or temporary loss of sites or values of national significance	5 - 9.9 GL/day reduction in system capacity		1.0 – 1.9 GL/day or greater reduction in system capacity	Loss of 250 – 500 river-dependent jobs	Permanent impacts to 200-500 private landholders and/or a single community	
Moderate *State significance* *Regional system impacts* *Head of Departments response*	10-50 GL change	20-100 GL+ reduction in system water	1-5% reduction of allocation for any class of entitlement	10-50 GL additional loss of SA storage right	Water quality emergency through a major section of the River Murray or tributary	Impacts to environmental water delivery across the major section of the River Murray or a major tributary	Permanent loss of sites or values of regional significance or temporary loss of sites or values of state significance	2.5 – 4.9 GL/day reduction in system capacity		0.5 – 0.9 GL/day or greater reduction in system capacity	Loss of 50 – 250 river-dependent jobs	Permanent impacts to 10-200 private landholders and/or temporary impacts to multiple communities	
Minor *Regional significance* *Local system impacts* *Officer level response*	1-10 GL change	2-20 GL+ reduction in system water	0.5 - 1% reduction of allocation for any class of entitlement	1-10 GL additional loss of SA storage right	Water quality emergency through a localised section of River Murray or tributary	Impacts to environmental water delivery across a localised section of River Murray or major tributary	Permanent loss of sites or values of local significance or temporary loss of sites or values of regional significance	1.0 -2.4 GL/day reduction in system capacity		< 0.5 GL/day or greater reduction in system capacity	Loss of 5 - 50 river-dependent jobs	Permanent impacts to 1-10 private landholders and/or temporary impacts to a single community	
Neutral	+/- 1 GL change	+/-2 GL+ change in system water	+/- 0.5% change on a single class	+/- 1 GL change in SA storage right	No water quality emergency or improvements	No identified change	Temporary change in sites or values of local significance	+/- 0.9 GL/day reduction in system capacity		No decrease to 0.4 GL/day increase in system capacity	+/- 5 jobs being affected	Temporary changes to private landholders	

Minor *Regional significance* *Local system benefits*		2-20 GL+ increase in system water	0.5 - 1% increase in allocation for any class of entitlement	1-10GL avoided risk of spill affecting SA storage right	Water quality improvements through a localised section of River Murray or tributary	Increased ability for environmental water delivery across a localised section of River Murray or major tributary	Permanent improvement to sites or values of local significance or temporary improvement to sites or values of regional significance	1.0 -2.4 GL/day increase in system capacity		0.5 – 1.4 GL/day or greater increase in system capacity	Creation of 5 – 50 river-dependent jobs	Permanent benefits to 1-10 private landholders and/or temporary benefits to a single community	
Moderate *State significance* *Regional system benefits*		20-100 GL+ increase in system water	1-5% increase in allocation for any class of entitlement	10-50GL avoided risk of spill affecting SA storage right	Water quality improvements through a major section of the River Murray or tributary	Increased ability for environmental water delivery across the major section of the River Murray or a major tributary	Permanent improvement to sites or values of regional significance or temporary improvement to sites or values of state significance	2.5 – 4.9 GL/day increase in system capacity		1.5 – 2.4 GL/day or greater increase in system capacity	Creation of 50 – 250 river-dependent jobs	Permanent benefits to 10-200 private landholders and/or temporary benefits to multiple communities	
Major *National significance* *Major system benefits*		100-200 GL+ increase in system water	5% - 10% increase in allocation for any class of entitlement	50-100GL avoided risk of spill affecting SA storage right	Water quality improvements through the River Murray and multiple major tributaries	Increased ability for environmental water delivery across the River Murray and multiple major tributaries	Permanent improvement to sites or values of state significance or temporary improvement to sites or values of national significance	5.0 – 9.9 GL/day increase in system capacity		2.5 – 4.9 GL/day or greater increase in system capacity	Creation of 250 – 500 river-dependent jobs	Permanent benefits to 200-500 private landholders and/or a single community	
Exceptional *International significance* *Basin-scale benefits*		200 GL+ increase in system water	10% or greater increase in allocation for any class of entitlement	100+ GL avoided risk of spill affecting SA storage right	Water quality improvements across the entire River Murray System and major tributaries	Increased ability for environmental water delivery across the Murray-Darling Basin	Permanent improvement to sites or values of international or national significance	10 GL/day or greater increase in system capacity		5.0 GL/day or greater increase in system capacity	Creation of 500 or more river-dependent jobs	Permanent benefits to more than 500 private landholders and/or multiple communities	

5.7 Risk assignment

Once likelihood and consequence ratings are assigned for each option at the sub-domain level, the risk assignment is then derived using the matrix provided in **Figure 34**.

LIKELIHOOD RATING	Almost Certain	NR1				N				PR1
	Likely									
	Possible		NR2						PR2	
	Unlikely									
	Remote				NR3		PR3			
		Catastrophic	Major	Moderate	Minor	Neutral	Minor	Moderate	Major	Exceptional
		CONSEQUENCE RATING								
		NEGATIVE RISK (Threats) - DISBENEFITS					POSITIVE RISK (Opportunity) - BENEFITS			

Risk Assignment	Outcome	Definition
PR 1	Positive Risk 1	Option provides a very positive opportunity
PR 2	Positive Risk 2	Option provides a medium opportunity
PR 3	Positive Risk 3	Option provides a low potential opportunity
N	Neutral	Option provides no risk impact or is not applicable
NR 3	Negative Risk 3	Option presents a low-risk potential
NR 2	Negative Risk 2	Option presents a medium risk potential
NR 3	Negative Risk 1	Option presents a high-risk potential
N/A	Not Assessed	Option unable to be assessed

Figure 34. *Matrix for risk assignment in the DMF*

6 Assessing the suites of options

6.1 'Do Nothing'

Assumed operational scenario

The 'do nothing' scenario is based on none of the intervention options being implemented and the system continuing to be operated as it is currently.

The following key assumptions have been made:

- The flow capacity of the Barmah-Millewa Reach continues to decline over the next decade by a further 1,000 ML/day as a result of sand aggradation and an additional 500 ML/day as a result of bank erosion (and hence loss of natural and constructed levees and effluent channel sills) resulting in the river being operated to a lower height.
- Tar-Ru operating rules remain unchanged. Tar-Ru filling would continue to prioritise waiting for unregulated flows during spring.
- As a result of reduced system capacity in the Barmah-Millewa Reach, river operators will need to:
  - manage transfers from Lake Hume during summer period at a lower rate and for a longer time than current operations, and/or
  - increase the frequency of transfers of consumptive water overbank at a time of the year when it is ecologically tolerable, incurring higher system losses (typically Nov – Dec).
- Current bypass routes are used to deliver historically similar volumes. No additional bypass or alternate flow paths are used to offset the reduction in Barmah-Millewa Reach flow capacity.
- There is no avulsion of the River Murray within the Barmah-Millewa Reach in the next 10-years (i.e., the river does not change its course).

Decision Making Framework Assessment

Table 62 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 62. Suite of Options Assessment – 'Do Nothing' considerations

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	N/A	N/A	N	Relative sharing of water between the States would not be affected.
	System water resources	Unlikely	Moderate impact	NR3	Additional losses in system water resources associated with additional overbank transfers. Additional overbank transfers might need to be made 1-2 times per 10 years to account for the reduced system capacity whilst meeting downstream demands ('unlikely' likelihood). If an additional overbank transfer were made through the Barmah-Millewa Forest, it is assumed that 50 GL of initial losses would be incurred (if there has been no water through the forest in the last 30 days), plus an ongoing use of 20% for the overbank component of flow. The initial losses may be offset if environmental water deliveries were made earlier in that season. The Tar-Ru transfers option (Option 3) identified an earlier transfer opportunity of about 120 GL of airspace in Tar-Ru that could have been filled with additional transfers in winter/spring. Assuming that a transfer of 4 GL/day overbank is made to Tar-Ru over 20 days = 80 GL * 20% loss component = 16 GL

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					losses. 50 + 16 = 66 GL additional losses. Moderate impact.
	Entitlements	Unlikely	Moderate impact	NR3	Additional overbank transfers = 66 GL of loss per transfer = 33 GL per State (Vic / NSW). 1,700 GL NSW general security 1,250 GL Vic high security ~ 2 - 3% of each State's entitlements affected by additional losses in the year it occurs. Moderate impact. Unlikely to occur in any given year, as described above.
	South Australian storage right	Rare	Moderate benefit	PR3	The increased losses and therefore reduction in system water resources would lead to a reduction in the risk of spills from storages. In turn, there may be some benefit for the South Australian storage right. As above, additional losses may be incurred 1-2 times in 10 years. Spill behaviour mostly unchanged. 'Rare' likelihood. Only positive outcome for events where not all entitlement would spill, potentially 10-50 GL of avoided spill if it occurred. Moderate benefit.
	Domain summary outcome			**NR3**	**Calculated as the 'average' of the above sub-domain assessments**
Environmental conditions	Water quality	Rare	Minor impact	NR3	Increased overbank deliveries through the Barmah-Millewa Forest in Nov-Dec could marginally increase the risk of blackwater events. At the flow range contemplated this would likely impact a localised section of the River Murray only. 'Minor' consequence. Increased overbank deliveries frequency 1-2 years in 10. Not every overbank event would cause blackwater. Therefore, 'rare' likelihood.
	Efficiency of environmental water use	Unlikely	Minor benefit	PR3	A reduction in flow capacity within the Barmah-Millewa Reach means that in years where the environmental water holders are targeting overbank flows to the forest, these deliveries would require less water to achieve. Around 2-3 deliveries per 10 years. 'Unlikely'. Only benefits the Barmah-Millewa Forest, a small section of the River Murray. 'Minor' benefit.
	Environmental conditions	Likely	Major impact	NR1	Extended periods of bankfull deliveries through the Barmah-Millewa Reach would increase in their frequency and duration, increasing the risk for environmental impacts associated with erosion and unseasonal flooding of the Barmah-Millewa Forest. Sand accumulation would continue to further impact on environmental values such as fish habitat. Extended bankfull events would be expected regularly and the environmental impacts of such prolonged flows are well documented. 'Likely' impact. Temporary (recoverable) loss of sites and values of international / national significance (within the Ramsar listed Forest). 'Major' consequence.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Domain summary outcome			NR2	The significant impact on environmental conditions and slight impact on water quality are considered the most substantial considerations for environmental conditions and inform this domain summary outcome.
Delivery risk	Environment	Rare	Minor impact	NR3	Environmental flow deliveries usually target the Winter – Spring period. Years targeting overbank deliveries would be unaffected. For years within channel capacity, there is likely spare unused capacity which could continue to support environmental flow deliveries. 'Rare' likelihood of increased shortfall risk to environmental flow deliveries. 1-2 GL reduction in system capacity. 'Minor' impact.
	Irrigators	Likely	Major impact	NR1	It is assumed that, if no intervention options are implemented, there could be a 1,500 ML/day reduction in the flow capacity in the Barmah-Millewa Reach in the next 10 years. This would most likely affect years of high-water availability and dry seasonal conditions. These conditions are expected around 2 - 5 years in 10. 'Likely'. 1.5 GL/day further reduction in flow capacity. 'Major' impact.
	Domain summary outcome			NR1	The significant increase in the risk of being unable to meet irrigation demand is the most substantial consideration in evaluating the overall delivery risk outcome for this domain.
River communities	River dependent businesses & townships	Unlikely	Neutral	N	No permanent or temporary loss of river dependent businesses expected. Neutral consequence. Note that this does not consider impacts to irrigators or communities as a result of reduced capacity as that is considered a flow-on impact in the 'delivery risk' criteria above.
	Landholder & social considerations	Likely	Minor impact	NR2	Barmah-Millewa Reach being run at bankfull for longer periods more frequently. Increased frequency and duration of prolonged bankfull events causing increased accelerated erosion of the riverbanks will have adverse social impacts. Environmental health and amenity further affected. Extended bankfull events would be expected regularly and the environmental impacts of such prolonged flows are well documented. 'Likely'. Impacts of more frequent overbank events would affect the local community. 'Minor' consequence.
	Domain summary outcome			NR2	The medium risk of impact on the local community is the most substantial consideration in evaluating the outcomes for this domain, noting that river dependent businesses and townships are expected to be largely unaffected.

6.2 Suite 1: Maintain current capacity at 9,200 ML/day

Assumed operational scenario

The options implemented under this scenario include:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (*no works*) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).

Under a 'Maintain current capacity' scenario, it is assumed that:

- All options are used in most years (5 – 9 years in 10) to manage the system and create flow variability in the Barmah-Millewa Reach. There will be some years where the bypass options are not used. This may include years with high unregulated flows across the system, or where their use would not be a cost-effective solution for that season.
- The delivery risk is assessed as the likelihood of the infrastructure being available to help manage a potential shortfall event (almost certain).
- The Victorian Mid-Murray Storages are only used for capturing Victorian tributary flows (rather than Hume transfers).
- Any additional losses incurred by using the bypass options are shared equally by Victoria and NSW.

Decision Making Framework Assessment

Table 63 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 63. Suite of Options Assessment – Suite 1: 'Maintain current capacity' considerations

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	N/A	N/A	N	Relative sharing of water between the States would not be affected.
	System water resources	Likely	Minor impact	NR2	0.5 GL/day delivered through MIL. 5 – 13 GL of additional losses incurred each year. 'Minor' consequence Assume that the bypass route is used most years to create variability. Likely.
	Entitlements	N/A	Neutral	N	Additional losses associated with bypass = 3 - 6 GL of loss per State per year (Vic / NSW). 1,700 GL NSW general security 1,250 GL Vic high security < 0.5 % of each State's entitlements affected by additional losses in the year it occurs. 'Neutral' impact.
	South Australian storage right	N/A	Neutral	N	The marginal change in losses and system water resources would not have any material impact on storage levels. No material change on South Australia's storage right (neutral consequence).
	Domain summary outcome			**NR3**	**Whilst there is a medium risk of system water resources being affected, there are neutral outcomes expected for State water shares, entitlements, and South Australia storage rights. Taking this**

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					into account, there is a low-risk potential impact on water availability.
Environmental conditions	Water quality	Likely	Minor impact	NR2	**Riverbank works** – no substantial changes in water quality compared to current conditions. **Sediment removal** – residual plumes of fine sediment in the reach increases nutrient loads in the water column. Potential, but unlikely, presence of heavy metals. Assume that these risks would be appropriately investigated, environmental effects documented, and mitigation controls are undertaken to prevent significant impacts. **VMMS** – salinity managed in accordance with salinity operating procedures and within limits. **MIL escapes** – flows to manage water quality in watercourses still delivered. **Overall -** Potential water quality issue in a localised section of the River Murray associated with the sediment removal. 'Minor' impact. Sediment removal planned to occur most years to every year. 'Likely'.
	Efficiency of environmental water use	Likely	Minor benefit	PR2	**MIL escapes** – environmental water used to manage water quality through natural watercourses. Part of these flows can be re-directed to other environmental purposes as bypass flows can be used for this purpose (as well as to deliver bypass volumes). **Overall –** 'Minor' benefit. 'Likely' based on the understanding that environmental water is used to manage water quality through MIL watercourses most years.
	Environmental conditions	Likely	Minor impact	NR2	**Riverbank works** – holding the line, not an improvement program, neutral environmental conditions outcomes. **Sediment removal** – potential for localised environmental impacts, but also has localised environmental benefits. Environmental impacts – setup works to put infrastructure in place, operational ongoing discharge, truck movements, etc. Environmental benefits – from restoring in-stream habitat, halting the continual supply of sand into the Barmah-Millewa Reach, restoring some localised values of the reach.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					MIL escapes – marginal (negligible) positive outcomes from flexibility in delivery of water in the Barmah-Millewa Reach as well as through in natural watercourses. **VMMS** – neutral environmental conditions outcomes, on basis that storages continue to be managed within operating limits including consideration of Ramsar requirements. **Overall –** considering the impacts associated with implementing the works in ecologically sensitive areas and considering that the sediment removal program aims to 'hold the line' rather than restore previous conditions, this is assessed as having temporary impacts on sites of regional significance – 'minor' impact. 'Likely' that there will be some impacts associated with implementing and operating the works (almost every year).
	Domain summary outcome			**NR3**	**There are medium risks of adverse outcomes for water quality and environmental conditions. These are slightly offset by the opportunity for improved efficiency of environmental water use. This results in an overall low risk potential at the domain level.**
Delivery risk	Environment	Likely	Neutral	N	Environmental flow deliveries usually target winter – spring period. For years targeting overbank deliveries, no change. For years within channel capacity, no change. 'Neutral' consequence.
	Irrigators	Likely	Neutral	N	No change to flow capacity. Assuming that development is maintained as current, 'Neutral' consequence.
	Domain summary outcome			**N**	**Delivery risk is unchanged as the current flow capacity is maintained.**
River communities	River dependent businesses & townships	Likely	Minor benefit	PR2	Creation of local opportunities for businesses through the construction and operation of the options. 15 – 25 jobs created from sediment management[95]. Assume 5 – 10 jobs from other options. 20 – 35 jobs created in total.

[95] Streamology (2022), *Barmah-Millewa Reach: Sand management options report*

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					This suite 'holds the line' – no existing businesses expected to be permanently adversely affected. Some may be impacted temporarily while works are put in place. **Overall –** sustained revenue being provided for 5 – 50 jobs provide a 'moderate' benefit. 'Likely' – implementing the options will create the sustained roles ongoing.
	Riparian landholder impacts	Likely	Minor impact	NR2	**Riverbank works** – minimal and localised social impacts when works are occurring. **Sediment management** – there could be negative impacts on social values with the extraction of sediment from the riverbed, such as the closure of areas of the river for recreation while the works are underway, or the removal of vegetation to install pipes and pumps to move the sand[96]. It is likely that there will be concern within river communities about the environmental, social, and cultural impacts of undertaking such works and how these will be managed. **MIL** – localised landholder benefits from created flows in watercourses. **VMMS** – localised recreational impacts on Lake Boga, Lake Charm & Kangaroo Lake. **Overall** – assessed as having temporary impacts or benefits to local communities, with impacts being more significant in this case. 'Minor' impact. 'Likely' – options in place most to every year.
	Domain summary outcome			N	River community outcomes are considered neutral as the job creation for local businesses and townships is considered to balance the potential impacts on local landholders and communities associated with the implementing the options.

[96] Streamology (2021), *Op. Cit.*

6.3 Suite 2A: Reinstate 500 ML/day of capacity (MIL options only)

Assumed operational scenario

Suite 2A consists of the options listed in Suite 1, as well as one additional option:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (no works) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).
- The MIL escapes are upgraded (Option 4A.2).

The MIL escapes are upgraded (Option 4A.2Decision Making Framework Assessment

Table 64 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 64. Suite of Options Assessment – Suite 2A: 'Reinstate +500 ML/day' considerations (MIL options only)

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	N/A	N/A	N	Relative sharing of water between the States would not be affected.
	System water resources	Likely	Minor impact	NR2	Around 1,000 ML/day delivered through MIL. 10 – 26 GL of additional losses incurred, average 18 GL – 'minor' consequence 'Likely' – bypass used most years.
	Entitlements	Likely	Minor impact	NR2	Additional losses associated with bypass = 5 – 13 GL of loss per State per year (Vic / NSW). 1,700 GL NSW general security 1,250 GL Vic high security 0.5 – 1.0% of each State's entitlements affected by additional losses in the year it occurs. 'Minor' impact. 'Likely', as above.
	South Australian storage right	Unlikely	Neutral	N	The marginal change in losses and system water resources would not have any material impact on storage levels. No material change on South Australia's storage right (neutral consequence).
	Domain summary outcome			NR3	There are medium risk impacts to both system water resources and entitlements; however, State water shares and the South Australian storage rights are likely unaffected. Accordingly, at the domain-level, it is assessed that there is a low-risk of impact to water availability from this option.
Environmental conditions	Water quality	Likely	Minor impact	NR2	Assessment for riverbank works, sediment removal and VMMS as per Suite 1 ('maintain current capacity'). Increased use of MIL escapes by 500 ML/day will not change water quality. Rating unchanged from Suite 1.
	Efficiency of environmental water use	Likely	Minor benefit	PR2	Assessment for riverbank works, sediment removal and VMMS as per Suite 1 ('maintain current capacity').

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					Increased MIL system capacity for some escapes will allow more environmental water to be delivered to the local watercourses in this system. Rating unchanged from Suite 1.
	Environmental conditions	Likely	Minor impact	NR2	Increased use of MIL escapes by a further 500 ML/day will provide additional positive outcomes from flexibility in delivery of water in the Barmah-Millewa Reach as well as through natural watercourses. This will provide opportunity for enhanced environmental outcomes. **Overall –** when considered against the environmental impacts of sediment management, it is considered that this suite still has an overall 'minor' impact. Unchanged from Suite 1.
	Domain summary outcome			**NR3**	**Consistent with Suite 1, there are medium risks of adverse outcomes for water quality and environmental conditions. These are slightly offset by the opportunity for improved efficiency of environmental water use. This results in an overall low risk potential at the domain level.**
Delivery risk	Environment	N/A	Neutral	N	Increased size of some MIL escapes would provide some additional opportunity for environmental flow deliveries to local areas. Marginal (neutral) opportunity.
	Irrigators	Likely	Minor benefit	PR2	Additional flow capacity over summer of 500 ML/day compared to current conditions. 'Minor' improvement. 'Likely' – bypass used most years.
	Domain summary outcome			**PR3**	**There is a medium opportunity for better managing delivery risks to irrigators; however, these flows are unlikely to meaningfully contribute to planned environmental watering. Accordingly, this result is an overall minor opportunity at the domain level.**
River communities	River dependent businesses & townships	Almost certain	Minor benefit	PR2	Some additional temporary jobs (minor) associated with upgrading some of the MIL escapes. No adverse impacts on river dependent businesses from the MIL escapes. No material change from Suite 1.
	Riparian landholder impacts	Likely	Minor impact	NR2	Some additional localised landholder benefits from additional watering. Some minor temporary impacts to private landholders associated with upgrade works. No material change from Suite 1.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Domain summary outcome			N	Business opportunities balanced by localised construction and operation impacts on communities.

6.4 Suite 2B: Reinstate 500 ML/day of capacity (MIL & Vic options)

Assumed operational scenario

Instead of increasing the MIL escape capacity (as for Suite 2A), this option considers using the existing MIL escape capacity and using Victorian infrastructure to provide the additional capacity. Having this option available would give the MDBA some additional flexibility between options and between different jurisdictions.

Suite 2B consists of the options listed in Suite 1, as well as one additional option:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (*no works*) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).
- The Rochester bypass channel is constructed (Option 5D).

Decision Making Framework Assessment

Table 65 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 65. Suite of Options Assessment – Suite 2B: 'Reinstate +500 ML/day' considerations (MIL and Vic options)

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	N/A	N/A	N	Relative sharing of water between the States would not be affected.
	System water resources	Likely	Minor impact	NR2	**MIL escapes -** 500 ML/day delivered through MIL 5 – 13 GL of additional losses incurred **RO 14 -** 500 ML/day delivered through RO14 5 GL of additional losses incurred, assuming no offset in reduced losses from current delivery routes. **Overall -** Total change in system water resource of around 10 – 18 GL per year. Average of 14 GL per year. 'Minor' impact. 'Likely' that bypass used most years.
	Entitlements	Likely	Minor impact	NR2	Additional losses associated with bypass = 5 - 9 GL of loss per State per year (Vic / NSW). 1,700 GL NSW general security 1,250 GL Vic high security 0.5 – 1.0% of each State's entitlements affected by additional losses in the year it occurs. 'Minor' impact. 'Likely', as above.
	South Australian storage right	Unlikely	Neutral	N	The marginal change in losses and system water resources would not have any material impact on storage levels. No material change on South Australia's storage right (neutral consequence).

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Domain summary outcome			NR3	There are medium risk impacts to both system water resources and entitlements; however, State water shares and the South Australian storage rights are likely unaffected. Accordingly, at the domain-level, it is assessed that there is a low-risk of impact to water availability from this option.
Environmental conditions	Water quality	Likely	Minor impact	NR2	Assessment as above for Suite 1. Water quality unaffected by the Rochester 14 channel being constructed.
	Efficiency of environmental water use	Likely	Moderate benefit	PR2	**RO 14 channel –** less IVT in the Goulburn River means that more environmental water could be used to meet environmental watering targets. This increases return flows and creates additional opportunities in the Murray. 'Moderate' benefits.
	Environmental conditions	Likely	Neutral	N	**RO 14 channel –** by delivering IVT water through the Rochester channel, the flow volumes may reduce over summer, and greater variability in flows could be achieved in the lower Goulburn and lower Broken Creek or alternatively larger volumes of environmental water can be delivered with return flows supporting better environmental outcomes in the Murray system. Significant ecological condition opportunities created. Construction of the new discharge structure to the River Murray will require works in environmentally sensitive areas which will need to be appropriately managed and offset. **Overall –** the environmental condition impacts associated with the sediment removal program offset the significance of the environmental opportunity provided by the RO14 option. 'Neutral beneficial outcomes overall.
	Domain summary outcome			N	The potential medium risk in water quality is offset by the potential medium opportunity to improve the efficiency of environmental water use. The environmental condition impacts associated with sediment removal are offset by the environmental opportunities created by the RO14 bypass channel. Neutral overall outcomes.
Delivery risk	Environment	Possible	Minor benefit	PR3	500 ML/day of IVT delivery through the RO 14 channel may free up channel capacity over summer in the Goulburn River and could allow for additional environmental water to be delivered, benefiting from return flows and contributing to environmental watering along the Murray system. This may provide a minor benefit for environmental water delivery.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					Assuming environmental water deliveries are prioritised outside of the summer period, likelihood is 'possible'
	Irrigators	Almost certain	Minor benefit	PR2	Additional flow capacity over summer of 500 ML/day compared to current conditions. 'Minor' improvement. Almost certain.
	Domain summary outcome			PR2	The moderate opportunity for better managing delivery risks to irrigators, combined with the minor opportunity to enhance environmental watering opportunities, provides a medium opportunity overall for this domain.
River communities	River dependent businesses & townships	Almost certain	Minor benefit	PR2	Some additional temporary employment opportunities during construction of the Rochester 14 channel upgrade. No increases in long-term employment opportunity, however. No adverse impact on river dependent businesses and townships associated with Rochester channel. No material change from Suite 1.
	Riparian landholder impacts	Likely	Minor impact	NR2	**RO 14 channel** – 100+ landholders temporarily impacted from construction works and expanded easement size but duly compensated. 'Minor' enduring impact.
	Domain summary outcome			N	Business opportunities balanced by localised construction and operation impacts on communities.

6.5 Suite 3: Reinstate 1,000 ML/day of capacity

Assumed operational scenario

This scenario is a combination of Suites 2A and 2B and consists of:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (*no works*) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).
- The MIL escapes are upgraded (Option 4A.2).
- The Rochester 14 bypass channel is constructed (Option 5D).

Decision Making Framework Assessment

Table 66 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 66. Suite of Options Assessment – Suite 3: 'Reinstate +1,000 ML/day' considerations

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	N/A	N/A	N	Assessment as above for Suites 2A & 2B. Relative sharing of shares between States would not be affected.
	System water resources	Likely	Moderate impact	NR2	**MIL -** 1,000 ML/day delivered through MIL 10 – 21 GL of additional losses incurred. **RO14 -** 500 ML/day delivered through RO14 5 GL of additional losses incurred. **Overall -** Total change in system water resource of around 15 – 26 GL per year. Average 21 GL per year. 'Moderate' impact. 'Likely' that bypass options used most years.
	Entitlements	Likely	Moderate impact	NR2	Additional losses associated with bypass = 8 - 13 GL of loss per State per year (Vic / NSW). 1,700 GL NSW general security 1,250 GL Vic high security 1.1% of Vic entitlements affected by additional losses in the year it occurs. 'Moderate' impact.
	South Australian storage right	Unlikely	Neutral	N	The marginal change in losses and system water resources would not have any material impact on storage levels. No material change on South Australia's storage right (neutral consequence).
	Domain summary outcome			NR3	There are medium risk impacts to both system water resources and entitlements; however, State water shares and the South Australian storage rights are likely unaffected. Accordingly, at the domain-level, it is assessed that there is a low-risk of impact to water availability from this option.
Environmental conditions	Water quality	Likely	Minor impact	NR2	Assessment as above for Suite 2A & 2B.
	Efficiency of environmental water use	Likely	Moderate benefit	PR2	Assessment as above for Suite 2A & 2B.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Environmental conditions	Likely	Minor benefits	PR2	Ecological outcomes enhanced by implementing both the RO channel as well as maximising use of the MIL escapes. **Overall –** the combination of environmental outcomes from both the RO channel and the MIL escapes is sufficient to be considered slightly positive, in the context of the impacts from the sediment removal program. 'Minor' benefits.
	Domain summary outcome			PR3	The moderate opportunity to enhance environmental condition provided from the upgraded MIL escapes and the RO14 bypass channel, combined with the opportunity to improve the efficiency of environmental water use, are somewhat balanced by managing the water quality risk associated with the sediment management program. Overall, there is expected to be a minor opportunity.
Delivery risk	Environment	Almost certain	Minor benefit	PR2	**MIL -** Some additional environmental capacity by upgrading MIL escapes. 1.0 GL of additional system capacity from upgrading MIL escapes. **RO14 -** 0.5 GL of additional system capacity in the lower Goulburn River and/or lower Broken Creek from the RO channel **Overall -** 1.5 GL of additional capacity for delivering environmental water deliveries in Spring. 'Minor' benefit.
	Irrigators	Almost certain	Minor benefit	PR2	Additional flow capacity over summer of 1,000 ML/day compared to current conditions. 'Minor' benefit.
	Domain summary outcome			PR2	Moderate opportunities for managing delivery risks for irrigators and the environment provides an overall moderate opportunity for this domain.
River communities	River dependent businesses & townships	Almost certain	Minor benefits.	PR2	As per Suites 2A & 2B.
	Riparian landholder impacts	Likely	Minor impact	NR2	Cumulative minor enduring impacts from implementing both all MIL upgrades and constructing the RO 14 channel.
	Domain summary outcome			N	Business opportunities balanced by localised construction and operation impacts on communities.

6.6 Suite 4: Reinstate 1,500 ML/day of capacity

Assumed operational scenario

Suite 4 consists of the options listed in Suite 3, as well as four additional options:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (*no works*) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).
- The MIL escapes are upgraded (Option 4A.2).
- The Rochester 14 bypass channel is constructed (Option 5D).
- Early transfers to Tar-Ru (Option 3) can be made using the risk-based framework.
- Perricoota Escape expansion is constructed (Option 4B)
- Mulwala Canal extension is constructed (Option 4C).
- The MVIA outfalls are upgraded (Option 5B)

For purposes of assessing the consequences of the Tar-Ru transfers option, it is assumed that any missed harvesting opportunities impact on internal spill behaviour and in turn, on State entitlements. There is a potential opportunity for the environmental water holders to agree to underwrite this potential risk if earlier transfers provide opportunity for enhanced environmental water deliveries.

Decision Making Framework Assessment

Table 67 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 67. Suite of Options Assessment – Suite 4: 'Reinstate +1,500 ML/day' considerations

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	Rare	Moderate impact	NR3	**Tar-Ru transfers -** Early transfer opportunity around 1 - 2 times per decade. The Tar-Ru option identified an opportunity of about 80-120 GL of airspace in Tar-Ru that could have been filled with additional transfers in winter/spring. Assuming that early transfers would be ceased if there are signs of unregulated inflows, the lost harvesting opportunity could be around a third of the transfer, in the range of 30 – 40 GL. This would be a 'moderate' impact. The likelihood of this occurring is less than 1 in 20 years, 'rare' likelihood. **Other options -** the other additional options would not affect the sharing of State water shares.
	System water resources	Likely	Moderate impact	NR2	**MIL escapes -** 10 – 21 GL additional losses. **RO14 -** 5 GL additional losses incurred. **Perricoota -** 2 – 4 GL additional loss **Mulwala -** 0 – 1 GL additional loss **MVIA outfalls -** 0 – 1 GL additional loss **Tar-Ru -** Assume a 30-40 GL loss (missed harvesting opportunity) occurs once every 20 years = 1.5 – 2 GL every year averaged. **Overall -** total change in system water resource of around 19 - 34 GL per year. Average of 25 GL per year. 'Moderate' impact. Likely to occur in any given year, noting that Tar-Ru losses have been annualised.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Entitlements	Likely	Moderate impact	NR2	**Tar-Ru -** In the year where lost harvesting opportunity occurs from early Tar-Ru transfers, Victorian entitlements could be affected by 30 – 40 GL. **All other options -** additional losses associated with bypass = 10 - 17 GL of loss per State per year (Vic / NSW). **Overall -** in these years, Victorian entitlements would be affected by 40 – 57 GL. 1,250 GL Vic high security 3 – 5% of Victorian state shares would be affected in the years that this occurs. 'Moderate' impact. The likelihood of this occurring is less than 1 in 20 years, 'rare'. Results in NR3 rating. Alternately, in years where Tar-Ru does not affect entitlements, Victorian losses would be up to 17 GL or 1.4%, every year (Moderate impact), likely in any given year. **Overall –** adopt most adverse outcome, NR2.
	South Australian storage right	Unlikely	Minor benefit	PR3	Early Tar-Ru transfers allows South Australia to move any deferred water in Tar-Ru to Hume, which results in less risk of spills of deferred water, providing a 'minor' benefit (1 – 10 GL). Early transfer opportunity around 1 – 2 times per decade, 'unlikely'.
	Domain summary outcome			**NR2**	**The moderate risks to system water resources and entitlements associated with bypass losses are compounded by the risk to State water shares associated with early Tar-Ru transfers and potential for internal spill behaviour changes. This results in a moderate overall risk to water availability at the domain level.**
Environmental conditions	Water quality	Likely	Minor impact	NR2	**Tar-Ru** - unlikely to affect water quality. **Perricoota** - unlikely to affect water quality. **Mulwala extension -** unlikely to affect water quality. **MVIA outfalls -** unlikely to affect water quality. **Overall -** assessment as for Suite 3.
	Efficiency of environmental water use	Likely	Moderate benefit	PR2	**Tar-Ru early transfers -** late Spring / early summer transfers to Tar-Ru would create additional opportunities for enhanced environmental flow deliveries by piggybacking in this period, recognising these beneficial outcomes are for reaches upstream of Tar-Ru. **Mulwala Canal extension -** some very marginal additional efficiency in environmental water use by enabling deliveries into the Yallakool Creek system, although, mostly constrained in volumes by Wakool system downstream.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					Moderate benefit as previously assessed. **Perricoota -** no change to efficiency of e-water. **MVIA outfalls -** no change to efficiency of e-water, assuming any additional capacity in the lower Broken Creek is used to provide additional bypass deliveries. **Overall -** some improvement in benefit from earlier Tar-Ru transfers creating more opportunity for environmental water piggybacking during winter/spring. Moderate benefit retained.
	Environmental conditions	Likely	Minor benefits	PR2	**Tar-Ru transfers -** opportunity to improve environmental condition along the River Murray associated with higher winter-spring flows and piggybacking opportunities for environmental watering deliveries. **Mulwala Canal extension -** very minor opportunity for improving environmental condition of the Yallakool Creek system, noting low volumes able to be delivered. **Perricoota Escape expansion -** no real impact or benefit. **MVIA outfalls -** no change. **Overall -** some additional environmental condition benefits associated with additional flow capacity and created opportunities for enhanced e-water outcomes along River Murray. Still assessed as minor benefit overall, noting the sediment management program impacts.
	Domain summary outcome			PR3	The moderate opportunity to enhance environmental condition combined with the opportunity to improve the efficiency of environmental water use, are somewhat balanced by managing the water quality risk associated with the sediment management program. Overall, there is expected to be a minor opportunity.
Delivery risk	Environment	Almost certain	Minor benefit	PR2	**MIL -** Some additional environmental capacity by upgrading MIL escapes. 1.0 GL of additional system capacity from upgrading MIL escapes. **RO14 -** 0.5 GL of additional system capacity in the lower Goulburn River and/or lower Broken Creek from the RO channel **Other bypass options -** 0.5 GL of additional system capacity from the new measures. **Overall -** 2.0 GL of additional capacity for delivering environmental water deliveries in Spring 'Minor' benefit.
	Irrigators	Almost certain	Moderate benefit	PR2	Additional flow capacity over summer of 1,500 ML/day compared to current conditions. 'Moderate' benefit.
	Domain summary outcome			PR2	Moderate opportunity from both sub-domain assessments.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
River communities	River dependent businesses & townships	Almost certain	Minor benefit	PR 2	Some additional short-term employment from constructing the Mulwala, Perricoota and MVIA options. Remains a minor benefit.
	Riparian landholder impacts	Likely	Moderate impact	NR2	**Tar-Ru:** no impacts on private landholders. **Mulwala Canal extension:** provides a positive outcome for local landholders on the Yallakool Creek system. Construction affects around 3 local landholders. **Perricoota Escape expansion:** around 12 local landholders impacted during construction. **MVIA outfalls:** localised and temporary impacts during construction. **Overall:** Multiple communities affected by temporary impacts. 'Moderate' impact.
	Domain summary outcome			N	Business opportunities balanced by localised construction and operation impacts on communities.

6.7 Suite 5: 'Do everything' – additional 3,000 ML/day capacity

Assumed operational scenario

In addition to the options implemented for Suite 4:
Suite 4 consists of the options listed in Suite 4, as well as two additional options:

- Riverbank works (Option 1).
- Sediment removal (Option 2).
- MIL escapes (*no works*) (Option 4A.1)
- Enhanced use of the VMMS (Option 5A).
- The MIL escapes are upgraded (Option 4A.2).
- The Rochester 14 bypass channel is constructed (Option 5D).
- Early transfers to Tar-Ru (Option 3) are available.
- Perricoota Escape expansion is constructed (Option 4B)
- Mulwala Canal extension is constructed (Option 4C).
- The MVIA outfalls are upgraded (Option 5B)
- The Barmah bypass gravity channel is constructed (Option 5C)
- Snowy transfers via the Murrumbidgee system are implemented (Option 6).

Under this scenario, it is assumed that:

- Snowy transfers are consistently delivered as 50 GL per annum (500 ML/day) and assuming limited ability to adjust deliveries during any given water year.
- Barmah gravity channel is assumed to be used for delivering bypass water for the entire summer period (and available in other seasons during the year).

Decision Making Framework Assessment

Table 68 provides a summary of the scoring for each of the decision-making framework domains and the key matters considered in determining each rating.

Table 68. Suite of Options Assessment – Suite 5: 'Do everything' considerations

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
Water availability	State water shares	Rare	Moderate impact	NR3	**Snowy transfers -** 50 GL of delivery via Murrumbidgee rather than via Murray. It is assumed suitable water accounting processes are implemented to ensure that there are no impacts on state water shares associated with the delivery of these transfers – neutral. **Barmah gravity channel -** no impact on State water shares. Unchanged from Suite 4.
	System water resources	Likely	Moderate impact	NR2	**MIL escapes -** 10 – 21 GL additional losses. **RO 14 -** 5 GL additional losses incurred. **Perricoota -** 2 - 4GL additional loss **Mulwala -** 0 – 1 GL additional loss **MVIA outfalls -** 0 – 1 GL additional loss **Barmah gravity channel -** 10 GL additional loss. **Snowy transfers -** 7 GL additional loss. **Tar-Ru -** Assume a 30-40 GL loss (missed harvesting opportunity) occurs once every 20 years = 1.5 – 2 GL every year averaged. **Overall -** total change in system water resource of around 36 - 51 GL per year. Average of 43 GL per year. 'Moderate' impact.

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
	Entitlements	Likely	Moderate impact	NR2	**Snowy -** may have some impacts on entitlements depending on if Snowy transfer water is being held in storage and affects Murrumbidgee entitlement holders during spills or spills are deducted from the Murray component and impacts Murray entitlement holders. Additional losses associated with bypass = 18 – 26 GL of loss per State per year (Vic / NSW) In the year where lost harvesting opportunity occurs from early Tar-Ru transfers, Victorian entitlements could be affected by 30 – 40 GL. In these years, Victorian entitlements would be affected by 30 – 40 GL from Tar-Ru, plus half of the increased system losses, being 18 – 26 GL, adding to a total of 48 – 66 GL. 1,250 GL Vic high security 4 – 5.5% of Victorian state shares would be affected in the years that this occurs. Moderate impact. The likelihood of this occurring is less than 1 in 20 years, rare. Alternately, in years where Tar-Ru does not affect entitlements, Victorian losses would be up to 26 GL or 2%, every year (moderate impact), likely.
	South Australian storage right	Unlikely	Minor benefit	PR3	Assessment as above for Suite 4.
	Domain summary outcome			NR2	The moderate risks to system water resources and entitlements associated with bypass losses are compounded by the risk to State water shares associated with early Tar-Ru transfers and Snowy intervalley transfers, as well as the potential for internal spill behaviour changes. This results in a moderate overall risk to water availability at the domain level.
Environmental conditions	Water quality	Likely	Minor impact	NR2	**Snowy -** unlikely to affect water quality. **Barmah channel -** unlikely to affect water quality. Assessment as above for Suite 4.
	Efficiency of environmental water use	Likely	Moderate benefit	PR2	**Snowy -** transfers being made in summer, assume no change to environmental watering in Murrumbidgee or River Murray. **Barmah -** no change. Moderate benefit as previously assessed.
	Environmental conditions	Likely	Major benefit	PR1	**Snowy -** potential impact on Tumut and lower Murrumbidgee, depending on the management of the Murrumbidgee and lower Goulburn. **Barmah channel -** potential benefits for enhanced flow regime in the Barmah-Millewa Reach. Drawback is construction works in environmentally sensitive areas associated with siphon under the lower

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					Broken Creek as well as the discharge structure on the River Murray banks. Benefits expects to outweigh short-term impacts, noting offsets would be required. **Overall** - major environmental conditions benefits expected by having significantly improved flexibility for managing deliveries in the Barmah-Millewa Reach as well as key tributaries such as the lower Goulburn, assuming that flows in other tributaries such as lower Murrumbidgee still managed in ecologically tolerable range. 'Major' benefit.
	Domain summary outcome			PR2	High opportunity for environmental condition outcomes associated with having all options operational is somewhat offset by the potential for water quality impacts, leading to an overall moderate environmental outcome.
Delivery risk	Environment	Likely	Moderate benefit	PR2	**Snowy:** no additional environmental capacity, only assumed to be used in summer. **Barmah channel:** could potentially be used to enhance or deliver environmental flows downstream of the reach in winter/Spring. **Overall** - 2.5 – 3.0GL of additional capacity for environmental flows. 'Moderate' benefit.
	Irrigators	Likely	Major benefit	PR1	Additional flow capacity over summer of 3,000 ML/day compared to current conditions. 'Major' benefit.
	Domain summary outcome			PR1	The high opportunity for mitigating risk to delivery shortfall events affected irrigators and the moderate opportunity for mitigating risks to delivering environmental water combine to provide a high opportunity generally for managing delivery risks.
River communities	River dependent businesses & townships	Almost certain	Moderate benefits	PR1	Significant additional temporary employment created from the construction of the major Barmah bypass channel.
	Riparian landholder impacts	Likely	Moderate impact	NR2	**Snowy** - local landholders may be adverse to additional flows in the Tumut River. **Barmah bypass channel** - more than 100 landholders and irrigators affected from the construction of the significant channel infrastructure, moderated by compensation Major impact, 100's of landholders affected across multiple communities **Overall** - Moderate impacts from having all options implementing impacting communities across the broader basin scale
	Domain summary outcome			PR3	The significant employment opportunities created by implementing all the options slightly outweigh the temporary and localised community impacts associated with their implementation, leading to a

Decision Domain	Sub-domain	Likelihood	Consequence	Rating	Key considerations
					minor opportunity for river communities through having all options implemented.

6.8 Summary of suites assessment

Table 69. Suites of options and assessment at domain level

					'Do nothing'	Suite 1	Suite 2A MIL only	Suite 2B MIL & Vic	Suite 3	Suite 4	Suite 5
			Annual system capacity (ML/day)	System capacity (rounded, ML/day)	Ongoing decline	Maintain current capacity	Reinstate +500 ML/day	Reinstate +500 ML/day	Reinstate +1,000 ML/day	Reinstate +1,500 ML/day	'Do everything'
Do nothing					-1,500	-1,500	-1,500	-1,500	-1,500	-1,500	-1,500
Implementation timeframe capacity loss							-500	-500	-500	-500	-500
Option 1	1	Riverworks	500	500		500	500	500	500	500	500
Option 2	2	Sediment removal	1,000	1,000		1,000	1,000	1,000	1,000	1,000	1,000
Option 3	3	Tar-Ru	100	100			[1]	[1]	[1]	100	100
Option 4	4A.1	Existing outlets	665	650		500	650	500	650	650	650
	4A.2	Upgraded outlets	295	350			350		350	350	350
	4B	Perricoota	200	200						200	200
	4C	Mulwala	38	50						50	50
Option 5	5A	VMMS[2]	0	0		Delivery shortfalls	Delivery shortfalls	Delivery shortfalls	Delivery shortfalls	Delivery shortfalls	Delivery shortfalls
	5B	Vic outfalls	110	150						150	150
	5C	Barmah channel	1,000	1,000							1,000
	5D	RO channel	500	500				500	500	500	500
Option 6	6	Snowy	500	500			[3]	[3]	[3]	[3]	500
Change from current (ML/day)					-1,500	0	500	500	1,000	1,500	3,000
Flow capacity (ML/day)					7,700	9,200	9,700	9,700	10,200	10,700	12,200
Construction and O&M costs ($ million)					-	$141 m	$171 m	$357 m	$382 m	$472 m	$1,325 m
Construction and O&M costs per ML/day bypass capacity					-	$95 k/ML	$85 k/ML	$178 k/ML	$153 k/ML	$157 k/ML	$294 k/ML
Water Availability Assessment					NR 3	NR 3	NR 3	NR 3	NR 3	NR 2	NR 2
Environmental Conditions Assessment					NR 2	NR 3	NR 3	N	PR 3	PR 3	PR 2
Delivery Risk Assessment					NR 1	N	PR 3	PR 2	PR 2	PR 2	PR 1
River Communities Assessment					NR 2	N	N	N	N	N	PR 3

[1] Note: While the Tar-Ru option is brought into the later suite of options, there are potentially significant outcomes in some years at a relatively low cost achievable by implementing this option. Governments may elect to include this option in earlier suites than shown.

[2] Note: The enhanced use of the VMMS is assumed to only contribute to mitigating delivery shortfall risks and not increasing system flow capacity.

[3] Note: The potential use of weirs in the Lower Murrumbidgee River, to reduce the risk of delivery shortfall in the River Murray, may warrant inclusion of a limited Snowy Transfer option in these suites.

Table 70. Summary of DMF outcomes per sub-domain

	Option suites						
	'Do nothing'	Suite 1	Suite 2A MIL only	Suite 2B MIL & Vic	Suite 3	Suite 4	Suite 5
	Ongoing decline	Maintain current capacity	Reinstate +500 ML/day	Reinstate +500 ML/day	Reinstate +1,000 ML/day	Reinstate +1,500 ML/day	'Do everything'
Water availability							
State water shares	N	N	N	N	N	NR 3	NR 3
System water resources	NR 3	NR 2	NR 2	NR 2	NR 2	NR 2	NR 2
Entitlements	NR 3	N	NR 2	NR 2	NR 2	NR 2	NR 2
South Australian storage right	PR 3	N	N	N	N	PR 3	PR 3
Summary Outcome	NR 3	NR 3	NR 3	NR 3	NR 3	NR 2	NR 2
Environmental condition							
Water quality	NR 3	NR 2	NR 2	NR 2	NR 2	NR 2	NR 2
Efficiency of environmental water use	PR 3	PR 2	PR 2	PR 2	PR 2	PR 2	PR 2
Environmental conditions	NR 1	NR 2	NR 2	N	PR 2	PR 2	PR 1
Summary Outcome	NR 2	NR 3	NR 3	N	PR 3	PR 3	PR 2
Delivery risk							
Environment	NR 3	N	N	PR 3	PR 2	PR 2	PR 2
Irrigators	NR 1	N	PR 2	PR 2	PR 2	PR 2	PR 1
Summary Outcome	NR 1	N	PR 3	PR 2	PR 2	PR 2	PR 1
River communities							
River-dependent business / townships	N	PR 2	PR 2	PR 2	PR 2	PR 2	PR 1
Riparian landholder impacts	NR 2	NR 2	NR 2	NR 2	NR 2	NR 2	NR 2
Summary Outcome	NR 2	N	N	N	N	N	PR 3

Timeframe to implement
The timeframe to develop and implement the individual options which form part of the suites have been estimated as part of the option assessment work. To understand the potential bypass flow capacity of the Barmah-Millewa Reach and how it may change over time under the different suites, this section graphs each of the suites from 2010 to 2032.

The flow capacity prior to 2022 is based on actual and observed flow-height relationships.

The flow capacity after 2022 represents the declining flow capacity associated with the continued aggradation of sand in the reach, which may be offset by implementing options considered in this report.

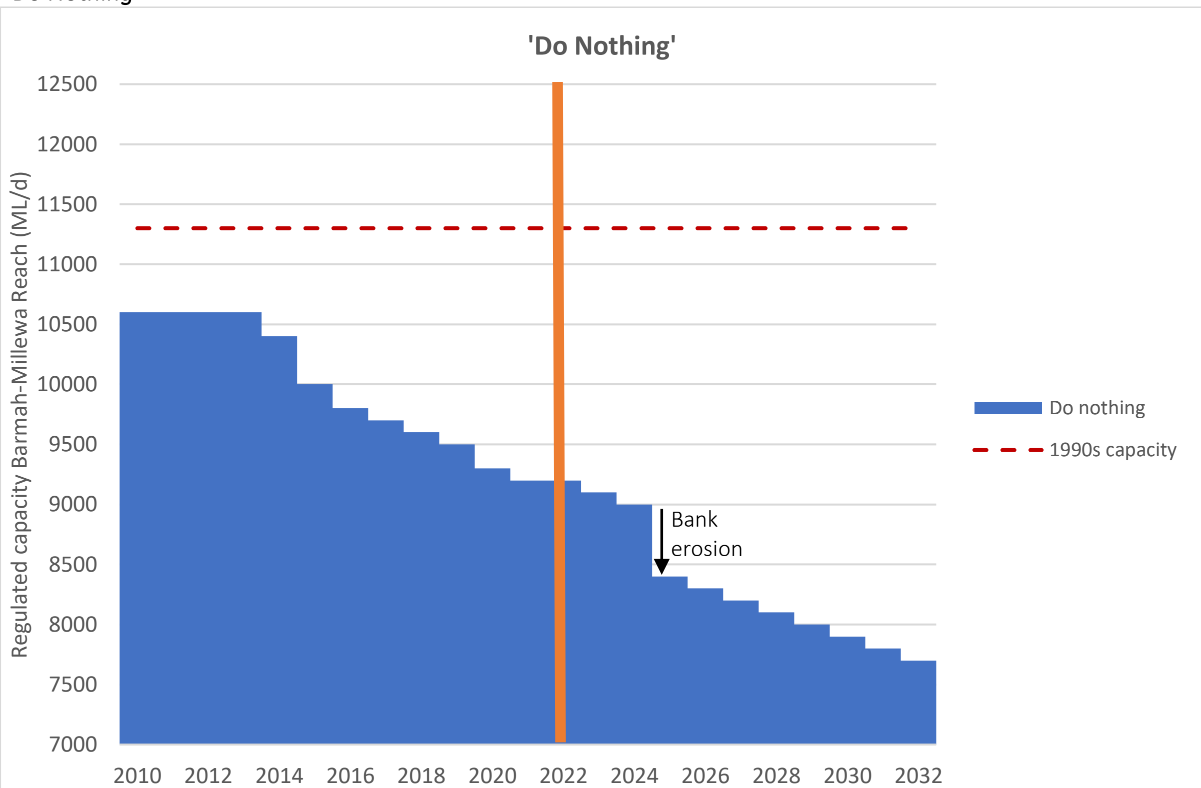
Note that the flow capacity for the 'do nothing' scenario assumes a further loss of 1,000 ML/day over 10 years (i.e., 100 ML/day loss of capacity per year), plus a further reduction of 500 ML/day due to bank erosion resulting in the river needing to be operated at a lower height to avoiding unseasonal forest flooding.

The 'do nothing' graph assumes that the 500 ML/day reduction occurs in around 2024. The timing of this event is entirely arbitrary, but considered realistic, noting that a 500 ML/day reduction in flow rate corresponds to operating the river around 200mm lower.

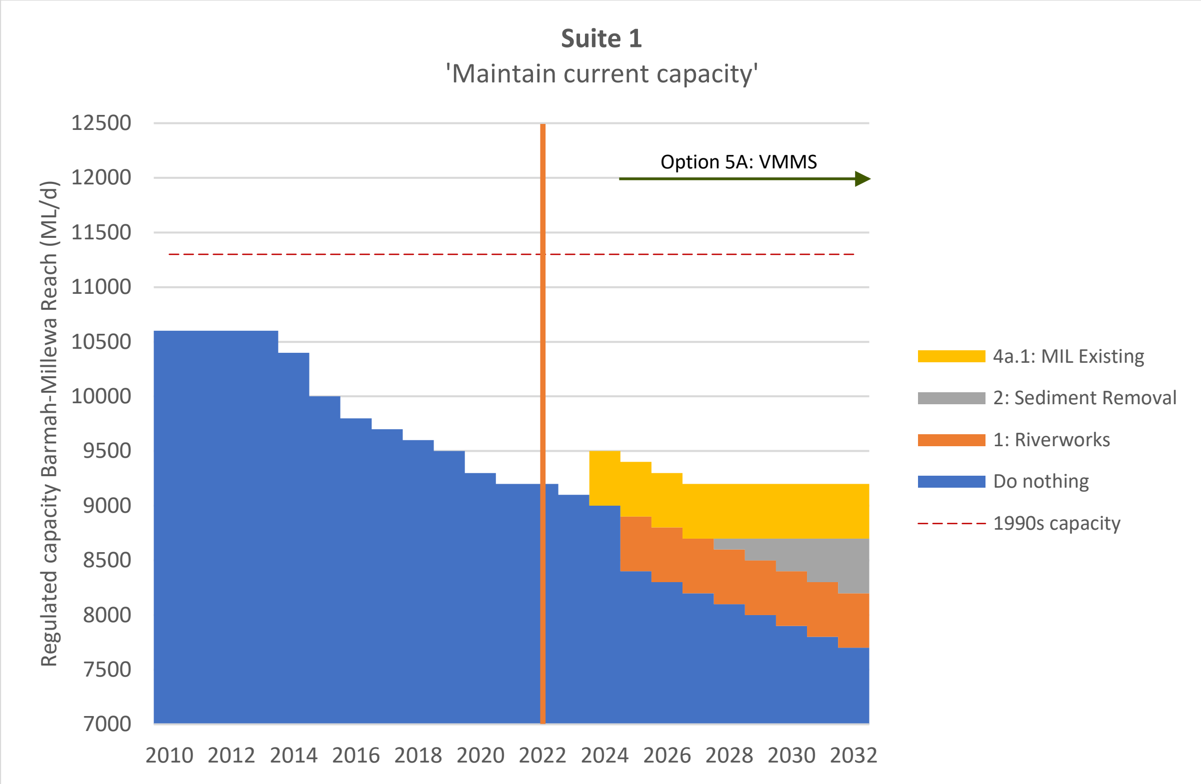
The dashed line represents the historical flow capacity as observed in the 1990s (11,300 ML/day).

The enhanced use of the Victorian Mid-Murray Storages (Option 5A) is shown separately, recognising that this option is most likely to contribute by helping to mitigate delivery shortfall risks in the lower Murray, rather than by adding bypass capacity to the system.

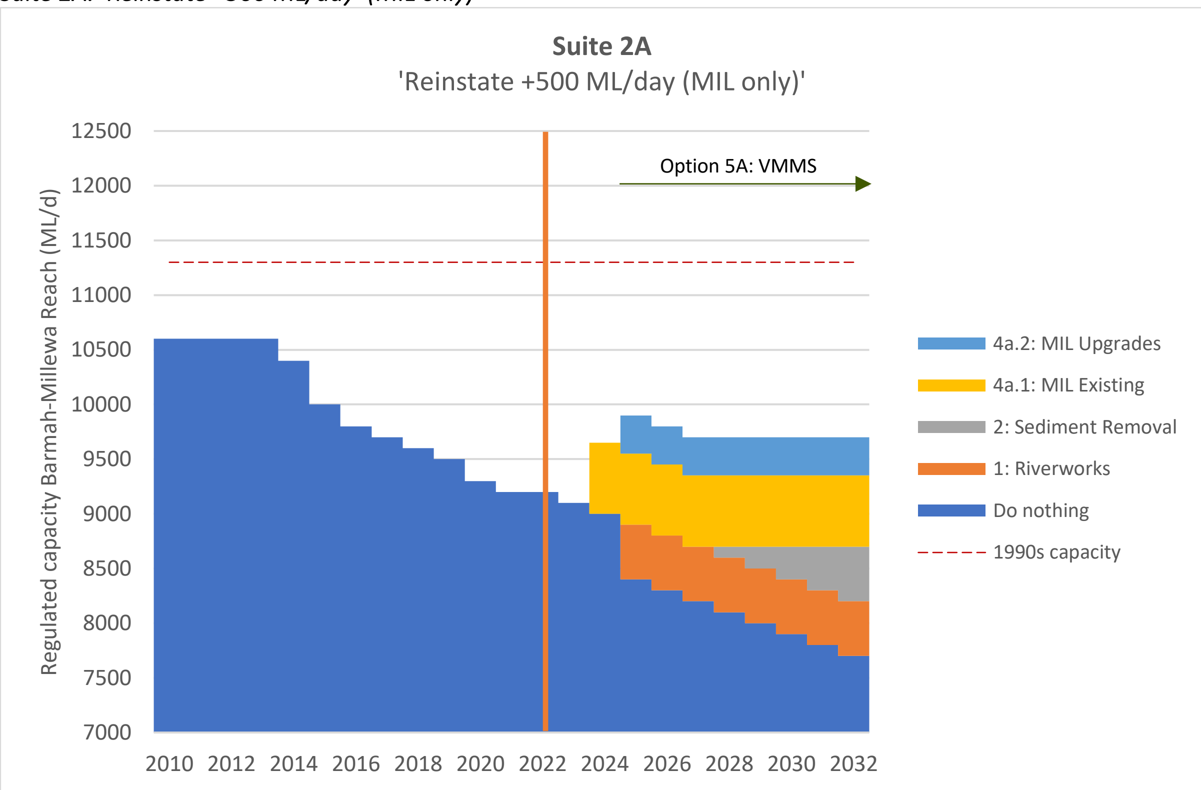
'Do Nothing'



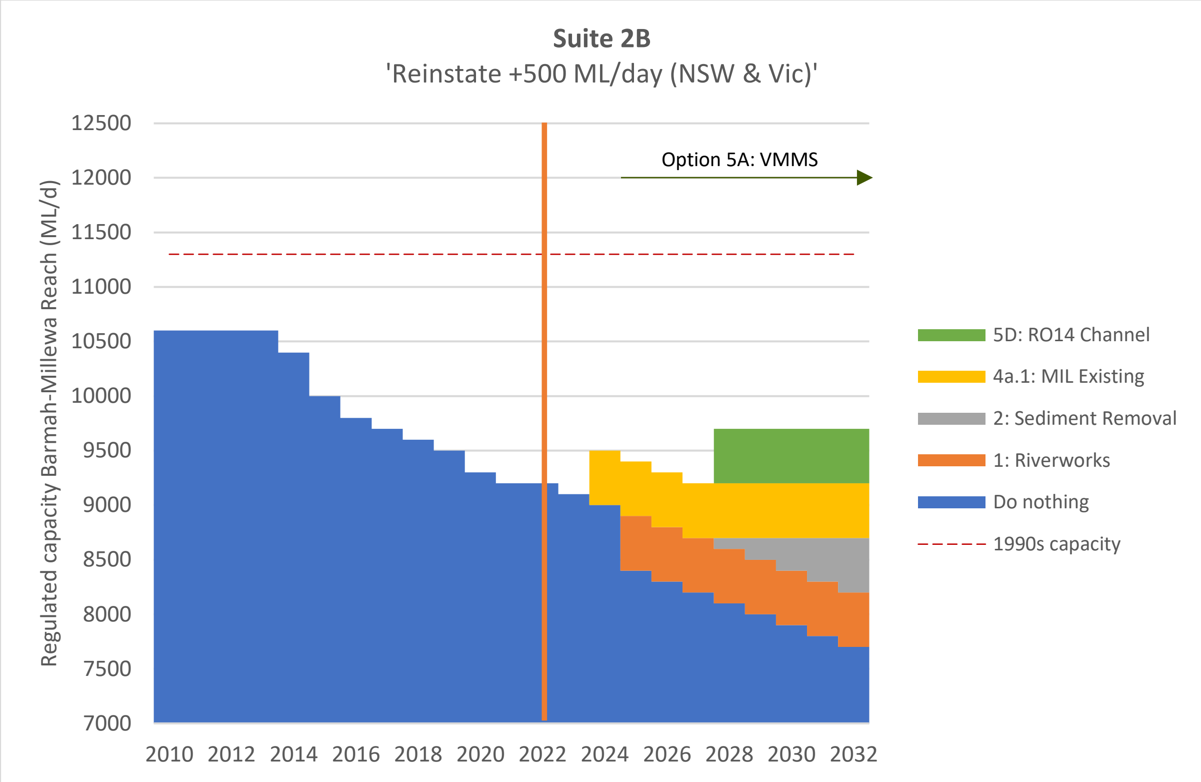
Suite 1: 'Maintain current capacity'



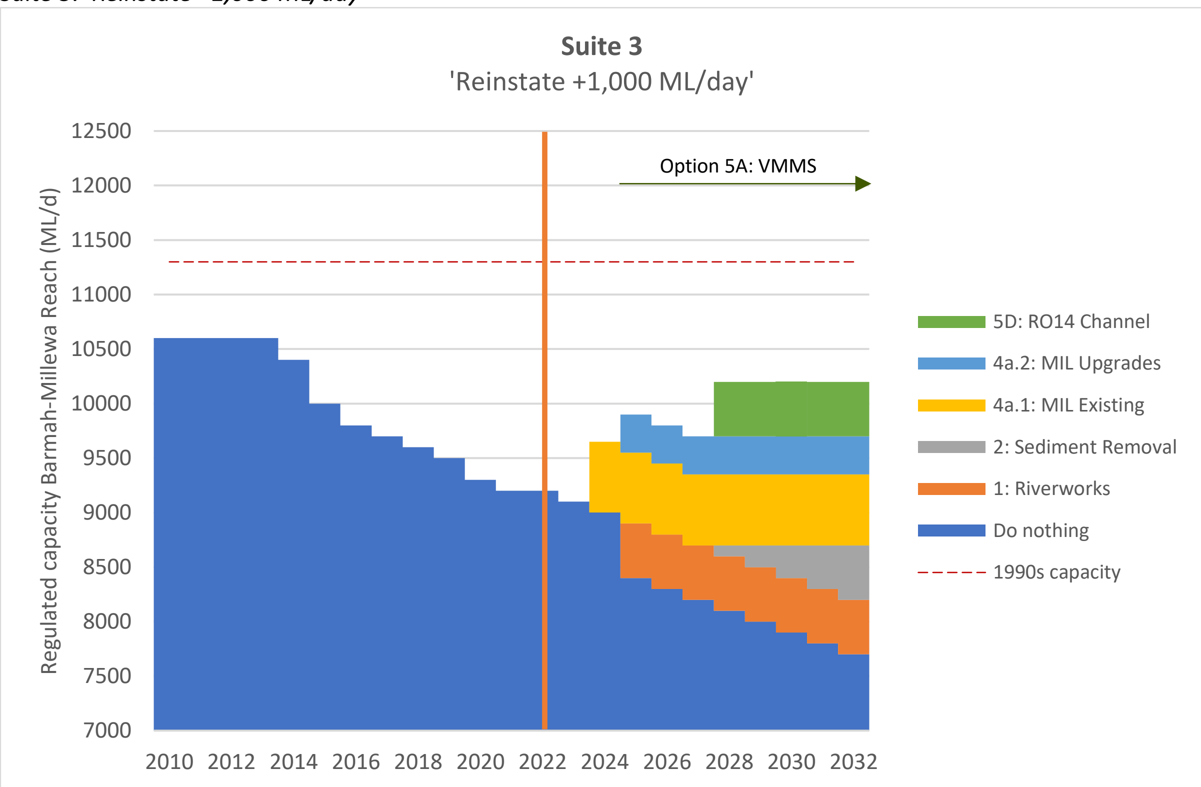
Suite 2A: 'Reinstate +500 ML/day' (MIL only)



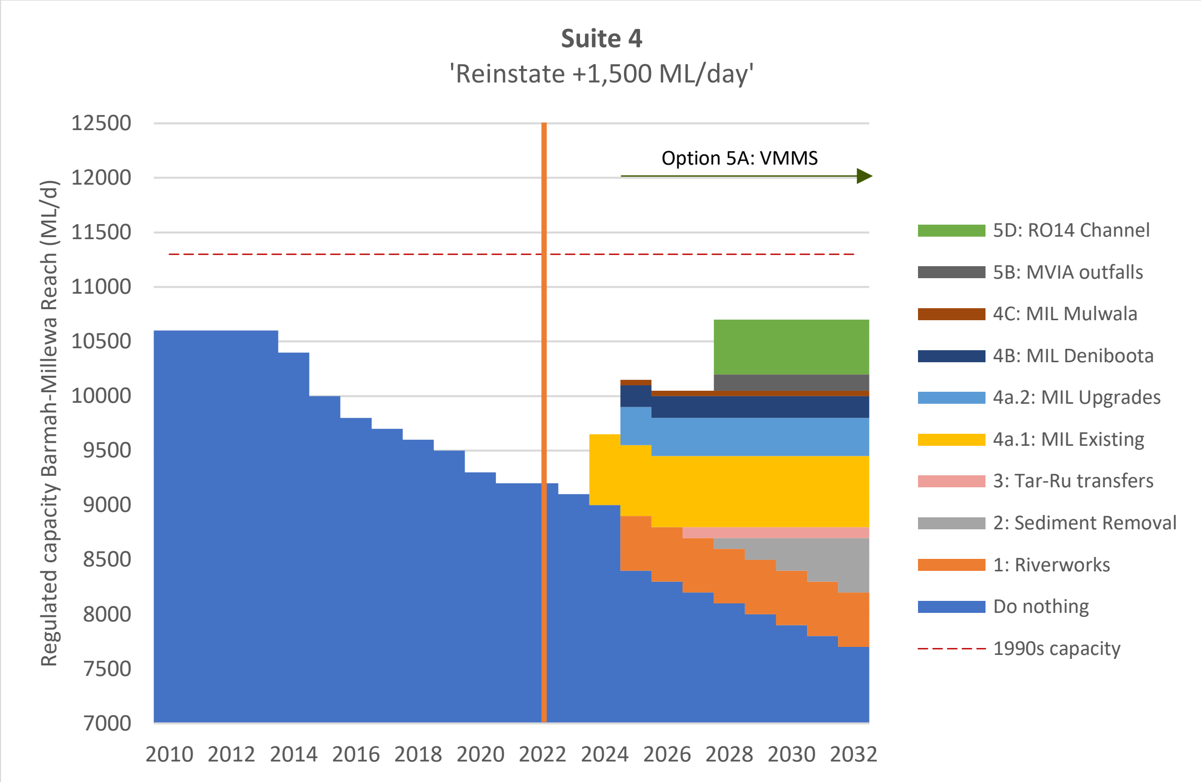
Suite 2B: 'Reinstate +500 ML/day' (MIL & Vic)



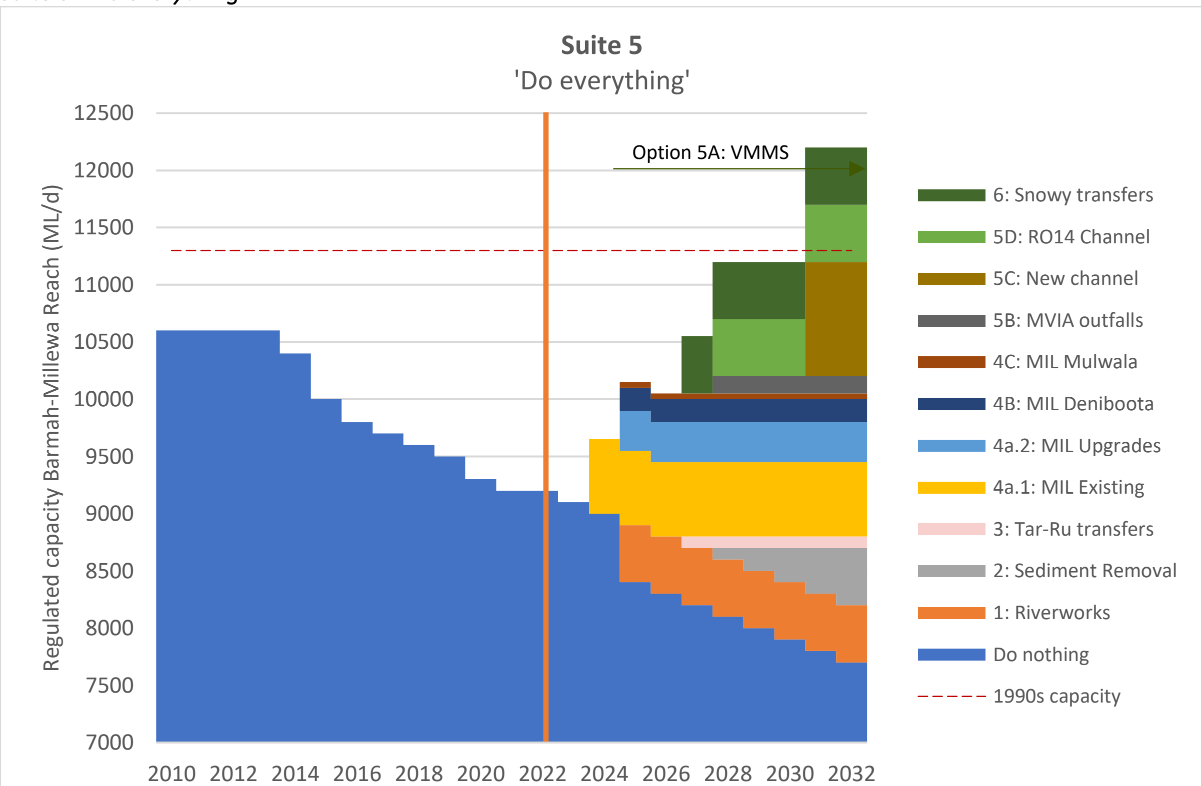
Suite 3: 'Reinstate +1,000 ML/day'



Suite 4: 'Reinstate +1,500 ML/day' (MIL & Vic)



Suite 5: 'Do everything'



Key observations

The following observations are made with respect to the assessment of the suites of options:

The 'do nothing' scenario scores the poorest of any option

- If no intervention measures are taken, all domains (water availability, environmental conditions, delivery risks, and river communities) are expected to have further negative impacts.
- The 'do nothing' scenario scores the poorest in the environmental conditions, delivery risk, and river community domains of any suite assessed. If no intervention measures are taken, there is a 'high risk' potential (NR1) for managing delivery shortfall risks to irrigators and the environment over the next 10 years.
- The 'do nothing' scenario scores relatively well in the water availability domain, as the bypass options generally result in additional conveyance losses being incurred. However, the differences in the assessment are relatively minor (from NR3 to NR2).
- While there are no direct costs associated with the 'do nothing' scenario, as detailed in Section 3 of this report, the continual decrease in flow capacity in the Barmah-Millewa Reach would be expected to increase the risk of shortfall events. Over the next 10 years, the declining flow capacity could affect more than $200 million per annum of irrigated agriculture in the lower Murray, as well as adversely affecting environmental condition, social values, cultural values, and reliability of entitlements.
- MDBA's Capacity Policy Working Group (CPWG) has identified that it is likely that a significant shortfall event would result in long-term damage to relationships between the jurisdictions and the ability to develop and implement good water policy for a considerable period.

'Holding the line' can offset the risk of impacts on environmental, social, and cultural values - but it requires several options to achieve this

- The 'maintain current capacity' suite substantially lowers the risks of doing nothing, including delivery risk to irrigators and e-water holders (from high risk to neutral), impacts on environmental condition (from medium risk to low risk) and impacts on river communities (from medium risk to neutral).
- To maintain the current capacity and achieve the objectives of the BMFS, the riverbank works, sediment management, enhanced use of the Victorian Mid-Murray Storages, and some bypass options are needed.
- The riverbank works and sediment management options are necessary to ensure that the environmental and social outcomes targeted by this study are supported.
- The enhanced use of the VMMS is necessary to improve the ability for river operators to respond to potential delivery shortfall events in the lower Murray.
- The increased use of the MIL escapes provides the best means available for increasing the system capacity and helps to 'hold the line' by offsetting the sand aggradation which is expected to occur while the mitigation options are being investigated and designed.

There is merit to further exploring bypass options in both NSW and Victoria

- Suites 2A and 2B would both reinstate around 500 ML/day of flow capacity (additional from current).
- Enhancing the use of the MIL escapes (option 4A.2) would be expected to provide the same bypass capacity at a relatively lower cost and better value-for-money than the Rochester channel option in Victoria (option 5D).
- However, the Rochester Channel provides the opportunity
    - for delivering Goulburn trade commitments to the Murray with the potential to reduce pressure on important natural waterways including the lower Goulburn River and lower Broken Creek. This option provides improved ecological outcomes and should also consider the enhanced use of the MVIA outfalls as a complementary measure.
    - Reduces the risks inherent in the reliance on a single solution. The inclusion of the Rochester Channel spreads the delivery capacity across multiple systems and providers reducing the risk of an 'outage' in one system impacting on water deliveries.

- The beneficial outcomes from these options can be combined to provide step-change, as seen in the assessment of Suite 3, where both the environmental conditions and delivery risk domains move to improved outcomes.
- The increased volume of bypass flows using both options however increase conveyance losses.
- There appears to be merit in further exploring these options. Having NSW and Victorian options under further investigation would also allow the MDBA and the joint governments to best manage risks and achieve commercial outcomes by having multiple options available under different scenarios and avoiding a reliance on only one option.

The ‘do everything’ scenario scores the most positive – but at significant cost

- The ‘do everything’ scenario scores the best in the environmental conditions, delivery risk, and river community domains of any suite assessed.
- The ‘do everything’ scenario however scores the poorest regarding water availability, as using a wide range of significant bypass solutions would be expected to increase conveyance losses, in turn affecting entitlement holders and potentially impacting State water shares. This suggests that implementing options which focus on protecting the river channel and banks should be prioritised in the first instance.
- In addition, the capital and operational costs for implementing all the options is around 2 – 3 times poorer value for money than other suites.

Traditional Owner perspectives must be considered alongside this assessment

- As detailed above, Traditional Owner perspectives on this project and the various options have been collated through discussions and collated into ‘what we heard’ reports.
- It was not considered appropriate for cultural values or Traditional Owner perspectives to be quantitatively assessed as part of this assessment.
- Accordingly, in considering the options, the suites, and this project, we strongly recommend that the Traditional Owner engagement report be read in conjunction with this report.
- Further engagement with Traditional Owners should form an important activity included in any additional development stage of this project.