Amendment date: 28 June 2017

1.	**Title of measure**	**Hume to Yarrawonga Constraints Measure**
2.	**Proponent undertaking the measure**	**Victoria and NSW**
3.	**Type of measure**	**Supply (constraint measure submitted as supply)**
4.	**Requirements for notification**	
a)	Date by which the measure entered into or will enter into operation *Must be before 30 June 2024*	The measure will be operational by 30 June 2024.
b)	Confirmation that the measure is not an 'anticipated measure' *'Anticipated measure' is defined in section 7.02 of the Basin Plan to mean 'a measure that is part of the benchmark conditions of*	Yes.
c)	Confirmation that the proponent state(s) undertaking the measure agree(s) with the notification ***Basin Plan 7.12(3)(c)*** *Joint proposals will need the agreement of all proponents*	Yes.
5.	**Surface water SDL resource units affected by the measure**	
	This measure identifies all surface water resource units in the Southern Basin region as affected units for the purposes of notifying supplying measures. The identification of affected units does not constitute an agreement between jurisdictions on apportioning the supply contribution.	
6.	**Details of relevant constraint measures**	
	Due to the high level of hydrological connectivity, this measure is closely linked to all constraints measures in the southern connected basin, including the Murrumbidgee, Yarrawonga to Wakool, Goulburn, and River Murray in South Australia proposals.	
7.	**Date on which the measure will enter into operation**	
	The date by which the measure will enter into operation is 30 June 2024.	
8.	**Details of the measure**	
a)	Description of the works or measures that constitute the measure	The Constraints Management Strategy (CMS) aims to optimise the environmental benefit gained from managed environmental flow events that will reconnect rivers and floodplain environments. There is currently a range of river based constraints which prevent the passage of higher environmental flows through the Murray Darling Basin. Relaxing these constraints to allow flows to reach the lower levels of floodplains would produce environmental benefits. This measure would allow environmental flows of up to 40,000 ML/day to be delivered through the Hume to Yarrawonga reach of the River Murray, generally in winter and spring. This measure aims to achieve the environmental objectives of filling wetlands, flushing of organic matter to improve water quality, provide organic matter and other food sources between the floodplain and river channel, and improve lateral and longitudinal connectivity facilitating movement of fish and other fauna.

		A number of infrastructure and operational activities will need to be undertaken to achieve the relaxation of constraints, including activities to avoid or mitigate third party impacts resulting from inundation of public and private land. Activities may include: a) Negotiating agreements with landholders for easements or other measures to allow inundation of low-lying land; b) Relocating private pumping infrastructure higher up river banks above anticipated flow levels, or improving the infrastructure allowing pumps to be easily moved; c) Increasing the height of low-lying infrastructure, including crossings and roads, above anticipated flows levels; d) Improving and maintaining low-lying roads that will be inundated by anticipated flows to ensure they are in good condition following events; e) Implementing erosion control measures to maintain public and private land after inundation; f) Installing pumps for stormwater systems where stormwater gates may have to close during events; g) Implementing notification systems so the community has the ability to undertake management measures prior to and during higher flows. See Section 2.1 of **Attachment A**.
b)	Capacity of the measure to operate as a supply measure *'Supply measure' is defined in section 7.03 of the Basin Plan to mean 'a measure that operates to increase the quantity of water available to be taken in a set of surface water SDL resource units compared with the quantity available under the benchmark conditions of development'.*	Yes.
c)	Geographical location of the measure	The River Murray and its floodplain, between Hume Dam and Yarrawonga. See Section 2.1 and Figure 1 of **Attachment A**.
d)	Spatial data describing the inundation extent associated with the operation of the measure	Spatial data has been produced by the MDBA that shows the inundation extent associated with the measure. See Appendix 8 of **Attachment A**. It is intended that inundation extent will be further investigated during the implementation phase, including through flow trials and observation.
e)	Representation of the measure in the MDBA modelling framework	The MDBA will represent the proposed operating strategy and water use in the MSM-BigMod model.

f)	Representation of each operating strategy in the MDBA modelling framework.	This measure would increase the regulated flow limit for environmental water releases in the Hume–Yarrawonga stretch of the river from 25,000 up to 40,000 ML/day, as measured at the Doctor's Point gauge around 15 km downstream of Hume Dam. The timing of high flows is expected to be between June and November. See Section 4 and Appendix 7 of **Attachment A**.

Attachments:

A	MDBA, 2015	Hume to Yarrawonga Constraints Measure Business Case

Hume to Yarrawonga Constraints Measure

Business Case

To be submitted by Victoria and New South Wales governments

Drafted by the MDBA on behalf of the governments of Victoria, New South Wales and South Australia

Version control

Date updated	Updated by	Comment
27 October 2015	MDBA	Version provided to Victoria and copy RMCSC
23 November 2015	Victoria	Version provided to MDBA with comments from Victoria
27 November 2015	MDBA Constraints Analysis team	Revisions made in response to Victorian comments, and to take into account revised modelling outputs from GHD
7 December 2015	MDBA Phys constraints team	Addressing/ responding to VIC comments
10 and 15 December 2015	MDBA Policy and coord team	Amend formatting issues
13 January 2016	MDBA Policy and coord team	Response to Vic comments
30 March 2016	MDBA Constraints Analysis team	Cost estimates reviewed and amended where required, as requested by Victoria
8 April 2016	NSW and Victoria	Final edits

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Executive summary

Historical regulation and management of the Basin's rivers has led to the declining health of our riverine environments. One of the key changes to hydrology that has occurred as a result of river regulation is a loss of small to medium overbank flows which connect rivers to their floodplains, cycle nutrients and fill wetlands to provide food and habitat for the plants and animals that depend on them. Addressing constraints provides an opportunity to restore some of these important flows and improve environmental outcomes in the Basin.

This business case investigates the feasibility of increasing the upper limit in the flow rate for the Hume-Yarrawonga reach of the River Murray from 25,000ML/day to 40,000ML/day at Doctor's Point, to better connect floodplains and wetlands with the river and allow overbank environmental flows to be delivered along its length. This stretch of the River Murray includes the channel and associated anabranches between Hume Dam and Yarrawonga Weir and is one the seven key focus areas identified in the MDBA's Constraints Management Strategy. This proposal is closely linked to the Yarrawonga-Wakool junction and South Australian River Murray proposals that form part of an integrated package of constraints measures along the River Murray.

The delivery of constraints proposals occurs in conjunction with other measures being investigated by Basin governments to adjust the Basin Plan Sustainable Diversion Limits. The 'adjustment mechanism' includes a phased assessment process to investigate the feasibility of seven physical proposals. Consistent with these arrangements, the Hume-Yarrawonga business case outlines the current status of investigative works and degree of landholder support at this site.

Victoria and NSW have agreed to put this proposal forward for assessment.

Comment [redacted]

Environmental benefits

Within the flows being explored, environmental benefits appear to increase linearly with flow rate. Within the Hume–Yarrawonga reach, an additional 3,200 ha of additional floodplain vegetation and 1,400 ha of wetlands could be inundated, with benefits to many flora and fauna floodplain species. The modelled inundation patterns indicate that an additional 94 wetlands commence to flow between flows of 25,000ML/day and 38,000ML/day as measured at Doctor's Point. Key environmental assets downstream that would benefit from these increased flows include the Barmah–Millewa Forest, Werai Forest, Gunbower–Koondrook–Perricoota forests, Hattah Lakes and the Riverland–Chowilla Floodplain.

Hydrology

Regulated flows to meet downstream demands in the Hume-Yarrawonga reach are currently restricted to 25,000 ML/day as measured at Doctor's Point, which is about five kilometres below Hume Dam just downstream of the Kiewa River confluence. This restriction limits the amount of water that can be delivered from Hume Dam to contribute to environmental outcomes in the reach, and to the lower River Murray reaches. The delivery of higher flows of water from Hume Dam to the lower River Murray reaches is also inhibited by constraints downstream (e.g. in the Yarrawonga-Wakool Junction Reach).

Increasing the regulated flow limit from 25,000ML/day to 40,000ML/day in this reach would allow for more frequent flows in the range of 25,000-40,000ML/day that could be used to deliver longer and/or higher peak events. The capacity to deliver flows up to 40,000ML/day could be achieved by releasing water from Hume Dam to coincide with downstream tributary flows when conditions are favourable.

Due to the high level of hydrological connectivity the Hume-Yarrawonga investigative work needs to be considered in conjunction with the other interdependent constraints measures. This includes the flows being investigated downstream of Yarrawonga Weir and flows at the South Australian border. In effect,

dependencies and interactions between reaches mean that it is not possible to take full advantage of relaxed constraints in one part of the Basin in isolation.

In addition to addressing physical constraints, operational and management constraints would also need to be considered to achieve the outcomes of increasing the flow rate to 40,000ML/day. Policies to address these constraints are essential for delivering environmental water on top of other in-stream flows and re-using environmental water along the length of the Murray. Basin jurisdictions have been developing implementation plans to address these policies.

River operations

All supply, constraints and efficiency measures must be fully operational by 1 July 2024. Implementation of constraints proposals is contingent on confirming that mitigation measures have addressed the effects of relaxing constraints and that communities are fully supportive. This type of approach is consistent with principles guiding best practice river operations. Time should be taken to carefully consider the potential for any interactions, dependencies and implications of higher environmental flow deliveries. The principle of implementing flows in a staged and incremental manner is also consistent with the concept of commissioning other works and measures in stages, rather than operating at full capacity on the initial event. Longer term environmental water planning and annual operating plans will need to consider the need to adaptively manage flows.

Third party impacts and mitigation measures

The business case presents the draft outcomes of investigative work to assess third party impacts, mitigation measures and costs for the site. Where it is agreed to proceed to next steps, the majority of further investigative work for this measure will include additional consultation with individual landholders about the feasibility of acquiring easements, options for the upgrade of private infrastructure, such as improved creek crossings or culverts, and options for the reinstatement and capital works to ensure that impacts on public infrastructure are mitigated.

As part of the investigations to date, a new hydrological model was developed to inform the assessment of impacts, mitigation measures and costs. The model assumes an environmental demand that includes translucency operations and provides an upper limit for future opportunities that could arise to deliver environmental water, if constraints were relaxed to 40,000 ML/day. Should this proposal proceed, in practice, not all these opportunities would necessarily be applied. Therefore the impacts, mitigation measures and costs identified in this business case represent an upper limit of the actual impacts, mitigation measures and costs that could be expected.

Engagement with stakeholders was carried out to inform this proposal. It is estimated that 1,117 hectares of private agricultural land across 207 riparian landholders (split almost equally between New South Wales and Victoria) could be affected by flows of up to 40,000ML/day in the reach. In general, riparian landholders are not supportive of the proposal to increase the environmental flow limit to this height. Concerns include the effects of prolonged overbank flows on their pastures, as well as the uncertainty about when environmental flows might be delivered. Landholders are also concerned that a rain event that occurs during or following an environmental flow event might lead to unintended flooding.

While based on the current level of information available, councils in the region consider impacts could be manageable. There are still concerns about access along roads that are inundated at these flows, particularly if the flows occur frequently or for long durations.

Costs of mitigation measures

Costs in the Hume-Yarrawonga reach will be influenced by proposed changes in the operating regime in the downstream Yarrawonga-Wakool reach. This business case therefore presents initial findings around two sets of costs relating to two distinct hydrological scenarios:

- A scenario which assumes that the regulated flow limit at Doctor's Point is increased from 25,000 ML/day to 40,000 ML/day, and that up to 65,000 ML/day can be delivered downstream of Yarrawonga Weir ("YAR65" scenario)
- A scenario which assumes that the regulated flow limit at Doctor's Point is increased from 25,000 ML/day to 40,000 ML/day, and that up to 50,000 ML/day can be delivered downstream of Yarrawonga Weir ("YAR50" scenario).

The currently estimated costs in the Hume-Yarrawonga reach reflect what would be required to implement the mitigation activities as they currently stand at this level of investigative work. The estimated costs of mitigation measures at present range from $26 million (moderate estimate) to $34 million (high estimate).

A detailed summary of cost investigations to date is presented in the business case.

1 Background

The way that rivers flow in the Murray–Darling Basin has significantly changed over the past hundred years of development. By building dams and irrigation infrastructure, we've provided for the growth of industries, towns and agriculture. That development has had a lot of benefits for all Australians, but it has often come at a cost to the health of the river system, including its floodplains, particularly downstream of dams and weirs.

Water used to regularly flow out of the main channels into surrounding creeks and flood runners, and onto the floodplains adjacent to the river, especially in late winter and spring. River regulation means that those creek flows and small overbank flows happen a lot less often than they used to. Instead, in many parts of the Basin, we now capture those flows in dams and release them as more constant flows during summer and autumn when irrigators need water. Of course, the big floods still happen and will continue to happen, and river operators will continue to provide as much protection from those damaging floods as they can.

Over the past few decades, Basin governments and communities have made substantial efforts to maintain and restore the health of the rivers and their floodplains. The Basin governments collectively recognise that governments — with people who live and work in the Basin — can manage the system better to get the best use of available environmental water. This recognition led to MDBA being asked, under the Basin Plan, to develop a Constraints Management Strategy which 'identifies and describes the physical, operational and management constraints that are affecting environmental water delivery'. Relaxing constraints can help to improve the environmental outcomes that can be achieved with the available environmental water, over and above what could be achieved by the Basin Plan alone.

A constraint is any river management practice or structure that restricts the volume and timing of water we can deliver through the river system. Addressing constraints is one of the ways we can improve our ability to do that. It means that environmental water holders can use their water in the most efficient and effective way possible.

The Constraints Management Strategy aims to build on past achievements to restore a small part of the natural flow pattern. We'll never return the rivers to what they were before the development of the past 100 years, but we can try to restore some of the smaller flows that are critical for the environment to stay resilient and healthy.

This business case builds on work done in the pre-feasibility phase of the Constraints Management Strategy. Combined with similar business cases for regions in the mid and lower River Murray, this business case investigates new ways to manage water delivery through the waterways to ensure their long-term health, while avoiding or mitigating the effects on people who also depend on the floodplain and these waterways.

Importantly, we are only talking about changing managed flows on the lowest parts of the floodplain. Generally this is not where there are buildings or crops (Murray-Darling Basin Authority, 2014b). Most impacts are about inundation of pastures or rising creek levels cutting off access to some parts of properties.

This business case focuses on the Hume to Yarrawonga key focus area of the River Murray defined in the Constraints Management Strategy. If implemented, it would be to be actioned in conjunction with the proposals in business cases for the Yarrawonga to Wakool Junction and Lower Murray key focus areas. This business case has been prepared consistent with the BOC agreed *Phase 2 Guidelines for constraint and supply measure business cases* (Basin Officials Committee, 2014). Appendix 1 shows how this business case delivers against each of the relevant requirements of the Guidelines.

In 2014 Basin Ministers agreed to develop business cases for seven key focus areas identified in the Constraints Management Strategy and asked that work should proceed as an integrated package for the three River Murray key focus areas – Hume to Yarrawonga, Yarrawonga to Wakool junction and SA River Murray. Following the decision of Basin Ministers in 2014, MDBA has developed this business case on behalf of the governments of New South Wales, Victoria and South Australia.

The Hume–Yarrawonga focus area covers the River Murray channel and associated anabranches between Hume Dam and Yarrawonga Weir. This region is close to the headwaters of the Murray with rainfall and some snowmelt contributing the main inflows in the winter period. This part of the River Murray is a meandering system with a multi-branched channel and a well-defined floodplain. The movement of anabranches across the floodplain has created a number of billabongs that are connected to the river at various flow heights.

Hume Dam and Yarrawonga Weir have dramatically changed the flow regime of the River Murray. Before regulation, the Hume–Yarrawonga stretch of the Murray would have experienced peak flows in winter and early spring, and low flows during the summer period. Hume Dam now captures winter and spring flows, with releases peaking in summer and autumn to support irrigation both locally, via the Mulwala and Yarrawonga irrigation channel system, and further downstream.

In developing this business case, MDBA has:

- reviewed inundation maps developed in the pre-feasibility phase of the Constraints Management Strategy
- refined hydrologic modelling to assess the potential frequency, timing and duration of higher environmental flows
- considered the feasible hydrological parameters for delivery of environmental flows and how this might work in practice
- refined the prefeasibility assessment of impacts on private land, the combination of mitigation options that would be required to address these impacts (i.e. easements and/or private infrastructure works) and the costs of those easements and/or private infrastructure;
- refined the prefeasibility assessment of public infrastructure that might be affected and mitigation options and costs
- considered specialist activities (e.g. tourist facilities, quarries and golf courses), how they might be affected by changes in flows, and mitigation options and costs
- consulted with key landholders, councils and community members about the potential impacts of higher flows and options to mitigate those impacts
- considered the environmental benefits of higher environmental flows in the Hume-Yarrawonga and downstream reaches of the River Murray, and
- ensured that the investigated changes to managed flows in this key focus area integrate with those in the Yarrawonga to Wakool Junction and the Lower River Murray (South Australia) River Murray areas.

2 Measure details

2.1 Description of the measure

The Hume to Yarrawonga reach refers to the River Murray channel and associated anabranches between Hume Dam and Yarrawonga Weir (Figure 1). It is a multi-branched channel with a well-defined floodplain. The anabranches historically moved across the floodplain as a result of natural erosive processes, creating a number of billabongs that are connected to the river at various flow heights (Thoms, et al., 2000) (Murray-Darling Basin Authority, 2014a).

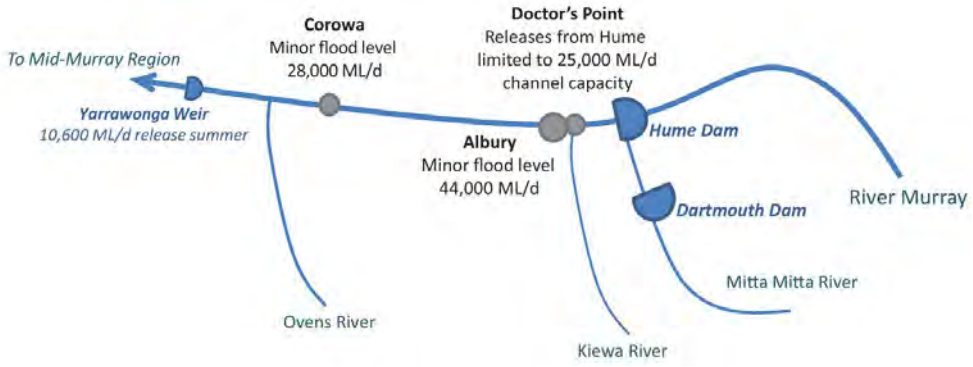


Figure 1: Hume Dam to Yarrawonga reach[1]

The major tributaries that contribute to flows in this reach are the Kiewa River and Ovens River. Other minor contributions are made from Indigo Creek and Black Dog Creek in this reach of the Murray. None of these tributaries are regulated, so regulated releases from the Hume Dam need to take into account additional flows that originate from within the reach (Murray-Darling Basin Authority, 2014a).

Regulated flows to meet downstream demands in the Hume–Yarrawonga reach are currently restricted to 25,000 ML/day at Doctor's Point, which is just downstream of the Kiewa River confluence and upstream of Albury/Wodonga. This restriction limits the amount of water that can be delivered from Hume Dam to contribute to downstream environmental outcomes. Given the large size of Hume Dam, altering this rule to allow a larger flow would be critical in using environmental water to the greatest benefit downstream. Releasing higher flows at seasonally appropriate times would also benefit the many billabongs and wetlands in the Hume–Yarrawonga reach of the Murray (Murray-Darling Basin Authority, 2014a).

Hume Dam and Dartmouth Dam have dramatically changed the flow regime of the Hume to Yarrawonga part of the River Murray. Prior to regulation, the Hume–Yarrawonga stretch of the Murray would have experienced peak flows in winter and early spring, and low flows in the summer period. Hume Dam now catches high flows in winter and spring, with peak irrigation demand causing high releases downstream during summer and autumn to supply irrigation water both locally, via the Mulwala and Yarrawonga irrigation channel system, and further downstream.

[1] Minor flood level at Corowa is 4.6 m, or around 28,000 ML/day, which results in the inundation of low-lying agricultural land and some council assets such as some grassed recreational areas. These impacts have been assessed as part of this business case.

The River Murray contains important environmental assets throughout each of the three River Murray constraints areas. The Basin-scale analysis of constraints conducted by the MDBA during the pre-feasibility phase showed that releases can be combined at multiple locations, based on natural cues, to build events that benefit these environmental assets throughout the southern-connected system. As a result of the high level of hydrologic connectivity the three River Murray constraints are inherently interrelated. A coordinated and integrated approach to all River Murray constraint measures would be required to enable system-wide benefits along the length of the River Murray. Recognising this, Ministers requested that investigations should proceed as an integrated package for the three River Murray key focus areas.

This business case investigates the feasibility of increasing the regulated flow limit in the Hume–Yarrawonga stretch of the river from 25,000 to 40,000 ML/day, as measured at the Doctor's Point gauge around 15 km downstream of Hume Dam. This could allow higher environmental flows to be delivered, primarily in winter and spring. Computer modelling shows that achieving flows in this range would allow for greater flows into the lower parts of the River Murray.

There are a number of possible benefits to the environment in the Hume–Yarrawonga area, if this proposal proceeds. MDBA's inundation mapping showed that around 5,100 ha of flood-dependent vegetation and approximately 3,700 ha of wetlands would be inundated in this reach at flows of 40,000 ML/day, compared to 1,800 ha of flood-dependent vegetation and 2,300 ha of wetlands that can be inundated by flows at the current constraint of 25,000 ML/day.

In addition, enabling higher regulated environmental releases from Hume Dam could mean that floodplain vegetation downstream would also be able to be watered at times when it would get the most benefit.

Flows of these heights would inundate private property and have impacts on some public and private land and infrastructure. Although the purpose of Hume Dam operations as set out in the Murray–Darling Basin Agreement is not to mitigate floods but to conserve water, a by-product of the dam collecting high winter and spring inflows has been that many floods may be captured, so the impact of these flows has been mitigated for landholders in the reach. This situation has guided the business decisions of floodplain enterprises. Landholders with smaller holdings situated on flood-prone country are most at risk, as they may not have adequate land to move stock onto during managed environmental flow events. While landholders currently have strategies to manage this risk (for example they may ask a neighbour to allow temporary agistment or truck livestock off-farm), some of these practices may not be available or acceptable if higher flows occur more frequently and with longer durations.

Landholders are also concerned about the risk to livestock if a regulated flow event is followed by a natural flow event. Although landholders might choose to leave stock on an island of higher ground for a regulated event of a certain duration, they are concerned that doing so might expose livestock to additional risk if a natural rainfall event follows.

This business case also investigates a number of mitigation activities to prevent or compensate for impacts that may be caused if higher environmental flow delivery proceeds.

2.2 Objectives of the measure

The objectives of this potential measure are:

1. to allow environmental flows of up to 40,000ML/day to be delivered through the Hume to Yarrawonga reach of the River Murray, generally in winter and spring,
2. to better connect floodplains and wetlands with the river, and
3. in conjunction with the constraints measures in the Yarrawonga-Wakool and the SA reaches, to allow overbank environmental flows to be delivered along the length of the River Murray and its effluent rivers (such as the Edward-Wakool system).

2.3 Sustainable Diversion Limit resource units affected

If implemented, this measure would involve works in the following Sustainable Diversion Limit resource units:

- Victorian Murray (SS2), and
- New South Wales Murray (SS14).

When combined with the Yarrawonga-Wakool and Lower Murray constraint measures, it would also involve:

- South Australian Murray (SS11).

2.4 Proponent

The proponents are the governments of New South Wales and Victoria.

Victoria and NSW have agreed to put this proposal forward for assessment as a constraints measure in the first instance. Basin governments will be formally advised, well ahead of 30 June 2016, if this proposal is also intended as a supply measure.

2.5 Impacts and mitigation activities

The most significant constraint to the possible increase of the regulated flow limit is the potential effect on local agricultural landholders and other businesses who operate close to the river, who have private property inundated at flows of more than 25,000 ML/day. Accessibility is also an issue, as rising water inundates low-lying land and cuts off areas of higher ground on some properties.

Another constraint is potential effects on public infrastructure, such as roads, which would be inundated more frequently under the proposed new flow regime.

Impact		Quantity of impact	
		NSW	**Victoria**
Impacts on private agricultural land	Number of properties affected	101	106
	Area of land inundated (ha)	596	605
	Area of land affected by interrupted access (ha)	656	666
Impacts on public infrastructure		1 km of roads 8 km of tracks 2 crossings and bridges Other minor impacts	1 km of roads 7 km of tracks 11 crossings and bridges Other minor impacts
Impacts on specialist activities		3 sites	No sites

As such, the majority of work for this measure would involve mitigating these impacts, including:

- agreements with landholders, such as through the purchase of easements which would allow flows over their land,
- upgrades to private infrastructure, such as improved creek crossings on private land;
- upgrades to public infrastructure, such as improved culverts on public roads or improved public jetties,
- arrangements with public infrastructure owners (e.g. councils) to fund reinstatement works that would be required in the context of the potential new flow regime,
- arrangements with operators of affected businesses (e.g. caravan parks) to mitigate impacts of higher flows,
- trials of potential flows to be conducted on an incremental and staged basis to test for effects on communities before larger flows are trialled, and
- operational strategies to manage the risk of flows that might be higher than intended.

Further details on the impacts in the Hume-Yarrawonga key focus area, and mitigation options, are provided in Section 5 of this document and in Appendix 6.

A key driver of the impacts and mitigation options in the Hume-Yarrawonga key focus area is the relatively high frequency (compared to other key focus areas considered by the Constraints Management Strategy) of potential additional flow events in the 25,000 – 40,000 ML/day range. It is important to recognise that the impacts, mitigation options and costs presented in this business case are based on a hydrological model which was developed to define a maximum extent to which future opportunities could arise to deliver environmental water, if constraints were relaxed to 40,000 ML/day. In practice, not all these opportunities would necessarily be taken up. Hence, the impacts and costs identified in this business case represent an overestimate of actual impacts and costs.

Impacts and costs in the Hume-Yarrawonga key focus area would also be influenced by the extent to which constraints may be relaxed downstream (in the Yarrawonga-Wakool reach). In this business case two scenarios for constraints relaxation in the Yarrawonga-Wakool reach have been considered: a scenario which assumes constraints downstream of Yarrawonga Weir are relaxed to 65,000 ML/day, and an alternative scenario which assumes constraints downstream of Yarrawonga Weir are relaxed to 50,000 ML/day. There is only a small difference between the assessed impacts and costs in the Hume-Yarrawonga reach, for these two scenarios.

Further details of the proposed changes to hydrology, and operating regime, are provided in Section 5 of this document.

An important issue in the Hume-Yarrawonga key focus area is the previous program of easements and access works, through which the then Murray-Darling Basin Commission (MDBC) confirmed the right to pass regulated flows of up to 25,000 ML/day at the Doctor's Point gauge. Most of the landowners who would be affected by flows of more than 25,000 ML/day were involved in this earlier program. Any new easement arrangements or infrastructure upgrades would need to complement those that have already been agreed, and it would be prudent to follow a similar process.

Constraints measures must be fully operational by 1 July 2024. At the commencement of any new flow capacity, environmental flows should be implemented in a staged and incremental manner to test for effects on the ground and on communities before larger flows are implemented. This objective is compatible with key principles that guide river operations.

2.6 Summary of estimated costs

The estimated costs comprise three components:

- escalated costs of mitigation measures
- additional infrastructure implementation costs, and
- program management costs.

Independent consultants have estimated that costs of potential mitigation measures in the Hume–Yarrawonga key focus area range from $25 million (moderate estimate) to $35 million (high estimate) for a "YAR65" hydrological scenario, which assumes that managed flows of up to 65,000 ML/day can be delivered downstream of Yarrawonga Weir. The main components of this estimate are (Table 3):

- easements over private agricultural land — approximately $7 million
- new or upgraded infrastructure on private agricultural land – $1 million
- operational response measures relating to public infrastructure – $1 million
- capital works on public infrastructure (e.g. roads, bridges and crossings) — from $4 to $6 million
- reinstatement works on public infrastructure (e.g. roads, bridges and crossings) — from $3 to $4.0 million, and
- arrangements with operators of specialist businesses – from $<1 to $5 million.

There could also be potential additional costs associated with infrastructure capital works. These costs are estimated as from $1 to $3 million. A key determinant of these costs would be whether or not capital works (particularly for small projects) are bundled.

Program management costs are indicatively estimated as $8 million, noting that it is difficult to estimate these costs when governance and implementation arrangements have not yet been agreed.

Table 1: Summary of estimated costs, YAR65 hydrological scenario.

Cost category		New South Wales ($m)	Victoria ($m)	Total ($m)
Costs of mitigation measures	**Easements**	3.4	3.4	6.7
	Infrastructure on private agricultural land	0.5	0.6	1.1
	Operational response measures relating to public infrastructure	0.4	0.4	0.8
	Capital works on public infrastructure	2.1 to 3.1	2.0 to 3.0	4.1 to 6.1
	Reinstatement of public infrastructure	1.8 to 2.2	1.5 to 1.8	3.3 to 4.0
	Arrangements with specialist businesses	0.2 to 5.0	nil	0.2 to 5.0
Potential additional infrastructure implementation costs		0.5 to 1.5	0.5 to 1.5	1 to 3
Potential program management costs		State split cannot be determined as governance and implementation arrangements have not yet been agreed		8.0
TOTAL ($m)		**9 to 16**	**8 to 11**	**25 to 35**

For an alternative "YAR50" hydrological scenario (which assumes that managed flows of up to 50,000 ML/day can be delivered downstream of Yarrawonga Weir), total costs would range from $25 million (moderate estimate) to $35 million (high estimate). The main components (Table 4) of this estimate are:

- easements over private agricultural land — approximately $7 million
- new or upgraded infrastructure on private agricultural land – $1 million
- operational response measures relating to public infrastructure – $1 million
- capital works on public infrastructure (e.g. roads, bridges and crossings) — from $4 to $6 million
- reinstatement works on public infrastructure (e.g. roads, bridges and crossings) — from $3 to $4 million, and
- arrangements with operators of specialist businesses – from $<1 to $5 million.

There could also be potential additional costs associated with infrastructure capital works. These costs are estimated as from $1 to $3 million. A key determinant of these costs would be whether or not capital works (particularly for small projects) are bundled.

Program management costs are indicatively estimated as $8 million, noting that it is difficult to estimate these costs when governance and implementation arrangements have not yet been agreed.

Table 2: Summary of estimated costs, YAR50 hydrological scenario.

Cost category		New South Wales ($m)	Victoria ($m)	Total ($m)
Costs of mitigation measures	Easements	3.3	3.4	6.7
	Infrastructure on private agricultural land	0.5	0.6	1.1
	Operational response measures relating to public infrastructure	0.4	0.4	0.8
	Capital works of public infrastructure	2.1 to 3.1	2.0 to 3.0	4.1 to 6.1
	Reinstatement of public infrastructure	1.9 to 2.3	1.5 to 1.8	3.4 to 4.1
	Arrangements with specialist businesses	0.2 to 5.0	nil	0.2 to 5.0
Potential additional infrastructure implementation costs		0.5 to 1.5	0.5 to 1.5	1 to 3
Potential program management costs		State split cannot be determined as governance and implementation arrangements have not yet been agreed		8.0
TOTAL ($m)		**9 to 16**	**9 to 11**	**25 to 35**

Broadly the following observations can be made regarding the estimated costs[2]:

- Overall, the estimated mitigation costs in the Hume-Yarrawonga reach are higher than those estimated during the 2014 prefeasibility phase.
- Costs for the YAR65 scenario are estimated to be marginally lower than those for the YAR50 scenario. This is because the YAR65 scenario envisages fewer high-flow events, resulting in lower costs.
- Costs for works to upgrade private infrastructure, such as bridges and crossings to mitigate interrupted access, could be lower if it is assumed that those upgrades are only undertaken where they are more cost effective than easements.
- Costs associated with public infrastructure would be largely for reinstatement works rather than capital works. This reflects advice from local stakeholders that environmental flows would generally be best dealt with through direct response to impacts of events, rather than capital upgrades. Agreements with asset managers (e.g. councils) would need to be negotiated whereby ongoing reinstatement activites are the responsibility of the asset manager affected.
- There are some capital costs associated with specific infrastructure items. The Kensall Green Road and crossing upgrade is the highest potential capital works item for the reach.
- Mitigation costs for specialist activities are not anticipated to be significant in the Hume-Yarrawonga reach.
- Program management costs could comprise a relatively significant proportion of the total cost.

[2] Unregulated flow risks were considered but not required.

2.7 Confirmation that the measure is consistent with the CMS

The measure being investigated in this business case is consistent with the Constraints Management Strategy, in that it relaxes a constraint in one of the priority key focus areas identified in the Strategy (Murray-Darling Basin Authority, 2013a). It is also consistent with the principles of the Strategy, in that, if it was to proceed:

- It would help maximise environmental outcomes that can be obtained from managing all water available for environmental use (and managing water for other purposes on route).
- Affected communities, including land holders and managers, water entitlement holders, Traditional Owners, management agencies and local government are being involved from the beginning to identify potential impacts and solutions.
- In pursuing environmental outcomes through the relaxation or removal of constraints, this measure includes solutions that:
    - would recognise and respect the property rights of landholders and water entitlements holders,
    - would not create any new risks to the reliability of entitlements,
    - have been identified in consultation with affected parties to determine if impacts can be, appropriately addressed and mitigated to enable changes to proceed
    - would identify and aim to achieve net positive impacts wherever possible
    - would be worked through in a fair and transparent/equitable way, and
    - would work within the boundaries defined by the Water Act, the Basin Plan and relevant state water access and planning systems.
- It would enable all water holders, whether existing consumptive users or environmental water holders, to use their water efficiently to meet the needs of that use, while not adversely affecting other entitlements
- Potential changes would be worked through with relevant Basin governments and relevant stakeholders to resolve issues before changes to on-ground arrangements were made
- Decisions to proceed with removing constraints would be made by Basin governments with investment being decided by the Commonwealth on the collective advice of governments, and
- Investing in this potential constraint measure would:
    - provide optimal Basin-wide environmental outcomes, taking into account economic and social considerations,
    - include lasting solutions to provide certainty and protection to stakeholders over time, and
    - avoid or address any impacts to third parties.

3 Environmental benefits

3.1 Ecological values

The reach of the River Murray between Hume Dam and Yarrawonga Weir is characterised by a complex network of anabranches along a 50-metre-wide main stem. There is an almost-continuous line of riparian vegetation along the main channel that is predominantly made-up of river red gums along both banks. The reach also contains more than 700 wetlands.

Overbank flows that inundate private and public land occur when flows approach 25,000 ML/day at Doctor's Point, which is just downstream of the Kiewa River confluence, upstream of Albury/Wodonga. Modelling has demonstrated the benefits to both local and downstream flood-dependent ecosystems that arise from potentially increasing the regulated flow limit at Doctor's Point to 40,000 ML/day (Murray–Darling Basin Authority, 2012).

There are also two nationally listed wetlands in this reach: Ryans Lagoon, downstream of Hume Dam; and another wetland at the junction of the Ovens and Murray in the upper reaches of Lake Mulwala. Although the latter relies largely on flows from the Ovens, and thus not likely to benefit from increased flows, it is expected the flows would have benefits for Ryans Lagoon.

Ryans Lagoon has been identified as ecologically important due to its diversity of species, from macro-invertebrates to birds that use it for breeding — including species such as the Australian white ibis, eastern great egret, rufus night heron, black swan, grey teal and black-fronted dotterel (Department of Natural Resources and Environment, 1995). Although Ryans Lagoon has been affected by flow changes, land clearing and grazing, it is still a good representation of riverine billabongs in the Hume–Yarrawonga reach (Department of Natural Resources and Environment, 1995) .

A preliminary assessment of species covered under the *Environment Protection and Biodiversity (EPBC) Act* has also revealed that a number of threatened and migratory species are likely to occur in this reach (Department of the Environment, 2015). Of these, species likely to benefit from the higher flows include the Australian painted snipe (*Rostratula australis)*, silver perch (*Bidyanus bidyanus*) and Murray cod (*Maccullochella peelii peelii*).

In Victoria, the Victorian Murray Floodplain Environmental Water Management Plan plan states that 16 species of native fish are recorded for this area, with seven of them listed under State or Federal threatened species legislation. Fish species have different requirements and preferences for habitation in large or small wetlands or the main channel, so increasing the diversity of floodplain inundated is likely to result in benefits to at least some of these fish species (Jacobs, 2015b).

The plan also mentions the presence of six species of frogs, 15 snakes and lizards and two turtles, with the giant bullfrog and broad-shelled turtle having conservation signficiance (Jacobs, 2015b)). The dependence of frogs and turtles on both permanent water and seasonal riverine floodplain habitats (Jacobs, 2015b), suggests they would be likely to benefit from higher flows, as more habitat is created.

Much of the native understorey vegetation, which would have been a shrub layer with an understorey of native grasses and sedges, has disappeared from the river red gum woodland. This vegetation community in the Hume–Yarrawonga stretch is in fairly poor condition, with much of the riverbank vegetation cleared or grazed. River regulation has concentrated flows to high, in-channel flows, rather than more variable low flows or high flows that would spill onto the floodplain (Erskine, Rutheford, Sherrard, & Tilleard, 1993). This practice has increased the power of the water to erode by up to three times more than what it would have been before river regulation. This has had a significant impact on bank stability and on bank vegetation persistence (Erskine, Rutheford, Sherrard, & Tilleard, 1993) (Murray-Darling Basin Authority, 2014a).

It should be noted that the primary driver for relaxing constraints in the Hume-Yarrawonga reach would be to provide benefits to the middle and lower parts of the River Murray. These potential benefits are described in this business case in the section on ecological benefits and in Chapter 4 on anticipated changes to hydrology. The potential downstream benefits are also explained in more deail in the business cases for the Yarrawonga Weir-Wakool Junction reach and the River Murray in South Australia reach. However, this proposal would help to deliver a more natural watering regime which would contribute to restoring floodplain vegetation and improving riparian health through a more natural wetting and drying cycle. It would also help improve bank stability and reduce erosion in the Hume-Yarrawonga reach of the River Murray. Further detail on the environmental benefits that are likely in this reach are described in Section 3.3.1.

3.2 Ecological objectives and outcomes

Relaxing constraints in this key focus area, in conjunction with relaxing constraints in the downstream River Murray areas, would contribute towards achieving the site specific ecological targets and flow indicators for the Murray region identified as important during development of the Basin Plan. These are linked to the Basin Plan's Environmental Watering Plan objectives and the system-wide environmental water requirements targets as well as the site specific ecological targets for each site, defined in the Environmentally Sustainable Level of Take report (Murray-Darling Basin Authority, 2011).

If combined with relaxed constraints downstream in the River Murray, this potential measure would contribute to pursuing the enhanced environmental outcomes of Schedule 5 of the Basin Plan, in particular (2)(f) and (2)(g):

> "(f) providing opportunities for environmental watering of an additional 35,000 ha of floodplain in South Australia, New South Wales and Victoria, improving the health of forests and fish and bird habitat, improving the connection to the river, and replenishing groundwater; and
>
> "(g) Achieving enhanced in-stream outcomes and improved connections with low to middle level floodplain and habitats adjacent to rivers in the southern Murray-Darling Basin." (Commonwealth Government of Australia, 2012)

The Basin-wide Environmental Watering Strategy identifies maintaining vegetation, wetlands and waterbirds as important outcomes; and identifies overbank flows, with water volumes greater than the channel capacity, as important to "recharge wetlands and important for floodplain vegetation, fish and waterbirds, as well as productivity." In addition, the Basin-wide Environmental Watering Strategy also identifies the importance of using environmental water to mimic natural patterns as this is "most likely to produce desired environmental responses" (Murray-Darling Basin Authority, 2014c).

This potential measure would also align with the river flows and connectivity outcomes identified in the Basin-wide Environmental Watering Strategy, specifically:

> "Improved connectivity with bank-full and/or low floodplain flows by 30–60% in the Murray, Murrumbidgee, Goulburn and Condamine–Balonne." (Murray-Darling Basin Authority, 2014c)

In addition this potential measure could assist in restoring connectivity between the River Murray and its surrounding floodplains, also identified as one of the 2014-15 environmental watering priorities:

> "Connectivity in the River Murray System: improve riparian, littoral and aquatic vegetation (e.g. *Ruppia tuberosa*) and native fish populations by increasing ecosystem connectivity through coordinating water delivery in the River Murray system." (Murray-Darling Basin Authority, 2014d)

Over time, delivering higher flow pulses in a more natural watering regime would also help to deliver on the water quality objectives of the Basin Plan.

Achieving the best ecological outcomes from overbank environmental watering actions would also be supported through a number of complementary programs that are operating to address issues such as erosion and salinity. Some of these complementary measures are outlined in Appendix 2.

3.3 Anticipated ecological outcomes

3.3.1 Anticipated ecological benefits — within reach

In 2014, the Murray–Darling Basin Authority (MDBA) undertook a modelling exercise to determine what sorts of environmental benefits might be achieved from increasing flows in each of the seven key focus areas. This exercise involved overlaying the various flood inundation footprints with vegetation maps for this reach to identify what types of vegetation would benefit from the flows under investigation.

Table 5 shows the extent of vegetation inundated for four different vegetation types and Australian National Aquatic Ecosystem wetlands currently inundated at 25,000ML/day and compared to 40,000 ML/day.

Table 3: Extent of vegetation and wetlands inundated in the Hume–Yarrawonga reach.

ANAE = Australian National Aquatic Ecosystem

Flow rate (Doctor's Point ML/day)	State	Total inundated vegetation			
		Red gum woodlands (ha)	Red gum forests (ha)	Black box (ha)	ANAE wetlands (ha)
25,000	Total	376	1444	5	2308
40,000		1,134	3,923	12	3,731
Difference between 25,000 and 40,000		758	2,479	7	1,423
25,000	NSW	37	1092	3	1615
40,000		81	2597	8	2244
Difference		44	1,505	5	629
25,000	VIC	339	352	2	693
40,000		1053	1326	4	1487
Difference		714	974	2	794

Table 5 shows that, within the flow bands we have explored, environmental benefits increase linearly with flow rate. Within the Hume–Yarrawonga reach, an additional 3,200 ha of additional floodplain vegetation and 1,400ha of wetlands is inundated at the 40,000ML/day, with benefits to many flora and fauna floodplain species likely at these flows.

The wetland inundation pattern indicated through the modelled inundation footprints is supported through surveys of wetlands in the reach which indicate that an additional 94 wetlands commence to flow between flows of 25,000ML/day and 38,000ML/day as measured at Doctor's Point (Green and Alexander, 2006). The water dependent vegetation that lives in wetlands provides important shelter and food for fish and birds during breeding events, and continues to provide important habitat for frogs and turtles after the recession of the flood peak (Murray-Darling Basin Authority, 2014c).

Importantly, the areas given in Table 5 provide the total area of vegetation inundated; the area of land for which easements and other mitigation measures would be needed, if the project proceeds, is significantly smaller.

The Victorian Murray Floodplain Environmental Water Management Plan has recently been finalised. The plan suggests there would be many opportunities to improve the health of the floodplain in the Hume-Yarrawonga reach if the flow limit was increased to 40,000ML/day. Some specific objectives of the plan that would utilise the 40,000ML/day flow include:

- Annual flows of up to 30,000ML/day would help to maintain a number of permanent cut-off meander / floodplain depressions. Providing a high water level during winter/spring that then draws down over summer – autumn, but with a permanent pool, would provide refuge for fish and other aquatic species that need permanently inundated wetland habitat.
- Flows of up to 40,000ML/day 1-4 times in five years, but ensuring the dry period is no more than 3-5 years to support a mosaic of wetland anf floodplain vegetation. (Jacobs, 2015b)

The environmental watering plan for the NSW Murray is due for completion in May 2019.

3.3.2 Anticipated ecological benefits — whole-of-system

Key environmental assets downstream that would benefit from increased flows include the Barmah–Millewa Forest, Werai Forest, Gunbower–Koondrook–Perricoota forests, Hattah Lakes and the Riverland–Chowilla Floodplain. Other lesser known but significant areas include various wetlands along the River Murray channel and the Wakool River system (Green & Alexander, 2006) (Murray-Darling Basin Authority, 2014a).

MDBA modelling has demonstrated that relaxing this constraint, in conjunction with a relaxation of the downstream constraint at Yarrawonga Weir, could produce tangible environmental benefits at Barmah–Millewa Forest. In practice, these events could be delivered by supplementing relatively high unregulated flows from the Ovens and/or Kiewa Rivers with environmental releases from Hume Dam, but only if the Doctor's Point constraint was modified to allow increased flow during the desired period.

In conjunction with constraints measures in the Yarrawonga – Wakool and the Lower Murray key focus areas, this potential measure would assist in delivering overbank watering events to help achieve the Basin-wide outcomes in Table 6 below. Relaxing constraints in all three key focus areas of the River Murray (Hume to Yarrawonga, Yarrawonga to Wakool and Lower River Murray) is important for achieving environmental flows and outcomes in the downstream reaches.

Table 4: Summary of environmental outcomes at whole-of-Basin level.

Habitat areas	General outcome across the Basin
Riparian or 'streamside' habitats	The ability to reinstate more frequent and variable 'bankfull' events which would maintain healthy streamside vegetation such as river red gums and river cooba.
Permanent and semipermanent wetland habitats close to the major rivers	The ability to reinstate more frequent and variable flow regimes to provide healthy wetland habitats and support the role that these systems play in the productivity of the river system more broadly - for example providing breeding and feeding habitats for birds and fish, and carbon/nutrient inputs to support instream productivity.
Low level floodplain habitats	The ability to reinstate more frequent and variable flow regimes to water low level floodplain vegetation communities such as red gum forests and woodlands, to maintain the health of these communities and the important role they play in the broader productivity of the Basin's rivers.

(Murray-Darling Basin Authority, 2011)

3.3.3 Potential adverse environmental impacts – within reach and whole-of-system

The Commonwealth Environmental Water Holder has set out a Framework for Determining Commonwealth Environmental Water Use. Under the framework environmental watering should have regard to the potential environmental risks, including downstream environmental risks, that may result from applying environmental water; and measures that may be taken to minimise those risks (Commomwealth Environmental Water Office, 2013). Potential environmental risks include things like the possibility of hypoxic blackwater events, and the spread of pest flora and fauna.

These risks and issues are considered for all environmental watering, but are especially important to consider for overbank environmental watering events, as higher flows could exacerbate some of these risks. However, the environmental benefits of environmental watering also work to reduce and compensate for these risks over the longer term. A more natural environmental watering regime that includes some overbank flows would therefore reduce and compensate for these risks more profoundly.

Generally the risks seem well within the scope of risks that can be managed by current controls.

A high level assessment of the potential adverse environmental outcomes, including some which are also associated with normal environmental watering, is presented in Appendix 2.

3.4 Hydrology of the area and environmental water requirements

Hume Dam and Dartmouth Dam have changed the flow regime of this part of the River Murray. Prior to regulation, the Hume–Yarrawonga stretch of the Murray would have experienced peak flows in winter and early spring, and low flows in the summer period. Hume Dam now catches high flows in winter and spring, with peak irrigation demand causing high releases downstream during summer and autumn to supply irrigation water both locally, via the Mulwala and Yarrawonga irrigation channel system, and further downstream (Murray-Darling Basin Authority, 2014b).

The current regulated operation of the river system provides flows within a range that is largely governed by irrigation requirements and minimum flow provisions. Irrigation requirements generally follow crop demand patterns and do not vary significantly during the summer irrigation season. Rivers are operated to maximise water availability for consumptive use and to limit evaporation losses on floodplains. Releases from storages resulting in overbank flows are a consequence of managing storages when they are close to full or spilling over, rather than to meet environmental objectives. Over time, such operations have led to a substantial decline in floodplain health across the Basin (Murray-Darling Basin Authority, 2014a).

The Snowy Mountains Hydro-electric Scheme has also exacerbated the effects of regulation. The scheme was completed in 1972 for the purposes of generating electricity and providing additional irrigation water to the west. Construction of the scheme means that, on average, an extra 620 GL per year of water is diverted from the Snowy River and directed into Hume Dam, increasing the amount of water that passes between Hume Dam and Yarrawonga Weir as regulated flows (Murray-Darling Basin Authority, 2014a).

During development of the Basin Plan, MDBA established environmental flow indicators which are linked to the environmental water requirements and objectives of the Basin Plan. These are outlined in the report *the proposed "Environmentally sustainable level of take" for surface water of the Murray-Darling Basin: Methods and outcomes* (Murray-Darling Basin Authority, 2011).

Summary

- This business case investigates the feasibility of a change in the regulated flow limit from 25,000ML/day to 40,000ML/day as measured at Doctor's Point.
- Environmental flows in the 25,000-40,000ML/day flow range at Doctor's Point could be used to:
  - deliver longer and/or higher peak events to downstream sites in the River Murray, and
  - fill gaps in dry years where there is environmental water available.
- Modelling undertaken in 2015 was used to show the total number of opportunities that river operators could have to deliver beneficial environmental flows using the new capacity generated between 25,000-40,000ML/day as measured at Doctor's Point.
- The model is not intended to show when environmental water *would* be delivered, but provides an indication of the total number of times that environmental water *could* be delivered.
- This modelling shows an upper limit of change for the frequency, timing and duration of flows in this reach if constraints are addressed (relaxed). The modelled changes include the following:
  - More than twice as many flows above 25,000ML/day at Doctor's Point.
  - Around half as many events that go over 40,000ML/day at Doctor's Point, as the delivery of environmental flows earlier in the year creates airspace and leads to a reduction in spill events from Hume Dam.
  - Up to 7 years in a decade could have one or more flows above 25,000ML/day, compared to current conditions when an event of this size occurs 4-5 years in a decade.
  - There are often multiple opportunities to deliver environmental water events in one year. Under current conditions, 3-4 years in a decade with a flow event over 25,000ML/day will have more than one flow event above this height. If constraints are relaxed (i.e. flows up to 40,000ML/day are allowed) 6 out of 10 years that have a flow event over 25,000ML/day will have more than one flow event above this height.
  - The modelled average duration of flows above 25,000ML/day if constraints are relaxed is around 13 days, compared to around 17 days under current conditions.
  - The modelled hydrology differs slightly depending on what the constraint at Yarrawonga is relaxed to. In general, at Doctor's Point:
    - the average duration of flow events above 25,000ML/day will be slightly longer if constraints are relaxed to 65,000Ml/day at Yarrawonga, and
    - there will be more opportunities to use environmental flow events above 25,000ML/day if constraints are relaxed to 50,000Ml/day at Yarrawonga.
  - It is important to note that many of the modelled flow events do not go up to 40,000ML/day, but that many are only between 25-35,000ML/day.
- Overall, the modelling is likely to overestimate the number of available opportunities to deliver environmental water.
- The frequency of environmental watering events in the Hume-Yarrawonga reach will depend on many factors not able to be considered in the modelling. These include:
  - weather and flow data that will be available
  - the extent to which river operators are able to safely 'piggy-back' environmental water on in-stream flows
  - the goals set by environmental water holders in long-term environmental water plans
  - the final volume of water held for the environment
  - the extent to which constraints in other areas are able to be relaxed, and
  - the changing climate.
- Any future environmental flows will be delivered according to river operators' guiding principles which include reducing risk and maximising environmental outcomes.

4 Proposed operating regime

4.1 Proposed changes to hydrology

This business case investigates the feasibility of increasing the regulated flow limit for environmental water releases in the Hume–Yarrawonga stretch of the river from 25,000 to 40,000 ML/day, as measured at the Doctor's Point gauge around 15 km downstream of Hume Dam. The timing of these flows is expected to be between June and November when natural tributary flow events usually happen, and when the floodplain needs the water most. This timing should also minimise competition for channel space by avoiding peak irrigation demands in late spring and summer.

Flows in this range are still relatively common in this reach, occurring every few years. Modelling conducted in 2015 shows that there are many opportunities to improve outcomes in downstream reaches of the River Murray by increasing both the number and duration of events in this range when flows from Hume Dam can be used to align with tributary flows downstream. This method can be used to increase the size of the peak event and water more floodplain, or to extend the duration of a natural flow event to keep water on the floodplain for longer.

The modelling intends to show what is hydrologically feasible by applying one possible method of environmental water delivery with the specified volume of environmental water recovered annually under the Basin Plan. It is important to note that this modelling is not intended to prescribe a future flow regime, but to provide an upper limit for how many times any new capacity created by relaxing constraints could be used in order to ensure the cost estimates adequately cover the costs associated with mitigating the effects of addressing constraints. Appendix 7 provides more detail on the hydrological model and the modelling assumptions and methodology.

Three modelled scenarios inform the results. These are:

- the "baseline" flow regime was assumed to be represented by modelling outputs from the MDBA's "baseline diversion limit" (BDL) model run. This is referred to as 'current conditions' as it provides a starting point for understanding the scale of change that would be observed if constraints are addressed or 'relaxed'
- the 'constraints relaxed' scenario where the regulated flow limit becomes 40,000ML/day at Doctor's Point and 50,000ML/day at Yarrawonga (YAR50), and
- the 'constraints relaxed' scenario where the regulated flow limit becomes 40,000ML/day at Doctor's Point and 65,000ML/day at Yarrawonga (YAR65).

The modelling results show that if constraints were relaxed, it might be possible to deliver higher flows in the range of 25-40,000ML/day at Doctor's Point much more frequently to meet the downstream environmental needs. The model shows that there are opportunities to deliver flow events that go above 25,000ML/day to meet environmental needs downstream more than twice as often as those flows occur under current conditions, with 160 events compared to 339 (YAR50) or 320 (YAR65). Utilising this additional capacity would increase the ability of river operators to achieve a higher and longer flow peak in the range of 50,000-65,000ML/day in ecologically significant sites downstream of Yarrawonga, including the Barmah and Millewa forests.

Increasing this flow limit would also contribute to an increase in the number of events in the 60,000-80,000ML/day flows at the South Australian border, enabling watering of up to 62,000 hectares of floodplain vegetation. Further detail on the ecological benefits of these flows is included in Section 3. The business cases for Yarrawonga-Wakool and the South Australian River Murray also provide further detail on the downstream benefits that would be supported by the higher flow limit in the Hume-Yarrawonga reach.

For the most part, environmental water delivery is modelled to occur in relatively wet years when flows above 25,000ML/day would often have happened anyway, either as spills or pre-releases from Hume Dam. Making environmental releases earlier in the season rather than allowing the dam to fill and spill later means that there is more likely to be an alignment of releases with the flows feeding in to the River Murray from tributaries. Such coordination and timing of environmental releases is critical in influencing higher flow peaks in the Lower Murray.

The modelled results also show flow events above 40,000 ML/day could be reduced by around fifty percent, with over 109 events over 40,000 ML/day at Doctor's Point modelled to occur under current conditions, compared to 56 (YAR50) or 53 events (YAR65) if constraints are relaxed. This is because delivering higher environmental flows means that overall there would be fewer spills from Hume Dam as water is released earlier in the season and airspace is created.

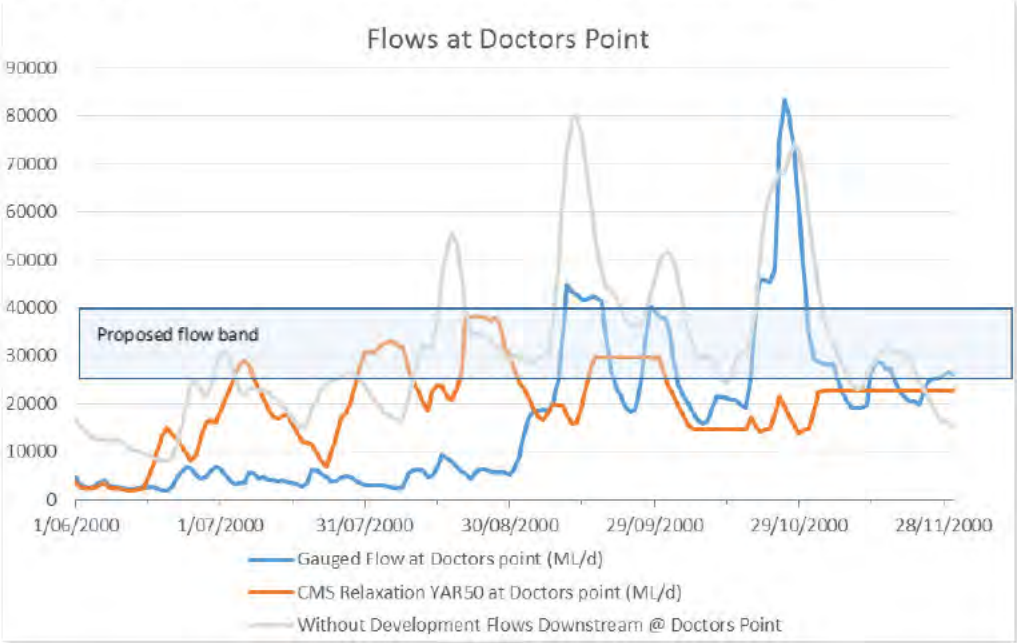
Overall, the modelled increase in events translates to more years with at least one event above 25,000 ML/day. The modelled current conditions show that an event above 25,000 ML/day currently occurs 4-5 years in a decade (46% of years) compared to the modelled results if constraints are relaxed which show flows 7 years in a decade (69% of years for YAR50 and 68% of years for YAR65). It is also important to note that in many years with a flow event above 25,000 ML/day there are there are multiple opportunities to deliver flows in the range of 25,000-40,000 ML/day to mimic natural flows. The modelling for relaxed constraints represents a slight increase in the number of years with more than one event, with multiple events in one year occurring in 3-4 years in a decade or 34% under current conditions compared to 6 years in a decade under a relaxed constraint scenario (59% for YAR50 or 58% for the YAR65 scenario).

The modelled flow events over 25,000 ML/day last for an average of about two weeks with constraints relaxed (13 days for YAR50, 14 days for YAR65). This compares to an average flow duration of about 17 days under current conditions. This reduction in average duration is reflected in the higher number of shorter duration events in the 25,000-40,000 ML/day range of regulated environmental flows, compared to the current regime where a flow above 25,000 ML/day reflects a spill which generally results in a higher peak and subsequently a longer duration.

Implicit in the model is an assumption that operators are able to manage flows above 25,000 ML/day for extended periods, because appropriate mitigation options have been put in place. Figure 2 below shows a hydrograph with modelled environmental flows and observed mean daily flows at Doctor's Point for the winter-spring period of 2000. The observed, rather than modelled 'current conditions' flows have been used for the hydrographs in this section as these allow a direct comparison between what actually happened and the nature of the changed flows. In general, observed flow events in the recent historical record (i.e. after the construction of major infrastructure during the sixties and seventies and changes in water sharing arrangements as a result of recent water reform initiatives) closely reflect the modelled 'current conditions'.

Figure 2 shows that in the year 2000 events with flows above 25,000 ML/day could occur four times in the winter-spring period under a modelled constraints relaxed scenario that assumes a flow limit of 40,000 ML/day at Doctor's Point and a flow limit of 50,000 ML/day downstream of Yarrawonga (YAR50). The total number of days that flow is modelled to be above 25,000 ML/day in this period is approximately 43 days, with the longest event lasting for 16 days. The highest flow peak reaches to ~38,000 ML/day. This is compared to the hydrograph of the observed flow events based on mean daily flow during the same period, which shows that flows went above 25,000 ML/day six times (*the final event in the series peaked at <26,000 ML/day so has been excluded*) for a total of around 53 days, with the longest flow event lasting for 18 days and the highest flow peak reaching to ~83,000 ML/day.

Figure 2: Gauged mean daily flow and modelled flow scenarios for Doctor's Point 2000.

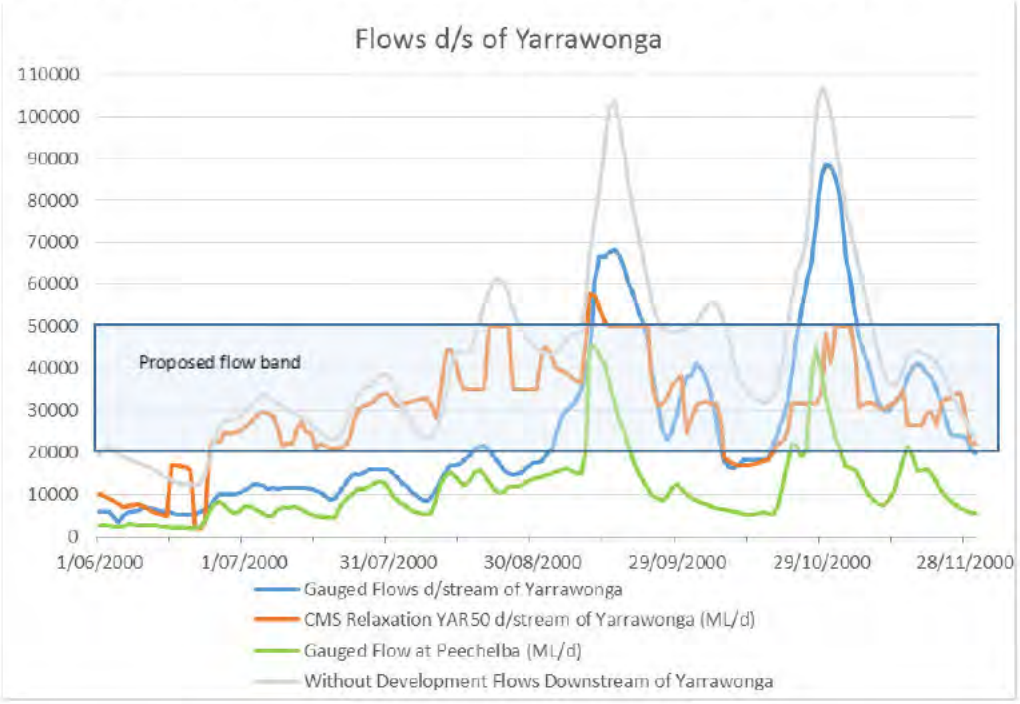


The hydrograph in Figure 2 also reflects the nature of the flow events above 25,000ML/day. Although there are four events above 25,000ML/day in the above hydrograph, two of the flow events only just reach 30,000ML/day and only one event approaches 40,000ML/day. In addition, the observed spill event in November 2000 was more than twice as high as it might have been if environmental releases had been made earlier that year.

The hydrograph shown in Figure 3 also provides the modelled 'without development scenario' i.e. what would have occurred without any dams in place, which shows that the peaks would be far larger than either the observed flows or what could be delivered if constraints are relaxed.

Figure 3 outlines what could have happened to flows downstream of Yarrawonga if the flows described for Doctor's Point in Figure 2 had been delivered. The hydrograph in Figure 3 shows that using the capacity realised through relaxing constraints at Doctor's Point resulted in a flow event downstream that still mimicked the natural or 'without development flow' but with much lower peaks. The modelled 'constraints relaxed' hydrograph also avoided the high peaks seen in the observed flows at Yarrawonga, although the high flow event in the unregulated Ovens River as represented by the observed flows at Peechelba still resulted in a flow that exceeded constraints at Yarrawonga.

Figure 3: Gauged mean daily flow and modelled flows downstream of Yarrawonga Weir 2000.



The capacity to deliver water up to 40,000ML/day at Doctor's Point is also a valuable tool to be used in some drier years. Where there is environmental water available, releasing water from Hume to coincide with downstream tributary flows would reduce the number of years between watering events for floodplain vegetation and wetlands.

Figure 4 shows modelled and observed flows at Doctor's Point in 2004. This hydrograph represents much drier conditions than those experienced in 2000, which is reflected in the lower peaks and shorter durations of events in the modelled constraints relaxed scenario at Doctor's Point. In this series of events, two of the three events over 25,000ML/day only reach around 27,000ML/day and flows exceed 25,000ML/day at Doctor's Point for a total of 27 days in the June-November period.

Figure 4: Gauged mean daily flow and modelled flows for Doctor's Point winter-spring 2004.

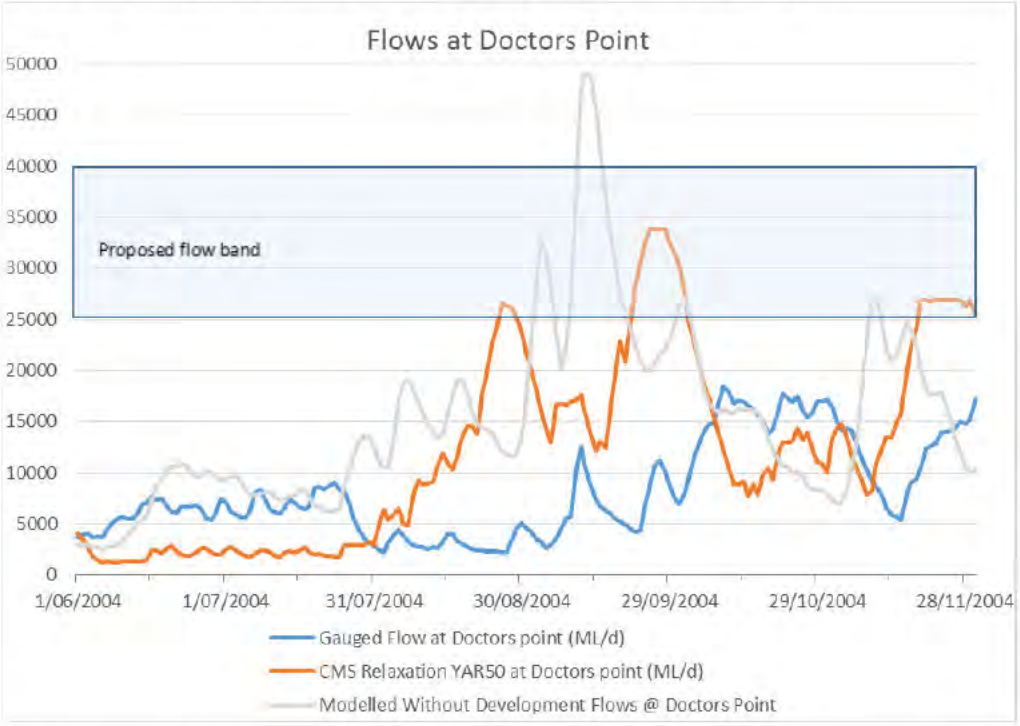
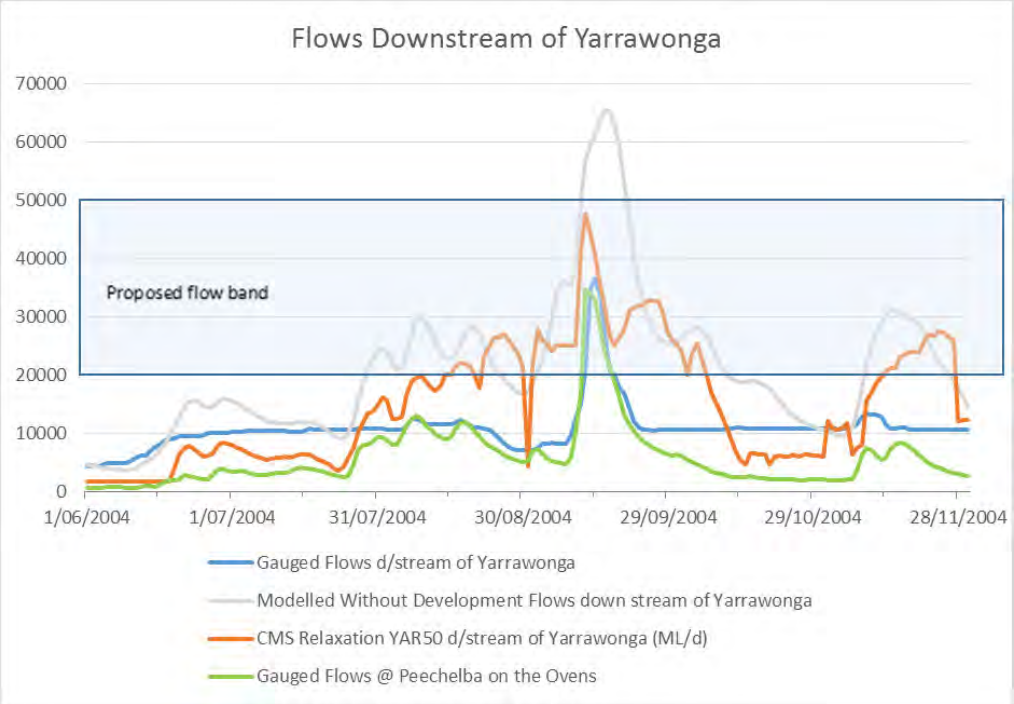


Figure 5 shows the modelled and observed flows for the same period in 2004 for Yarrawonga with constraints relaxed to 50,000ML/day. The modelled constraints relaxed flow shows that there could have been an opportunity to take advantage of a reasonable flow in the Ovens River to get a longer and higher flow event in the mid-Murray.

Figure 5: Gauged mean daily flow and modelled flows for Yarrawonga winter-spring 2004.



While the environmental water delivery approach applied in this modelling follows river operators logic and provides an overview of the total number of opportunities available for delivering flows of up to 40,000ML/day at Doctor's Point to support downstream demands, this modelling represents only one of many potential ways of delivering environmental water. The number of times that flows of this height would actually be delivered is likely to be less than what has been indicated by modelling for several reasons. Firstly, limitations in the modelling approach mean that in some instances releases from Hume Dam will have been requested to achieve a downstream flow height or rate. In practice river operators would consider whether the downstream needs could be met by flows from downstream tributaries (such as the Ovens, Goulburn and Lower Darling rivers) or by use of Menindee Lakes system.

The model also shows that flows would be delivered according to natural flow cues downstream whenever possible to meet those demands, but does not fully account for decision making by environmental water holders or river operators. In some cases river operators may release water from Hume Dam in a more conservative way than is modelled to avoid unintended flooding. For example, releases from Hume are likely to be smaller than the model suggests if the Kiewa and Ovens are experiencing high flows to ensure flows do not exceed the new regulated limit. This conservatism is likely to decrease over time as river operators gain confidence in their ability to accurately deliver environmental flows up to the new regulated limits for environmental flows.

Likewise, environmental water holders would have to make decisions about the best use of environmental water to look after rivers and wetlands, which won't necessarily reflect the modelled flow patterns closely. For example, environmental water holders might want to water lower parts of the downstream floodplain that would not require the use of the 40,000 ML/day flow capacity every time.

The modelling approach does not include any adjustment to the SDLs resulting from supply contributions. Likewise the need to utilise the additional flow capacity above 25,000ML/day at Doctor's Point will also depend on the extent to which constraints downstream are relaxed, particularly downstream of Yarrawonga and in the Goulburn and Lower Darling systems.

Furthermore, the modelled scenarios described in this section rely on the historical rainfall and flow records. It is now widely acknowledged that the climate is likely to be changing and is likely to result in less rainfall and warmer temperatures which will contribute to decreased runoff and lower volumes in our dams. As is the case with irrigation allocations, environmental water allocations in any year will reflect the available water in storages. As the climate changes, environmental water allocations are likely to be lower than those we applied in the modelled scenarios.

4.2 How flow rates would be delivered operationally

Creating a flow of 40,000 ML/day in the River Murray between Hume Dam and Yarrawonga Weir would typically be achieved by coinciding releases from Hume Dam with inflows from the Kiewa River. For example, if there was a flow of around 7,000 ML/day coming in from the Kiewa, then the release from Hume Dam may be 25,000-30,000 ML/day. Topping-up unregulated inflows with environmental releases to generate a higher peak flow and/or longer event duration has proved successful and is a common tool for water managers.

The April 2012 river operators and modellers workshop concluded that reaching the target range of flows (50,000–80,000 ML/day) in the Lower Murray would require the coordinated release of water from multiple valleys to achieve a single event outcome. For example, high flows of 50,000–80,000 ML/day in the Lower Murray could be delivered through coordinating releases from storages such as the Hume Dam, Lake Eildon and the Menindee Lakes, combined with unregulated flows entering the Murray from tributaries such as the Kiewa, Murrumbidgee or Ovens rivers during winter or early spring (Murray-Darling Basin Authority, 2013c).

Any regulated environmental release will have to be managed in a way to minimise flood risk. River operators are experienced in managing this risk, and use a range of tools to help assess and manage risks in delivering environmental water, such as:

- Bureau of Meteorology rainfall forecasts
- Rainfall/runoff models
- MDBA's operations daily river model
- Dedicated flood models
- Annual scenario planning in the Annual Operating Plan, and
- MDBA is testing the Murray Source model.

It is possible that easement areas slightly larger than the modelled inundation footprint on private land could be purchased to limit the risk of an environmental watering event causing flooding in areas that would not otherwise be covered. However, more work needs to be done to determine how large this additional 'freeboard' or 'buffer' area should be to minimise the risk. This would include further work to better understand and demonstrate how flood risk would be managed in the context of overbank environmental watering.

4.2.1 Implementing flows incrementally

All supply, constraints and efficiency measures must be fully operational by 1 July 2024. Leading up to 2024, mitigation activies would be assessed and place, and incremental flow increses would be trialled to ensure mitigation activities are effective.

This approach is compatible with key principles that guide river operations.

These include adaptive management principles, to find better ways to operate the River Murray system; and, avoiding unnecessary large-scale changes to river conditions. Generally speaking and where possible, time should be taken to carefully consider the potential for any interactions, dependencies and implications, for example as a result of large releases from storages.

The principle of implementing flows in a staged and incremental manner is also consistent with the concept of commissioning structures in stages rather than operating at full capacity on the initial event. This principle has been applied in the commissioning of environmental works and measures under The Living Murray program.

4.3 Principles for river operations

River Murray system operators apply a set of guiding principles which involve exercising judgement and consideration of numerous opportunities, risks, uncertainties and options while maintaining the flexibility to effectively respond to conditions and system drivers. The following guiding principles provide the foundation for operations in the River Murray system:

- **Apply adaptive management to find better ways to operate the River Murray system.** Applying adaptive management gives a framework for evaluating and documenting lessons learnt, so that they can be applied in the future. The Independent River Operations Review Group (IRORG) process is a key part of the adaptive management framework.
- **Contribute to environmental outcomes.** This principle applies to demand driven system conditions, however it may become increasingly relevant to inflow driven conditions in the future if operational constraints to managing higher flows are relieved or resolved. River regulation has had significant impacts on both the in-stream, riparian and floodplain environment in the River Murray System. River operations have been changing overtime to try and reduce these impacts. These changes are supported by major reforms, such as The Living Murray program, the Basin Plan and the recovery of water for the environment. River operations in the River Murray system contribute to environmental water management and delivery in a range of ways, such as providing information to help inform annual environmental watering priorities and helping to identify opportunities to coordinate environmental watering.
- **Coordinate River Murray System operations with tributary inflows.** This principle supports the achievement of the general objectives and outcomes for water storage and delivery and accounting, River Murray Operations' assets and environment. It applies in both demand and inflow driven conditions. Coordinating River Murray System operations with tributary inflows provides for efficient and effective operation of the River Murray system by conserving water and minimising undesirable losses or unnecessary transfers between storages while maximising water available to the States.
- **Meet water orders, as far as possible**. This principle applies during demand driven conditions. This principle requires water orders and water entitlements along the River Murray system to be met, as far as possible, by river operators making appropriate dam releases. A water order may be for consumptive or environmental water use.
- **Other principles**. Other principles that guide River Murray operations include: passing floods safely; anticipating problems and exercise judgment; releasing water from downstream storages first; avoiding unnecessary big changes to river conditions; using historic data, information and modelling to guide operations; monitoring and considering relevant climate outlooks and weather forecasts; and maintaining open communications.

4.4 Policy or operational changes required

In order to deliver flows in the way investigated in this business case, it would be necessary for the policy changes identified as the "Pre-requisite Policy Measures" to be implemented. Protecting environmental flows from extraction, delivering environmental water on top of other in-stream flows and using environmental water throughout the length of the river are the most significant factors for achieving environmental outcomes. Inadequate implementation may reduce the effectiveness of this measure, and reduce or entirely offset the SDL adjustment resulting from supply measures (Murray-Darling Basin Authority, 2014b).

If the proposal proceeds, the Objectives and Outcomes for River Murray Operations may need to be updated to reflect a new maximum regulated flow rate of 40,000 ML/day at Doctor's Point for the purpose of environmental watering.

5 Third Party impacts and mitigation measures

5.1 Assessment of impacts, mitigation measures and costs

5.1.1 Hydrological basis for this assessment

This business case investigates the feasibility of increasing the regulated flow limit for environmental water releases. Increasing the regulated flow limit would result in a changed hydrological regime, which would result in impacts, mitigation measures that would be required to address those impacts, and associated costs.

A hydrological model was developed to define this potential future hydrological regime, and to inform the investigation of impacts, mitigation measures and costs. This model is described in more detail in Appendix 7 to this business case.

Importantly, the modelled future flow regime represents a maximum extent to which future *opportunities* could arise to deliver environmental water, if constraints were relaxed to 40,000 ML/day. It is important to recognise that in practice, not all these opportunities would necessarily be taken up. Hence, the impacts, mitigation measures and costs identified in this business case represent an overestimate of the actual impacts, mitigation measures and costs that would be required.

5.1.2 Improvements on prefeasibility assessment

This business case presents the outcomes of work to investigate third party impacts, mitigation measures and costs, which aimed to address key uncertainties and/or limitations in the work that was undertaken in the CMS prefeasibility assessment (completed in 2014).

Table 7 summarises the key issues that were addressed, and the implications for the impacts, mitigation measures and cost estimates presented in this business case.

Table 5: Key issues addressed in feasibility assessment of impacts, mitigation measures and costs.

Issue	Approach taken in prefeasibility phase (2014)	Improvements in feasibility phase (2015)	Implications for this business case
Hydrology (what flows could be delivered, when, and how often).	Used the MDBA's "BP2800RC" relaxed constraints hydrological model, developed in 2012 to inform finalisation of the Basin Plan.	Revised and improved hydrological model (refer to Appendix 7).	Better reflects the potential hydrological opportunities to deliver higher flows.

Issue	Approach taken in prefeasibility phase (2014)	Improvements in feasibility phase (2015)	Implications for this business case
Crossings (how many crossings are affected, their specifications, and what would need to be done to mitigate impacts)	It was assumed that all crossings which were found to intersect with a modelled inundation layer would be affected and would require capital works.	This assumption was tested through ground truthing with on-ground stakeholders, and through further analysis of the appropriate mix between crossings and other mitigation options (e.g. easements).	Takes into account estimate of how many crossings would actually require capital works. Note however that it was not possible to specifically identify individual crossings on private land; this would require detailed property-by-property consultations and would be undertaken in the implementation phase.
Roads (which roads are affected, their specifications, and what would need to be done to mitigate impacts).	It was assumed that all roads (of certain classes) which were found to intersect with a modelled inundation layer would be affected. It was also assumed that the majority of these roads would require capital works.	This assumption was tested through ground truthing with on-ground stakeholders.	Recognises that it many cases stakeholders have indicated that rather than major capital works, inundation of roads would be better addressed through a mechanism to allow for reinstatement activities.
Land use assumptions (what agricultural land uses would be affected).	ALUM land use classifications underpinned the modelling of easement costs. These land use classifications can sometimes be misleading in assessing impacts of flows, as they represent the dominant land use for a particular cadastre, rather than the land that is affected (e.g. if only part of the cadastre is inundated).	Land use classifications were refined through analysis of aerial photography.	Assumptions are as accurate as possible in the context of a regional level assessment. While there may be individual cases where there are inaccuracies, these inaccuracies are expected to balance each other out overall, and have an insignificant effect on the overall assessment.

Issue	Approach taken in prefeasibility phase (2014)	Improvements in feasibility phase (2015)	Implications for this business case
Other assumptions relevant to easements (e.g. land values, gross margins, impacts on agriculture).	Assumptions were made drawing on publicly available datasets.	Assumptions were tested with local experts, and through consultations with landholders.	Assumptions are as accurate as possible in the context of a regional level assessment. While assumptions will not necessarily be accurate at a micro (e.g. property) level, this is expected to have an insignificant effect on the overall assessment.
Specialist businesses (e.g. golf courses, caravan parks)	Did not consider specialist businesses.	Considered during feasibility phase. A selection of specialist businesses were identified as "case studies" and studied in detail, including through on-ground consultations.	Investigation of impacts, mitigation options and costs is considered appropriate for a regional level assessment. Further work would need to be undertaken during implementation phase to assess implications for individual businesses in detail.
Other impacts on landowners (e.g. pumps, fences) and options for mitigating those impacts.	Considered other impacts but only to a limited extent.	Considered in more detail in the feasibility phase, and discussed through consultations with landholders.	Assessment of impacts, mitigation options and easement costs takes into account these impacts in a general sense. It was not possible to consider all impacts in detail, particularly at a micro (e.g. property) level. This would be undertaken in the implementation phase.

Issue	Approach taken in prefeasibility phase (2014)	Improvements in feasibility phase (2015)	Implications for this business case
Interactions between different mitigation measures (e.g. easements vs infrastructure) and the appropriate mix of mitigation measures in different contexts.	Noted during the prefeasibility phase, but not considered.	Considered through a high-level cost-benefit assessment.	Assessment takes into account these interactions in a regional context. Quantum of infrastructure mitigation options (e.g. private crossings) is therefore considered reasonable for feasibility purposes. It was not possible however to identify specific measures at a micro (e.g. property) level. This would be undertaken in the implementation phase.
Implementation and approvals processes.	Considered through addition of a contingency allowance.	Considered in detail, including through assessment of what processes would be required in different jurisdictions.	Assessment recognises these processes. However they have not been costed in detail as specific processes required would be subject to implementation and governance arrangements which have not yet been agreed.

Issue	Approach taken in prefeasibility phase (2014)	Improvements in feasibility phase (2015)	Implications for this business case
Spatial uncertainties associated with implementation of environmental flows, including: • Potential for flows to be higher than anticipated, for example if water releases are combined with natural events, and there is more rain than expected, • Uncertainties in inundation modelling and mapping, • Potential for channel cross sections to change over time.	Recognised but not taken into account.	Considered through: • Sensitivity analysis of key input parameters (e.g. areas of land affected, km of road affected) to take into account implications of spatial uncertainty for cost estimates, • Contingency in cost estimates.	Assessment recognises that there are uncertainties and takes them into account.

5.1.3 Projects commissioned

Independent consultants were engaged to undertake four projects to inform the investigation of impacts, mitigation measures and costs. These projects focused on:

- private agriculture
- public infrastructure
- specialist businesses, and
- implementation and approvals.

Further details of the projects are included in Appendix 6.

Impacts identified

Table 8 shows the potential impacts that were identified through these projects and the recommended activities to mitigate those impacts. Further details of these impacts and associated mitigation activities are included at Appendix 6.

Table 6: Impacts and mitigation options.

Impact		NSW	VIC	Mitigation activity
Inundation of agricultural land	Number of properties affected[3]	101	106	Easements
		Total 207 across both jurisdictions		

[3] Affected properties were identified as those on private agricultural land that were subject to inundation (based on modelling) within any part of the property boundary. "Property" means an area of land subject to private tenure and delineated as such in the relevant state land/property register. The "number of properties" is likely to be different to the "number of landholders" as one property may have multiple owners, and one landholder may own multiple properties. The individual costings reports for each reach provide more information on the number of properties with inundation extents categorised by size.

Impact		NSW	VIC	Mitigation activity
	Cropping (ha)	2	1	
	Tolerant pasture (ha)	364	336	
	Vulnerable pasture (ha)	230	268	
	Total area affected (ha)	596	605	
Impacts on farm infrastructure	Haysheds, silos, livestock yards	Generally located off the floodplain and it is considered there will be minimal impact.		
	Pumps	Minimal impact. River, creeks and farm dams supply the vast majority of livestock drinking water although some portable pumps are infrequently used. Irrigation pumps on the river are rare.		
	Fences	Flooding could result in a build-up of debris along fences and weaken their structure and reduce longevity.		
Farm management issues	E.g. animal health, weeds, clean up and farm planning	Range of impacts – see details in Appendix 6.		
Interrupted access to private agricultural land	Area of land (ha)	656	666	
	Affected private bridges (number of)	On-ground property assessment required to develop estimate. 41 properties were assessed as having inundation of >10 ha and are considered more likely to have affected bridges and crossings.		New or upgraded bridges and crossings
	Affected private crossings (number of)			
Reinstatement of public infrastructure	Sealed roads (m)	801m	93m	Reinstatement activities
	Unsealed roads (m)	579m	981m	
	Tracks (m)	8304m	6687m	
	Shared user paths (m)	270m	20m	
	Culverts (number of)	1	6	
	Bridges (number of)	1	5	
	Landscaping (ha)	42ha	35ha	
Significant impacts on public infrastructure requiring capital works	Isolated Property Access road upgrades	Assumed that 1% of impacted properties required 100m of unsealed road upgrade		Raise road
	Upgrade to Kensall Green Road			Raise road / crossing
Access roads to specialist activity sites	Norieul Park Café access			Raise road / crossing
Impacts on specialist activities	Quarries (number of)	2	nil	Easements
	Visitors Centre	1	nil	Easement or Upgrade crossing

The estimated costs associated with these mitigation measures are presented in section 7 of this document.

As discussed further in the section below, a previous easements acquisition process was undertaken to allow regulated flows of up to 25,000 ML/day at Doctor's Point. Approximately half the properties that have been assessed as impacted by flows of up to 40,000 ML/day are also affected by flows of up to

25,000 ML/day, and were involved in that earlier easements acquisition process. Easements (for flows of up to 25,000 ML/day) were obtained for a majority of those properties. Easements were not obtained for a minority of properties.

Table 7: Comparison with properties involved in earlier 25,000 ML/day easements process

Number of properties	NSW	Victoria	Total
Assessed as inundated by flows of 40,000 ML/day	101	106	207
Also affected by flows of 25,000 ML/day	37	70	107
- **Easements were obtained for flows of 25,000 ML/day**	26	59	85
- **Easements (for flows of 25,000 ML/day)** were offered but not obtained	11	11	22

5.2 Stakeholder comments

The MDBA and previously the Murray Darling Basin Commission (MDBC) have a long history of engagement with stakeholders in the Hume-Yarrawonga reach of the River Murray. These relationships have been formed over many years of consultation with riparian landholders, councils and other stakeholders concerning water management in the reach, including a previous easement acquisition process to confirm the current regulated flow limit of 25,000ML/day at Doctor's Point. The following provides an overview of the perspectives of the key stakeholder groups in this reach.

5.2.1 Riparian landholders

An assessment of inundated land shows that around 200 properties could have areas of land affected at these flows. The number of landholders that are affected is likely to be somewhat lower, as it is likely that individual landholders may own multiple properties. Conversations about the proposed flows have been conducted with the executive and committee members of the Murray River Action Group (MRAG) who are the nominated representatives to promote the interests of riparian landholders in this reach. The executive members of this group also sit on the Advisory Group for Hume-Yarrawonga Waterway Management (AGHYWM). One-on-one consultations have also been held with a number of landholders.

The Hume-Yarrawonga reach report (Murray-Darling Basin Authority, 2014a) described in detail discussions with MRAG over a number of years. These discussions helped to inform the understanding of potential impacts at different flow rates and the eventual decision by states to investigate a flow of 40,000ML/day as measured at Doctor's Point as the upper limit for flows in this reach.

In general, riparian landholders are not in favour of managed flows to this height and would prefer that the flow limit for all regulated flows remained at 25,000ML/day. However, landholders have previously indicated that they believe governments are likely to proceed with actions to acquire flow easements to this level, and have outlined their key concerns regarding impacts and mitigation options.

The key concerns raised by riparian landholders, as well as comments on mitigation measures, are outlined below.

5.2.1.1 Flood risk

Riparian landholders are concerned that unanticipated rain could lead to managed environmental flows exceeding purchased easement areas and indicative durations (if specified). Such flows would cause additional impacts, and might result in threshold effects if livestock are stranded on islands for longer than anticipated and run out of food.

The close proximity to Hume Dam combined with the relatively minor tributary inflows in this reach mean that this risk is likely to be low. Modelling undertaken to inform cost estimates in 2015 suggests that in general the risk of flooding (i.e. exceeding flows above 40,000ML/day at Doctor's Point) in the reach would be lower as increased environmental releases provide airspace in the dam (see Section 4.1).

However, it is recognised that work would need to be done to further investigate inflow scenarios of concern to landholders, to ensure appropriate risk minimisation procedures are in place.

To investigate this risk, consultants were commissioned to develop the scope for a flood risk study. In developing this scope, the consultants have spoken to landholders, including some in the Hume-Yarrawonga reach, to ensure that this future work would investigate their specific concerns. While a flood risk study will not be available to inform this business case, it is anticipated that this work will help to inform how environmental water is delivered in the future. Furthermore, provisions have been made in the cost estimates to ensure that there would be adequate money to enable slightly larger easement areas to be purchased to help ensure easement areas will not be exceeded during regulated environmental flows if necessary.

5.2.1.2 Duration

Landholders have consistently stated that they are concerned about the duration of overbank environmental flows. While a few days is generally considered to cause little harm, time-frames over four or five days are considered problematic. Landholders commented that they thought the hydrology modelling should reflect flows above five days, rather than seven to account for this. Landholders consider that flow durations of longer than five days are likely to kill improved pastures; lead to long periods of stock exclusion, as saturated land needs to dry out before livestock can be returned; and mean that leaving livestock on islands of land with impeded access may be an unviable option due to uncertainty about how long feed reserves may last. Landholders with small holdings are considered particularly vulnerable, as they may have inadequate feed reserves to provide for all livestock during prolonged inundation events and be forced to transport livestock off-farm. The duration threshold of events of greater than/less than seven days was based on advice from qualified consultants with extensive agronomic experience and is considered an appropriate measure for use in a regional-scale model to assess effects on pastures for the purposes of costing impacts in the feasibility phase. However, it is possible that local conditions may affect pasture survival in this reach and that five days could be investigated as a more appropriate threshold for determining final costs in future work.

It is not possible to be explicit about the frequency, timing and duration of future environmental releases up to 40,000ML/day, although the upper limit for change has been described in Section 4.1. The cost estimates developed this year have been based on this upper limit of change indicated by modelling that assumes a flow of between 25,000ML/day-40,000ML/day would be delivered whenever possible, whereas in reality this is not the way environmental flows would be delivered in this reach. Thus the costs of the productivity losses described above have been costed at the upper level of effects likely to be felt by riparian landholders.

5.2.1.3 Timing

The MRAG advised that 40,000 ML/day flows would have the least impact in winter and spring, with a strong preference for winter flows. The later the flows occur in spring, the less desirable they would be for landholders, as inundation means that pasture growth during the warmer spring weather would be limited during the inundation and recovery periods, and re-sowing pastures may be impractical on saturated land.

Landholders have also reported that the uncertainty around both timing and duration is causing anxiety, with the potential for higher flows 'hanging over their heads'. As described above, the lack of certainty around frequency, timing and duration of flows has been accommodated in cost estimates for the business cases by basing costs on an upper limit of flows.

5.2.1.4 Mitigation measures

Payments to establish easements are currently proposed as the main mechanism to compensate landholders for the effects of higher flows. Most riparian landholders in this area have previously been through an easement acquisition process for easements for the 25,000ML/day flow limit, and thus have clear ideas about how the process should be run and conditions that they think should be included in easement agreements. Landholders have been adamant that they will not sign up to easements that simply allow a 'right to flood' at any time, from fears that flows may be delivered with little notice at times that they feel could have severely detrimental effects on their businesses, such as during the summer months. Such conditions in easement agreements might include specifying times when environmental flows could be delivered, i.e. not after a certain date and possibly limiting the duration of flows.

Some landholders have also expressed strong reluctance to participate in an easement process at all. In some cases this is due to the 'once-off' nature of payments associated with easements, which means that future generations in the farming business would not receive compensation for the effects of higher flows. People are also fearful that easements, combined with uncertainty about the proposed environmental flow delivery regime, have a negative effect on the desirability and value of their properties. Furthermore, landholders do not have confidence in the inundation maps that have been produced to date. While MDBA has contracted an aerial photography service to be available at short notice to photograph an event of around 40,000ML/day when one occurs, it is difficult to predict when such an event might occur, so hard to know if and when additional information might be available to further validate inundation footprints to be used in an easement acquisition process.

For these reasons some landholders have suggested that they would prefer to be compensated for the effects of flow events as they occur, rather than through a prospective and permanent easement agreement. It has been assumed for the purpose of cost estimates in this business case that enduring solutions with one-off payments to mitigate the effects of addressing constraints (such as easements) would be feasible. An alternative arrangement (e.g. ongoing payment scheme) would be likely to offer some savings as costs would only be associated with actual events, rather than the predicted future opportunity for events (which may not actually occur). Thus, such an alternative arrangement could be accommodated within the existing cost estimates if necessary.

5.2.1.5 Other issues for riparian landholders

There were also a few other issues that were raised. This includes concerns that ongoing impacts, such as erosion effects and clean-up costs, would occur. Where possible these issues have been considered in the cost estimates work in 2015. If the project is progressed to implementation, erosion would need to be monitored when flows started to be delivered, however it is important to note that erosion already occurs within this reach and is being managed through other programs.

The burden of ongoing engagement has also been raised as an issue among landholders. Landholder representatives on the Advisory Group for Hume-Yarrawonga Waterway Management were heavily involved in representing landholder interests during the previous process to establish the right to deliver 25,000ML/day at Doctor's Point. However, given the time burden of this activity they wish to have funds available to employ appropriate technical experts such as a lawyer and/or valuation expert to undertake this role in providing advice to MRAG as the group representing the interests of riparian landholders in the reach. Funding for this service has been incorporated into the cost estimates.

5.2.2 Councils

There are six councils that have land or assets that may be affected by inundation at flows of above 25,000ML/day at Doctor's Point. These councils are Albury City, Wodonga, Corowa, Indigo, Moira and Greater Hume. Of these councils, Albury City, Wodonga Council, Corowa Council and Indigo Shire Council all have representation on the AGHYWM.

Of the potentially affected councils, the only council to raise significant concerns is Albury City Council, who have expressed concerns about the potential of higher flows to inundate the road access to existing business activities in Norieul Park, including a café that may become isolated at these flows. Council staff are also concerned that these higher flows may limit the potential for economic development around the river if the flows were delivered frequently or for long durations.

Albury City Council is also concerned that these flows might inhibit recreation activities such as boating and fishing, and lead to an overall reduction in tourism activity in the region. In general, environmental flows would be delivered both on top of natural flows, and when they are likely to have occurred in an unregulated system. This preference generally correlates with times that are less desirable for recreation on or near the river, given the weather is likely to be wet. Thus for the majority of river related recreation activities, the impact on the community should be minor at most times.

Corowa Council has also raised some minor concerns related to the higher flows, including inundation of some grassed recreational areas adjacent to the river. While the council believes the grasses used in these areas could survive a few days' inundation, longer periods of inundation are likely to kill these grasses. Overall, Corowa Council have expressed that the effects on land and assets are minimal.

Greater Hume Council has also identified one gravel road that may require an upgrade to ensure continuous access for several residents that live near the river.

The other councils generally feel that the effects of the flows on council infrastructure are likely to be small, although this depends on the duration of the flows given longer flows would mean that infrastructure such as paved roads and walking tracks suffer significant damage.

5.2.3 Traditional Owners

The Yorta Yorta, Wiradjuri, Waywurru, Bangerang and Dhudhuroa nations have been identified as the Traditional Owners of Country in the Hume-Yarrawonga reach of the River Murray. Initial conversations with these groups, as well as ongoing conversations with representatives from Murray Lower Darling Rivers Indigenous Nations (MLDRIN), indicate that in general, overbank flows that benefit country are desirable, provided any possible negative effects are addressed. Negative effects include changes that may disturb cultural heritage sites, such as changes to levees, and also concern about increasing erosion or black water events. These risks are discussed in more detail in Appendix 2.

Traditional Owner representatives have also emphasised the importance of an engagement process that involves people in a meaningful and ongoing way over time, rather than a 'fly in, fly out' approach. Given the significant overlap of Indigenous Nations between constraint reaches and the high demand placed on individual Traditional Owners to meet the needs of governments in providing a voice for their people, a coordinated, multi-reach approach is indicated for the ongoing engagement of Traditional Owners in constraints work. There is also an opportunity to discuss the possibility of delivering higher overbank environmental flows in more general discussions with Traditional Owners about environmental and cultural heritage flows.

5.3 Technical feasibility and fitness for purpose of mitigation options

5.3.1 Details of mitigation activities

As outlined in previous sections, the main mitigation activities would include:

- easements over private and public land
- capital works on private infrastructure (especially bridges and crossings), and
- reinstatement works on public infrastructure (e.g. roads, bridges, crossings).

In addition to the above, mitigation activities could also include:

- long-term forecasting of, and advice on, overbank flows to enable councils and the local community to plan for effective management of flows
- inclusion of buffers to manage any potential risks of exacerbated flooding e.g. purchase of larger easements, and
- improved rainfall and runoff monitoring to improve models to better assess the risk of environmental watering exacerbating flood risks.

Easements are required on the basis that they would provide water managers with the right to pass managed flows, subject to the terms of the easement. The cost of easements would reflect the long-term impact of such an arrangement, including the various impacts identified in Section 5 and Appendix 6. Easements would be negotiated with landholders through a voluntary process.

While there is a precedent for such a process (the acquisition of easements to allow higher managed flows of up to 25,000 ML/day in Hume-Yarrawonga) considerable time and effort would be required to set and manage relationships with affected landowners, gather detailed information relating to impacts on individual properties, agree and apply principles by which easements should be costed, and implement legal and other administrative arrangements.

It is recognised that some stakeholders have expressed reluctance to participate in an easement process (Section 5.2). Note however that even if an alternative mitigation option were pursued, the impacts and costs would be similar.

Capital works on private infrastructure have been proposed on the basis that they would be necessary to maintain access to areas of land which would suffer from “interrupted access” caused by proposed higher flows. Works on private infrastructure would need to be negotiated with landholders through the same process as easements. Given the landholders in the Hume-Yarrawonga region are currently opposed to higher regulated flows in this reach, the time and effort likely to be required to gain agreement for such works would be likely to be significant.

Reinstatement works on public infrastructure have been proposed on the basis that they would mitigate the additional impacts of more frequent higher flows on public assets, and would be more appropriate than capital works in most cases, as those capital works would either be more expensive, and/or create problematic flow-on effects (e.g. raising a road would effectively create a new levee, and re-direct flows to other locations, leading to further issues).

It is proposed that agreements would need to be negotiated with individual councils or asset owners, through which those councils or asset owners would agree to a specified flow regime being allowed to affect their assets in perpetuity, and upfront funding would be provided in consideration for such an arrangement. Similar to the proposed easements, time and effort would be required to set up and manage arrangements with affected asset owners, agree on details of the impacts on their assets, agree on the basis by which costs would be met, and implement legal and other administrative arrangements.

Further details of the proposed steps in implementation are included in Section 8.

5.3.2 Principles/ process for determining mitigation options

When determining the specific mitigation options to address each impact, this business case has assumed that the process should start with a least cost option, but consider using a higher cost option in order to ensure that the measure effectively and appropriately mitigates the impact, including:

1. that the affected parties are not worse off
2. that any safety considerations (such as critical public access routes) are not compromised
3. that measures would help communities adapt to a changed flow regime

4. arrangements are enduring, and
5. other practical and policy considerations have been considered, particularly as they relate to working with stakeholders on just terms and avoid creating perverse incentives.

Recognising the above principles, in assessing the appropriate mitigation measures to address interrupted access to private agricultural land, and to address impacts on specialist activities, two distinct options have been considered:

1. an "easements focused " option, in which it is assumed that easements would be the preferred mitigation option, and that infrastructure works (e.g. upgrades to private crossings, or infrastructure to protect specialist businesses) would only be implemented where it is more cost effective to do so than to purchase easements, and
2. an "infrastructure focused" option, in which it is assumed that infrastructure would be the preferred mitigation option. In the context of the Hume-Yarrawonga reach, this generally means that more significant infrastructure works would be required than under option 1.

Note that in the context of this business case, mitigation options were considered at a regional rather than a property-by-property scale. If this business case were to be implemented, further assessment would be required at a property-by-property level, in consultation with landholders.

5.3.3 Uncertainties

This business case has also built "buffers" and/or contingencies into the proposed mitigation options and costs, to take into account inherent risks or uncertainties. Key uncertainties included:

- actual frequency, timing and duration of environmental flows (refer also to discussion in Section 4)
- potential errors in inundation modelling (refer also to discussion in Appendix 8)
- economic assumptions
- appropriate balance between easement and infrastructure-based mitigation measures (noted in section above)
- available information to inform costs, and
- costs of engineering works.

Key uncertainties, and how they were considered in the context of the proposed impacts and mitigation activities, are summarised in Table 10. The implications of this approach for cost estimates are presented in Section 7.

Table 8: Mitigation measures assumed, and approach to taking into account uncertainties.

Impact	Assumed mitigation activity	Key uncertainties	How uncertainties were considered
All impacts	All mitigation activities.	Actual frequency, timing and duration of environmental flows.	Hydrological modelling was deliberately designed to represent an upper limit to potential new flow regime. See discussion in Section 4.1.
Inundation of agricultural land	Easements.	Area of land that would be inundated (uncertainty in inundation modelling). Economic assumptions (e.g. land value,	Sensitivity testing of area of land assumed to be inundated. Sensitivity testing around key economic parameters. Contingencies built into easement costs.
Impacts on farm infrastructure			

Impact	Assumed mitigation activity	Key uncertainties	How uncertainties were considered
Farm management issues		agistment costs, clean-up costs). Easement negotiation costs.	
Interrupted access to private agricultural land.	Combination of easements and new or upgraded bridges and crossings.	Area of land that would suffer from interrupted access (uncertainty in inundation modelling). Economic characteristics of the land (e.g. land value, agistment costs). Appropriate mix of easements vs infrastructure works.	Sensitivity testing of area of land assumed to suffer from interrupted access Sensitivity testing around key economic parameters. Two options were considered: (i) an "easements focused" option (whereby infrastructure works would be proposed only to the extent they would be more cost effective than easements) and (ii) an "infrastructure focused" option which assumes a preference for infrastructure works. This business case presents the cost estimates associated with option (ii), which would be more expensive.
Damage to public infrastructure.	Reinstatement activities	Quantum of infrastructure affected (uncertainty in inundation modelling) Frequency on which such reinstatement activities would be required.	Sensitivity testing of quantum of key infrastructure items. Sensitivity testing of hydrological assumptions (frequency of flow events). Contingencies built into infrastructure costs.
Significant impacts on public infrastructure requiring capital works.	Capital works	Cost of engineering works required.	Contingencies built into infrastructure costs.
Impacts on specialist activities.	Combination of easements and infrastructure works.	Appropriate mix of easements vs infrastructure works.	Two options were considered: (i) an "easements focused" option (whereby infrastructure works would be proposed only to the extent they would be more cost effective than easements) and (ii) an "infrastructure focused" option which assumes a preference for infrastructure works.

5.3.4 Recommended further work if this measure were to progress to implementation

If this measure were to progress to implementation, it is recommended that further work be undertaken to develop a more refined assessment of third party impacts, mitigation options and costs. Key actions are summarised in Table 11. These matters are also discussed further in Section 8.2.

Table 9: Recommended further work to assess impacts, mitigation options and costs.

Issue	Further work that would be required
Proposed operating regime	Future environmental watering and/or river operation decisions could provide more specificity regarding the future environmental flow regime
Private crossings	Property-by-property assessment required to identify specific private crossings that are affected, and specific mitigation measures required
Public infrastructure (e.g. roads, crossings)	Need to negotiate agreements with asset managers (e.g. councils). This negotiation process would require further ground-truthing of impacts, mitigation measures and costs.
Easements (or other arrangements) over agricultural land	Need to negotiate agreements with landholders. This negotiation process would require further ground truthing of impacts, mitigation measures and costs, at a property-by-property level.
Specialist businesses	Need to negotiate agreements with business operators. This negotiation process would require further ground truthing of impacts, mitigation measures and costs, at a property-by-property level.
Inundation footprint	Knowledge of the inundation footprint would need to be further improved. This would need to involve: • Developing new, and/or and refining existing inundation models • On-ground assessment of actual flow events, involving local stakeholders (e.g. monitoring and measuring flows over specific properties) • Aerial photography of actual flow events.
Refine risk assessment	Refine the risk assessment once more detailed is available.

6 Complementary actions and dependencies

6.1 Interactions with other constraint measures

Due to the dependencies between them, the three parts of the Murray — Hume to Yarrawonga, Yarrawonga to Wakool Junction and the lower Murray — should be considered as a single package. Without relaxing constraints in all three key focus areas, it would not be possible to take advantage of relaxed constraints in just one part of the River Murray (Murray-Darling Basin Authority, 2014b).

The River Murray contains important environmental assets throughout each of the three River Murray constraint areas. Relaxing constraints along the main stem of the River Murray could provide some of the greatest environmental outcomes, particularly if regulated releases can be timed, based on natural cues, to combine with unregulated flows from the Kiewa, Ovens, Goulburn and/or Murrumbidgee rivers to build a flow of 60,000 to 80,000 ML/day at the South Australian border. For example flows from Hume Dam could be used to connect with tributary flows downstream to increase the size of the peak event and water more floodplain, or to extend the duration of a natural flow event to keep water on the floodplain for longer.

The majority of flows into the lower River Murray system come from the Upper Murray, Goulburn, Murrumbidgee and Darling Rivers. The Upper Murray is usually the dominant contributor to a target event in the Lower Murray, and therefore the characteristics of flows in the Lower Murray can usually be directly correlated with those in the upper Murray. An increase in upstream flow leads to a linear increase in the probability of a successful watering event downstream.

As a result of the high level of hydrologic connectivity the three River Murray constraints proposals are inherently interrelated. A coordinated and integrated approach to these measures is required to enable system-wide benefits along the length of the River Murray. Recognising this, ministers requested that work should proceed as an integrated package for the three River Murray key focus areas.

6.2 Interactions with Prerequisite Policy Measures

Protecting environmental flows from extraction, delivering environmental water on top of other instream flows and using environmental water throughout the length of the river are the most significant factors for achieving environmental outcomes. Inadequate implementation may reduce the effectiveness of this measure, and reduce or entirely offset the SDL adjustment resulting from supply measures (Murray-Darling Basin Authority, 2014b).

In Victoria, the legislative arrangements to support implementation are already in place. These arrangements are reflected in the draft implementation plan for pre-requisite policy measures, submitted to the MDBA in August 2015. The plan also identifies opportunities to improve implementation, operability and transparency of the pre-requisite policy measures. These focus on actions to improve the environment under which they take place.

NSW has also prepared a draft implementation plan, and is continuing to consult with stakeholders prior to finalisation of the implementation plan.

6.3 Interactions with other supply measures

Some supply measures would benefit from constraints in the River Murray being relaxed. Supply measures with such potential interactions in the River Murray include:

- Hume Dam airspace: supporting the operators' flexibility and adaptability by improving the airspace rules and management options could change spill behaviour which may increase the

risk of flooding public and private land. This constraints measure would significantly help to address the impacts on landholders and potential liabilities for governments.

- Menindee Lakes Water Savings Project: if the outlet capacity is to be increased and higher flows are released in the Lower Darling.
- Modification of Locks 8 and 9 weir pool raising and lowering: if there are impacts on private property.
- The Living Murray works and measures: to maximise the efficiency of operation of The Living Murray works and measures, icon sites would benefit from being able to deliver water to and operate structures at higher flow rates (in particular Koondrook-Pericoota), and
- Nine proposed Victorian works and measures.

7 Costs and funding arrangements

7.1 Costs of mitigation measures

The estimated costs for the proposal being investigated in this business case, in the Hume-Yarrawonga reach, reflect what would be required to implement the mitigation activities identified in Table 8 (Section 5.1). The estimated costs incorporate an escalation factor of 2.68 percent per year for each year between 2014-15 and project implementation.[4] This is consistent with Commonwealth requirements for cost escalation in supply and constraints measure business cases.

The Hume-Yarrawonga reach is being considered as part of the overall Murray system. Because of this, costs in the Hume-Yarrawonga reach would be influenced not only by the proposed change in operating regime in the Hume-Yarrawonga reach (i.e. regulated flows of up to 40,000 ML/day), but also by the proposed change in operating regime in the downstream Yarrawonga-Wakool reach.

Accordingly, cost estimates that have been developed for the Hume-Yarrawonga reach are based on the two potential changes in operating regime that were previously investigated in the Yarrawonga-Wakool reach: a relaxation of constraints to allow maximum regulated flows of 65,000 ML/day downstream of Yarrawonga Weir ("YAR65"), and an alternative scenario whereby maximum regulated flows would be 50,000 ML/day downstream of Yarrawonga Weir ("YAR50"). Lower flow rates are currently being investigated in the Yarrawonga-Wakool reach concept plan.

These earlier alternative scenarios in the Yarrawonga-Wakool reach would affect the modelled flows in the Hume-Yarrawonga reach, and the costs presented in this draft business case for the Hume-Yarrawonga reach are based on modelling of these earlier scenarios as a conservative approach to cost estimates. Broadly speaking, under a "YAR65" scenario it is expected that there would be a slightly smaller number of flow events in the Hume-Yarrawonga reach compared to the "YAR50" scenario, but with those events being on average slightly longer in duration.

Note that the estimated costs for the YAR50 scenario are marginally higher than those for the YAR65 scenario (Table 12). This reflects the fact that the YAR65 scenario envisages fewer high-flow events. However, the difference in costs is small.

[4] Costs have been escalated according to the following assumptions regarding timing of implementation:

- Easements and infrastructure on private agricultural land are negotiated and implemented over the period 2017 to 2022
- Capital works on public infrastructure are undertaken over the period 2015 to 2020 (escalating until 2025 would add around $0.8M)
- Reinstatement works are undertaken over the period 2021 to 2051.
- Mitigation measures for specialist activities are undertaken over the period 2017 to 2047.

Table 10: Estimated costs (excluding additional infrastructure implementation costs).

Mitigation activity	Issues taken into account in estimating costs (further details in Appendix 6)	Estimated cost ($m) (YAR65)		Estimated cost ($m) (YAR50)	
		NSW	Vic	NSW	Vic
Easements	• Inundation impacts on tolerant pastures. • Inundation impacts on vulnerable pastures • Inundation impacts on crops. • Livestock husbandry. • Fencing. • Effects of interrupted access, including loss of grazing, delayed harvesting. • Pumps.	3.4 (includes negotiation costs)	3.4 (includes negotiation costs)	3.3 (includes negotiation costs)	3.4 (includes negotiation costs)
New or upgraded infrastructure, such as private bridges, crossings, pumps	• Cost-benefit analyses of easements vs infrastructure. • Estimates of numbers of properties where infrastructure works may be required. • Costs of representative engineering works.	0.5	0.6	0.5	0.6
Operational response	• Asset Managers (councils) have incur additional resourcing costs associated with flood preparations. • Enacting flood mitigation controls (such as road management/closing and shutting off backflow prevention valves) was a common cost, not captured by asset costing.	0.4 (moderate and high cost[5])	0.4 (moderate and high cost)	0.4 (moderate and high cost)	0.4 (moderate and high cost)

[5] "Moderate cost" is the expected cost of public infrastructure works. "High cost" also represents an upper bound to what is considered likely.

Mitigation activity	Issues taken into account in estimating costs (further details in Appendix 6)		Estimated cost ($m) (YAR65)		Estimated cost ($m) (YAR50)	
			NSW	Vic	NSW	Vic
Reinstatement works on public infrastructure	• Rehabilitation of roads (potholes, pavements, regrading). • Maintenance of tracks. • Replacement or reinstatement of culverts. • Grading and removal of debris in fords. • Impacts on landscaped areas		1.8 (moderate cost) 2.2 (high cost)	1.5 (moderate cost) 1.8 (high cost)	1.9 (moderate cost) 2.3 (high cost)	1.5 (moderate cost) 1.8 (high cost)
Capital works on public infrastructure	Isolated property access		Estimated <0.1	Estimated <0.1	Estimated <0.1	Estimated <0.1
	Kensall Green Road		2 (moderate cost) 3 (high cost)	2 (moderate cost) 3 (high cost)	2 (moderate cost) 3 (high cost)	2 (moderate cost) 3 (high cost)
	Norieul Park Café access		0.1 (moderate and high cost)	nil	0.1 (moderate and high cost)	nil
Specialist activities (Quarries and Visitor Centre)	Option 1: Easements focussed		0.2 (moderate cost) 0.3 (high cost)	nil	0.2 (moderate cost) 0.4 (high cost)	nil
	Option 2: Infrastructure focussed		3.1 (moderate cost) 5.0 (high cost)	Nil	3.1 (moderate cost) 5.0 (high cost)	nil
TOTAL COSTS	**Option 1: Specialist Activities Easement focussed**	**Moderate Costs**	**8.3**	**7.9**	**8.4**	**8.0**
		High Cost	**9.9**	**9.2**	**10.0**	**9.3**
	Option 2: Specialist Activities Infrastructure Focussed	**Moderate Costs**	**11.2**	**7.9**	**11.3**	**8.0**
		High Cost	**14.6**	**9.2**	**14.7**	**9.3**

7.2 Potential additional infrastructure implementation costs

Jacobs was commissioned to provide advice on infrastructure implementation costs (refer to project summary in "Implementation Costs" section of Appendix 6). They identified CAPEX rates that provide an

indicative estimate of engineering design, approvals and construction costs associated with infrastructure works.

Estimates derived using these CAPEX rates were compared to the contingencies already included by GHD, AECOM and Jacobs in their assessment of costs associated with private agriculture, public infrastructure, and specialist activities (as summarised in the table above).

Jacobs also recommended that consideration be given to bundling of small projects into a package of works, as this would provide cost savings.

Table 13 therefore presents potential additional infrastructure implementation costs as a "low" estimate (where it is assumed that projects are bundled, and cost savings are thereby realised) and a "high" estimate (where it is assumed that projects are not bundled).

Table 11: Additional infrastructure implementation costs.

Mitigation activity		**Potential additional infrastructure implementation costs**			
		Estimated cost ($m) (YAR65)		**Estimated cost ($m) (YAR50)**	
		NSW	**Vic**	**NSW**	**Vic**
TOTAL COSTS	**Lower** (assuming bundling)	**0.5**	**0.5**	**0.5**	**0.5**
	Higher (assuming no bundling)	**1.5**	**1.5**	**1.5**	**1.5**

7.3 Potential program management costs

It is not yet known what governance and implementation arrangements might be agreed, if this measure were to be implemented (refer to Appendix 3).

It is considered that the equivalent of one "program management group" would be required to implement this measure. If it is assumed that such a program management group would have to be resourced from scratch (i.e. existing resources cannot be mobilised) the indicative cost for one program management group is $1 million per annum, or $8 million over the period 2016 to 2024.

Program management costs would be similar for the YAR65 and YAR50 scenarios.

7.4 What is included in cost estimates

The cost estimates presented in section 7.2 include contingencies which were added by consultants to their "base cost" estimates for easements, infrastructure, levees, and specialist activities. Contingencies for specific infrastructure items varied depending on those items. The methodologies applied to infrastructure costings for the public infrastructure and specialist activities projects were peer reviewed by independent engineering consultants (see Appendix 6 for more details).

The "additional infrastructure implementation costs" discussed in section 7.2 were then added to the base cost estimate plus contingency, to cover design, approvals and/or site supervision where these potential costs were not already considered.

The overall makeup of the costs is summarised in Tables 14 and 15.

Table 12: What is included in "Moderate" costs.

Source of cost estimates	GHD	GHD	AECOM	AECOM	Jacobs	MDBA/ States
Base costs Contingency	Easements 10 percent Plus other costs (negotiation and advice)	Private infrastructure No contingency, but GHD has advised that $50,000 per property is generous	Public infrastructure 15 to 25 percent (new capital typically 25%)	Levees 40 to 60 percent	Specialist activities 100 percent	Program management Assumes starting from scratch (i.e. no resources already available)
Jacobs Additional implementation costs	Not added	Additional to above 50 percent (assume bundled approvals)	Added to capital works component 12 to 50 percent	Additional to above 12 percent	Added to infrastructure component 30 percent	Not added
TOTAL ESTIMATE	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates

Table 13: What is included in "High" costs.

Source of cost estimates	GHD	GHD	AECOM	AECOM	Jacobs	MDBA/ States
Base costs Contingency	Easements 10 percent Plus other costs (negotiation and advice)	Private infrastructure No contingency, but GHD has advised that $50,000 per property is generous	Public infrastructure 40 to 60 percent (capital typically 50%)	Levees 80 to 120 percent	Specialist activities 100 percent	Program management Assumes starting from scratch (i.e. no resources already available)
Jacobs Additional implementation costs	Not added	Additional to above 160 percent (assume approvals are not bundled)	Added to capital works component 17 to 160 percent	Additional to above 17 percent	Added to infrastructure component 100 percent	Not added
TOTAL ESTIMATE	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates	Σ of above estimates

7.5 Assumptions and uncertainties

Table 16 summarises key assumptions and caveats associated with the cost estimates, and the implications of those assumptions and caveats for the level of certainty associated with the estimates.

Table 14: Assumptions and caveats associated with the cost estimates.

Issue	Assumption/caveat	Implications for cost estimates
Hydrology	Cost estimates are based on very specific hydrological assumptions (refer to description of modelling in Appendix 7). For costing purposes, it has been assumed that the outcomes of that hydrological modelling represent an outer envelope of what is hydrologically feasible, if constraints were relaxed.	Expected to result in overestimate rather than underestimate
Easements	Assume that land values, agricultural gross margins and impacts of higher flows can be generalised in a model. Model assumptions have been "ground truthed" through consultation with relevant local experts, but by necessity they are still average values. In reality they would vary from property from property.	Estimates are considered fit for purpose at regional level but not at a more local scale. A contingency of 10% has been built into the easement costs.
Easements – administrative costs	A $5,000 "administration" cost has been assumed per property. These costs include establishing the criteria for calculation of the level of compensation, site inspections and negotiations with land owners and legal costs to include easements on land titles. Based on previous experience in negotiating easements along the Hume-Yarrawonga and Mitta-Mitta regions.	Estimate may be too low if stakeholders require a different level of administrative cost to what was required in Hume-Yarrawonga.
Infrastructure works on private agricultural land	In the context of the timeframes available for the feasibility work, and associated constraints to on-ground consultation with landowners, it was not possible to identify precisely which private crossings or other infrastructure would require works. The number of private crossings, and the nature of works required, has been estimated on a regional basis, drawing on intelligence gathered from sample "case study" properties.	Estimates are considered fit for purpose at regional level but not at a more local scale. A contingency ranging from 50 to 160 percent has been built in. Estimates are considered more likely to be overestimates than underestimates. Cost estimates reflect an infrastructure-focused approach to addressing interrupted access. Such an approach is considered realistic. The implications of an alternative "least cost" approach (whereby infrastructure would only be built where more cost effective than easements) were also considered.

Issue	Assumption/caveat	Implications for cost estimates
Capital works on public infrastructure	These assets were identified by stakeholders (e.g. councils) and reviewed by engineering experts (AECOM). However, there were practical limitations to the level of detail to which cost estimates could be made for these works.	Cost estimates are considered "prefeasibility" in terms of accuracy. A contingency of 15 to 60 percent has been built into the base cost estimates. A further 12 to 160 percent contingency has been added to cover potential additional implementation costs. Estimates are considered more likely to be overestimates than underestimates.
Reinstatement works on public infrastructure	Identified through a desktop analysis, supplemented by consultation with stakeholders (e.g. councils). However, there were practical limitations to the level of detail to which the consultation process could consider individual infrastructure items.	Estimates are considered fit for purpose at LGA level but not at a more local scale.
Specialist activities	Identified through a desktop analysis, supplemented by selected "case studies" from which costs have been extrapolated.	Estimates are considered fit for purpose at regional level but not at a more local scale, or for individual activities (or categories of activity). A contingency of 100 percent has been built into base cost estimates. A further 30 to 100 percent contingency has been added to cover potential additional implementation costs. Estimates are considered more likely to be overestimates than underestimates.

A number of key uncertainties were tested, through analyses of what would happen if key assumptions were changed. The outcomes of these analyses are presented in Table 17. The figures below relate to the **YAR65** scenario.

Table 15: Outcomes of uncertainty analyses.

Impact	Key uncertainties considered	Analyses undertaken	Implications for cost estimates
Inundation of agricultural land	Area of land assumed to be inundated	Impacted area varied by up to +/- 20 percent	Up to +/- $1m
	Economic assumptions (e.g. land value, agistment costs, clean-up costs).	Land worth varied by up to +/- 20 percent	Up to +/- $1m
		Agistment costs varied by up to +/- 50 percent	Up to +0.1m or - $0.2m
		Clean up and management costs varied by up to +/- 50 percent	Up to +/- $0.1m
	Easement negotiation costs.	Negotiation costs varied by up to +/-100 percent	Up to +/- $1.0m

Impact	Key uncertainties considered	Analyses undertaken	Implications for cost estimates
Interrupted access to private agricultural land.	Area of land assumed to be suffer from interrupted access.	Interrupted access area varied by up to +/- 50 percent	Up to +/- $0.2m
	Economic characteristics of land (e.g. land value).	Land worth varied by up to +/- 20 percent. Agistment costs varied by up to +/- 50 percent.	(Already included above)
	Appropriate mix of easements vs infrastructure works.	Range of combinations of easements and infrastructure works considered.	An easements focused approach would reduce the costs by around $0.5m
Impacts on specialist activities.	Appropriate mix of easements vs infrastructure works.	Both "easements focused" and "infrastructure focused" combinations of easements and infrastructure works considered.	Infrastructure focused approach increases estimated costs by ~$2 million

7.6 Proposed funding arrangements

The proponents would seek Commonwealth Constraint Measure Funding from the Water for the Environment Special Account to fund this measure. Funding allocations would be then considered and agreed by jurisdictions.

7.6.1 Co-contributions

For the purposes of this business case, it has been assumed that, if the proposal proceeds further, all costs would be met by Commonwealth constraints measure funding.

It is possible that some stakeholders may make co-contributions towards the costs. If this were to occur, then the required level of Commonwealth funding could be less than that estimated in this business case.

A precedent for co-contributions exists in the context of the assistance that the Murray-Darling Basin Commission (MDBC) provided to landowners whose access was adversely affected by higher regulated flows in the anabranches of the River Murray between Hume and Yarrawonga. In that program, principles were developed and agreed with landowners, which determined the respective contributions of the MDBC and landowners, taking into account the nature of the structure and the effects of flows.

It is likely that any co-contributions to this measure would also be made on the basis of agreed principles. These principles would need to be negotiated with relevant stakeholders during the implementation phase.

7.6.2 Arrangements for ongoing ownership and maintenance of infrastructure

The delegation of asset ownership and operation in relation to this project, including any associated financial responsibility, cannot be confirmed at this time. Victoria and NSW currently have agreed arrangements in place through the BSOG to resolve asset ownership arrangements for works-based supply measures. This process would inform any arrangements that are finalised for this project. A formal position on this matter will be clarified as part of the broader decision process as to whether or not this project will proceed.

8 Project governance and management arrangements

8.1 Proposed governance and project management arrangements

Once a decision has been made to proceed, to ensure this project is delivered on time, joint New South Wales and Victoria arrangements would be put in place that ensure appropriate senior oversight of project governance and delivery. It is envisaged that these arrangements would be informed by those that were used to deliver the Living Murray Environmental Works and Measures Program (EWMP) projects, complemented with existing state government frameworks, which together would underpin a set of robust and thorough processes for procurement and project management.

A detailed scoping of the governance and project management arrangements would be carried out if it is agreed that this project will be included in the final adjustment package. Relevant sections of the Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases would be drawn upon in finalising the governance and project management arrangements for this project, to ensure that all relevant matters are identified and addressed.

8.2 Implementation plan

Due to the interaction of the three River Murray constraint measure business cases (Hume to Yarrawonga, Yarrawonga – Wakool Junction and the Lower River Murray) the measures need to be implemented in a coordinated manner. To this end, a high-level Implementation Plan for the River Murray constraints measures has been included in Appendix 3.

The Implementation Plan describes six key phases:

- governance arrangements
- information refinement
- private tenure mitigation options
- public tenure mitigation options
- operational trials, and
- delivery of relaxed constraint flows.

Figure 6 depicts the timing and relationship between phases. It shows the establishment of governance, followed by a period of information refinement, negotiations, construction and transfer of private and public assets. Introduction of relaxed constraint flows are initiated when mitigation measures are in place. Delivery of increased flows would be an incremental process, slowly working towards maximum flow rates over time.

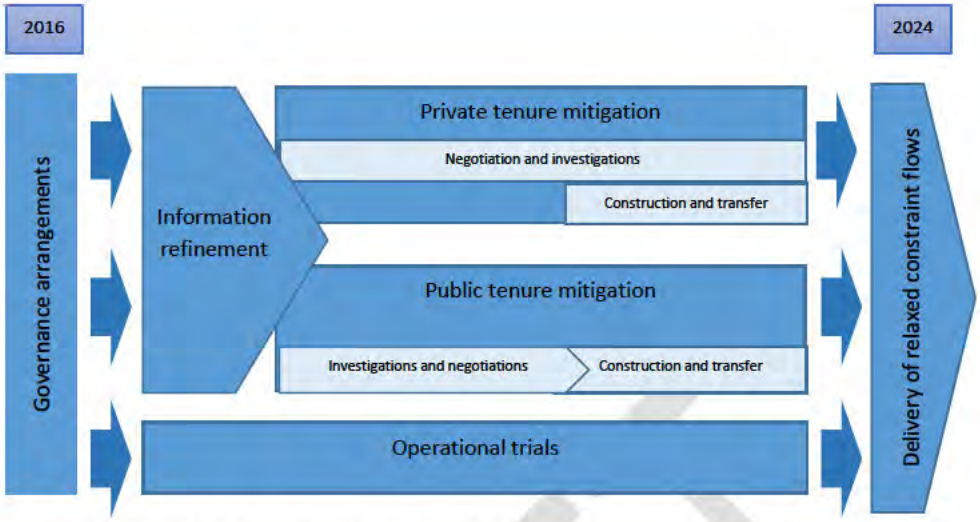


Figure 6: Relationship between key phases of implementation.

8.3 Stakeholder engagement strategy

Implementation of constraints proposals is contingent on confirming that mitigation measures have addressed the effects of relaxing constraints, and that communities are fully supportive. Where it is agreed to proceed to next steps, the majority of further investigative work for this measure will include additional consultation with individual landholders about the feasibility of acquiring easements, options for the upgrade of private infrastructure, such as improved creek crossings or culverts, and options for the reinstatement and capital works to ensure that impacts on public infrastructure are mitigated.

A draft stakeholder engagement strategy is provided at Appendix 4.

8.4 Legal and policy issues to be addressed

There are a range of policy and legislative changes that are likely to be required to give effect to constraints measures. With respect to land tenure, easements would be sought from landholders and negotiated on a voluntary basis over the area of land impacted by a change in managed flows. The easement would set out the limits of use and the rights and responsibilities of both landholders and governments. The landowner is otherwise still free to use the land.

Easements would be obtained by the proponents according to the lands acquisition requirement in their respective jurisdictions. Whoever holds the easements would need to provide beneficial use of these easements to river operators in all jurisdictions with the responsibility for delivering environmental flows.

There is also likely to be changes needed to the Murray–Darling Basin Agreement, to give effect to a range of constraints and supply measure projects. A process has been agreed for making changes to the general framework for River Murray System operations. As part of this, an independent expert is being engaged to document the proposed changes to the framework for in-principle agreement.

The report 'Infrastructure Implementation under the Constraints Management Strategy' maps out a broad approvals pathway for the under State and Commonwealth legislation. Approvals refers to all environmental and planning consents, endorsements and agreements required from Government agencies by legislative or other statutory obligations to conduct works. The strategy identifies the relevant legislation governing the proposed actions and the type of approvals likely to be required.

In addition to applications, a range of supporting documentation would be required or would be likely to be requested through referral decisions or planning permit conditions. A contingency has been allocated for the preparation of these assessments and documents.

It is not possible to capture all permit requirements at this stage as the proposal is not developed sufficiently. The 'Infrastructure Implementation under the Constraints Management Strategy' therefore represents the approvals likely to be required at time of writing. If the proposal proceeds further, this strategy would need to be reviewed once the project scope and associated works were confirmed, prior to commencing the approvals.

8.5 High level risk assessment

A high level risk assessment that provides mitigation strategies to address identified risks during project development, implementation and operation is provided at Appendix 5.

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10 Appendix 1 - Phase 2 Guidelines Eligibility criteria

This section confirms how this business case delivers against each of the relevant requirements of the Phase 2 Assessment Guidelines (Basin Officials Committee, 2014). Table 18 lists the requirements and then records where the issue is dealt with in this business case.

Table 16: Concordance- Phase 2 Guidelines and Business Cases.

Guidelines Section	Heading	Requirement	Business Case Section
4.1	Project details	Key project details and overview	2.1 to 2.7
4.2	Ecological values of the site	Description of the ecological values of the site	3.1
4.3	Ecological objectives and targets	Confirm objectives and targets	3.2
4.4.1	Anticipated ecological benefits	proposed outcomes from the investment	3.3.1 and 3.3.2
4.4.2	Potential adverse ecological impacts	Assessment of potential adverse impacts	3.3
4.5.1	Current hydrology and proposed changes	Clear articulation of current and proposed hydrology	3.4 and 4.1
4.5.2	Environmental water requirements	Water requirements of new inundated areas	3.4
4.6	Operating regime	Explanation of the role of each operating scenario	4 (Summary), 4.2 and 4.3
4.7	Assessment of risks and impacts of the operation of the measure	Assessment of risks and mitigation options	5.1, 5.2 and Appendix 5
4.8	Technical feasibility and fitness for purpose	Evidence that the project infrastructure is technically feasible	Appendix 7
4.9	Complementary actions and interdependencies	Confirm interaction with other initiatives	6.1 to 6.3
4.10	Costs, Benefits and Funding Arrangements	Detailed costing and listing of benefits	7.1 to 7.3
4.11.1	Stakeholder management strategy	Confirm stakeholder list and stakeholder management strategy	Appendix 4
4.11.2	Legal and regulatory requirements	Legal and regulatory requirements	8.4
4.11.3	Governance and project management	Governance and project management	8, Appendix 3
4.11.4	Risk assessment of Project Development and Delivery	Risks from project development and delivery	Appendix 5

11 Appendix 2 – Assessment of potential adverse environmental outcomes

Table 19 is based on existing work, including work by the Commonwealth Environmental Water Office (Commonwealth Environmental Water Office, unpublished).

Table 17: Potential adverse environmental outcomes or risks associated with relaxed constraints water delivery in the River Murray.

Risk	Geographical scope	Description	Mitigation/control
Hypoxic blackwater	Whole of system	Given that the measure intends to increase the frequency of overbank flows, this should reduce both the frequency and severity of blackwater events over time. However, without considering program controls, blackwater events could still occur in the short-term given that organic matter can build up over only one season.	Watering may be designed to specifically avoid high risk periods, such as warm weather in late spring and summer, in order to reduce the potential for hypoxic blackwater. Where possible and where natural dilution flows are not available, dilution flows may be provided to provide aquatic refuge habitat in the main river channel during blackwater events and provide localised dilution of incoming blackwater from the floodplain. Additional monitoring activities may include testing of dissolved oxygen levels to assist in the active management of the watering action and for adaptive management.
Blue-green algae	Limited to weir pool lowering only	Blooms that may occur at the same time as environmental watering events cannot be attributed solely to river flows and environmental watering is not considered to amplify most of the individual risk factors, but without controls it could potentially help create stable water levels through the use of weir pool lowering, which could amplify the risk of blooms under certain conditions.	Watering may be designed with specific flow variability provisions to avoid stable water levels for prolonged durations: for example, while the weir pool is lowered the water levels are fluctuated around a mean to prevent stratification. A follow-up flow may be incorporated to encourage mixing of water layers following weir pool lowering and provide flushing to reduce potential impacts associated with blue-green algae.
Geomorphic impacts	Whole of system	By providing more variable and overbank flows, the measure should help mitigate the risk factors that contribute to scouring, notching and other erosion impacts in the long term. However, without controls,	Manage the rate of recession of the flow tail to most effectively manage the risk of erosion and bank slumping. Ongoing monitoring and a commitment to help address potential impacts. Detrimental geomorphic impacts in

Risk	Geographical scope	Description	Mitigation/control
		higher environmental flows could potentially contribute to individual cases of accelerated erosion that might have localised impact in the short term. Also, river banks are more susceptible to erosion under current conditions so unless the rates of recession associated with flow events are managed, environmental watering may amplify the risk of bank slumping as well as associated turbidity impacts.	this reach are currently being monitored and mitigated through the implementation of the Hume-Yarrawonga River works program.
Inundation of cultural heritage	Whole of system	By increasing the frequency of small to medium floods, the Program may amplify the risk of inundation-related impacts to cultural heritage. Potential hotspots have been identified where extra care would need to be taken to minimise erosion and other impacts.	Consent for enhanced protection of at risk heritage could be sought from landholders and Indigenous cultural groups.
Salinity and groundwater recharge	Whole of system	If spikes in salt concentrations associated with individual watering events are not mitigated by the provision of dilution flows, environmental watering could potentially amplify the risk of salinity spikes during watering actions on a short-term basis. In addition, given that post-watering spikes are a product of multiple factors that affect groundwater salinity, by providing additional river flows and weir pool manipulations environmental watering may amplify the risk of post-watering salinity spikes.	Application of the *The Living Murray* framework for salinity spike management to help ensure that environmental watering is undertaken with regard to the Basin Plan salinity targets. Dilution flows may be provided, where possible and where natural dilution flows are not available, to reduce the concentration of mobilised salt. Communication materials may be provided to affected communities where relevant. This includes media releases by the delivery partner/s and river operators.
Spread of disease (particularly chytrid fungus)	Whole of system	Environmental watering is likely to reduce the overall risk of mosquitoes by changing the seasonality and variability of flow events. Psittacine Circoviral (beak and feather) disease is not	The peak flow of the watering action would be designed to most effectively manage inundation of risk areas. This may include avoidance of the area altogether (where possible and appropriate).

Risk	Geographical scope	Description	Mitigation/control
		water-borne and water flows are only one of a number of factors that may contribute to the spread of infected parrot species. River flows are only one of a number of factors that can spread root-rot fungus. However, by increasing the frequency of small to medium flows that promote hydrologic connectivity, the measure may increase the frequency with which frog species are exposed to the chytrid fungus.	
Spread of pest flora species	Whole of system	By increasing the frequency of small to medium flows that promote hydrologic connectivity and seeking to provide flows during potential risk periods such as spring, the measure may amplify the risk of spread or population increase of pest flora spread by flows. A more natural flow regime would also help to benefit establishment of native species and provide non-beneficial conditions for the spread of some non-native species.	As this is an exacerbation of an existing risk, existing weed control programs may help to manage it. Easement agreements may also include a recognition of the greater need for weed management to help supplement existing weed management on private land.
Spread or population increase of pest fauna species	Whole of system	By increasing the frequency of small to medium flows that promote hydrologic connectivity and seeking to provide flows during potential risk periods such as spring, the measure may amplify the risk of spread or population increase of aquatic and amphibious pest fauna.	Site managers may be requested to use existing exclusion devices, such as carp screens, to minimise the additional contribution to the spread of pest fauna. Regulatory structures may be used to complement the watering action and help mitigate pest fauna impacts. For example, a wetland system may be watered to support vegetation outcomes and once watering has concluded regulating structures may be closed to prevent further inflows. This allows the wetland to be dried out to kill invasive fauna, while vegetation condition is maintained through soil moisture as a result of the watering action.

12 Appendix 3 – Implementation Plan

The implementation of the three River Murray constraint measure business cases; Hume to Yarrawonga, Yarrawonga – Wakool Junction and the Lower River (SA) should only be considered in conjunction with each other.

This Implementation Plan outlines the key phases, estimated times, key tasks and dependencies that would be required if the River Murray Constraints Business Cases were progressed to implementation. The six key phases identified and discussed in this Implementation Plan are:

- governance arrangements
- information refinement
- private tenure mitigation options
- public tenure mitigation options
- operational trials, and
- delivery of relaxed constraint flows.

Figure 7 identifies the relationship between the broad phases in the Implementation Plan.

If ministers decide to progress to the implementation phase of the three River Murray constraints projects, the Implementation Plan would require further development.

		2016		2017				2018				2019				2020				2021				2022				2023				2024	
		Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sept	Oct - Dec	Jan - Mar	Apr - Jun
	Key phases	Basin Ministers decision										Sustainable Diversion Limits come into effect																			Sustainable Diversion Limits Adjustment Reconciliation Day			
Governance	**Establish governance arrangements**																																
	- establish agreements between agencies - establish advisory group roles - refinement of detailed implementation plan - establish program guidelines - establish program management																																
Information	**Information refinement**																																
	- data gathering/ refinement - cost information - confirm mitigation activities - develop standard designs for infrastructure																																
Private	**Private tenure mitigation**																																
	Negotation and Investigations - discussions include relevant mitigation options - contract agreement - record of agreement																																
	Construction and transfer - Engage construction agency - construction, upgrade and commission - transfer of title																																
Public	**Public tenure mitigation**																																
	Negotiations and Investigations - discussions include all relevant mitigation options - standard designs for infrastructure - re-instatement agreements - confirm mitigation activities and processes																																
	Construction and transfer - engage construction agency - construction and commissions - transfer of title																																
Operational	**Operational Trials**																																
	- trial delivery of environmental water to higher levels																																
	Delivery of relaxed constraint flows																																

Figure 7: Constraints measures estimated implementation timeline.

12.1 Governance arrangements

July 2016 – December 2016

If Ministers agree to implement the proposed River Murray constraint measures, governance arrangements would need to be formally established to ensure the long-term continuity and success of the program.

12.1.1 Key tasks

Key tasks for the governance arrangements phase include:

- establishing **agreements between jurisdictions (and associated agencies)** on the responsibilities, roles and functions of the State and Commonwealth governments;
- establishing **program structures in agencies** expected to implement the constraints business measures, their roles, inter-agency liaison routes and how they would incorporate any new information into negotiations;
- establishing **program guidelines** for the implementation of the constraint measures for the River Murray;
- defining coordinated **program management approach** in order to oversee the work allocation, resourcing, budgeting, progress of implementing constraints measures, initial activities for the program management group would include:
    - finalisation of a **detailed Implementation Plan** and distribute between the implementing organisations;
    - oversee the **stakeholder engagement strategy**, including confirmation of roles and establishment of advisory groups (where appropriate). The role of an existing or a new group in regards to implementing constraints measures must be clearly identified and incorporated into the groups' Terms of Reference; and
    - establishing **supporting mechanisms** for stakeholders to access independent advice on any technical, legal or engineering issues.

12.1.2 Key dependencies

Key dependencies are:

- clarification of managerial and financial delegation of the mitigation measures proposed in each reach
- clarification of the consent (approval) authorities
- the role and capacity of the community advisory group (or similar) to coordinate technical and community information, and
- funding arrangements for funding mitigation works are agreed, including resourcing.

12.1.3 Program Management and Resourcing

The Program Management approach is subject to the decision of the long-term governance arrangements.

However, regardless of what governance arrangements are agreed, appropriate resourcing would be required for mitigation responses to third-party impacts (e.g. easements and infrastructure upgrades) and program management. Effective program management would be required to ensure accountability under the PGPA Act, and for effective stakeholder engagement, negotiation and approvals processes in implementing constraints measures.

A key issue would be resourcing working with landholders at a detailed one-on-one level working towards negotiating property level agreements. For the Hume to Yarrawonga constraints this means over 400km of river length and at least several hundred directly affected riverbank landholders. Public and private infrastructure works also requires working with six local councils, riverbank landholders and multiple regional authorities and river user groups.

Possible Resourcing Approach for Hume to Yarrawonga reach

While it is difficult to be definitive at this stage, it is proposed that effective program management would require a "program management group" as summarised in Table 20.

Table 18: Indicative resourcing required for program management group (Hume to Yarrawonga).

FTE	Role	Tasks
1	Team supervisor	Responsible for planning, coordinating and team management
1	Team admin support	Secretariat support for various steering committees and project control board, team administration and logistics, reporting, and developing communications material for the project
2	Riparian landholder project officer	One-on-one meetings, property ground- truthing surveys, development of landholder specific maps, inclusion of local knowledge, field days, community meetings (note need a minimum of 2 people for Work, Health and Safety requirements)
1	Public infrastructure project officer	Public infrastructure project management, site visits and inspections, reporting, council briefings, field days, community meetings.
0.5	Legal officer	Responsible for providing legal advice to project team regarding easement acquisition and other issues as they arise
TOTAL 5		

Potential additional resources for Infrastructure Implementation

Assumptions for costing Infrastructure Implementation have been developed by Jacobs and are outlined in Appendix 6.

Jacobs have found that bundling of small infrastructure works (particularly on private land) into a package of works would be beneficial to achieve the greater scale needed to provide efficiencies and cost savings for design, approval and contracting/supervision of infrastructure works.

Bundling small work packages together would also be more efficient and cost effective, attracting contractors with the required processes, practices and systems for these types of works.

Resourcing for Public Asset Mitigation

It is likely that local asset managers generally have the in-house expertise to undertake public reinstatement works after events. We anticipate local asset managers including local councils would have sufficient capacity to manage most of these additional public capital works detailed in Section 7.1.

Skills required to implement the measure

The personnel / agencies managing the program should have skills in contract management, legal, technical, scientific and stakeholder liaison / engagement.

A summary of the respective skills required for implementation of the Program is summarised in Table 21.

Table 19: Resourcing requirements for each phase of implementation.

Resourcing skill/requirement	Information refinement	Private Tenure Mitigation	Public Asset Mitigation	Operational Trials
Community liaison	Required	Using local engagement teams to negotiate easement or other mitigation measures may assist in the negotiation process.	Using local engagement teams to negotiate easement or other mitigation measures may assist in the negotiation process.	Required
Costing analysis	Final appraisal, easement agreements, number of options and locations.	final appraisal, easement agreement, number of options and location.	final appraisal, including agreement to facilitate asset reinstatement issues.	
Legal advice	Contractual, land acquisition, State and Commonwealth.	contractual, land acquisition, state and Commonwealth	contractual, land acquisition, state and Commonwealth.	
Technical analysis	Engineering, scientific, technical, data analysis.	engineering, scientific, technical, data analysis.	engineering, scientific, technical, data analysis.	
Construction		labour, earthworks, etc.	existing council teams	
Engineering		design, project management, environmental assessments, applications, approvals	existing council teams	
River operators				State, MDBA
Environmental water holders				Required
Environmental Assessments			for processing regulatory approvals.	

12.2 Information refinement phase

July 2016 – December 2017

This phase ensures critical data and costing information is refined or updated, to ensure that all information is available, and governance arrangement agreed to begin negotiations with individual stakeholders.

As outlined in the RMCSC Feasibility Phase work plan, following handover of constraints Business Cases to State Governments (November 2015), the MDBA Constraints Management Branch will continue to refine feasibility phase analysis until June 2016. This includes the preparation of final public reports for the Costings Projects. The MDBA will also assist governments in advice on Implementation Decisions (including development of draft program guidelines).

12.2.1 Key tasks

The key tasks of this phase would include:

- obtain or refine data for:
  - Improved inundation Mapping- (new LiDar mapping, and aerial photography of high flow events)
  - Hydrodynamic Modelling, and further refine how water moves through the system;
  - Development of draft landholder agreements
  - Surveys – property ground- truthing surveys, development of landholder specific maps, site visits or inspections, inclusion of local knowledge
  - Verification – confirmation of landholder ownership
  - Finalise qualification of flood risk and appropriate method(s) to reduce risk
- refine any remaining or identified costing information on easements, infrastructure or specialist activities
- establish liaison with stakeholders establish the liaison channel with the community advisory group or stakeholder, as identified per the engagement strategy, and
- jurisdictions work with representative stakeholder groups to develop principles on which to base negotiations for individual land tenure agreements.

12.2.2 Key dependencies

Dependencies that have been identified include:

- information required to be used as part of the negotiation process, for example identification of affected land, supporting maps, data and costs, and
- agreement of the program guidelines by governments.

12.3 Private tenure mitigation

June 2017 – January 2023

In collaboration with landowners / landholders and communities, the program management group would negotiate a fair and transparent process to reimburse expenditure or loss of income due to impacts resulting from increased flows. These agreements could include easements allowing a right of inundation (see Appendix 6 for costed easement and infrastructure mitigation options).

The case study below, provides an insight into a similar program run historically in the Hume to Yarrawonga reach of the River Murray. The case study highlights the extensive time required for negotiation. It is expected that during the negotiation phase, affected stakeholders may seek independent advice on legal, engineering or technical aspects.

The infrastructure implementation costs have been broadly quantified through costings work undertaken by Jacobs (JACOBS, unpublished (a)).

12.3.1 Negotiations and investigations

June 2017 – January 2023

This phase aims to reach a resolution with the affected private landholder(s) on suitable ways to mitigate or offset third party impacts, mostly through easements and infrastructure upgrades.

Negotiations would need to be done in a coordinated manner, addressing all mitigation activities proposed for the land holder as one package, and would require a formal agreement to be established. If negotiations with stakeholders are still not settled by December 2022, advice would need to be sought by the overseeing agency in accordance with the Program Guidelines.

12.3.1.1 Key tasks

The key tasks of this phase would include:

- negotiating mitigation options with effected stakeholders
- refine draft easement agreements with stakeholders, this process is likely to include lengthy periods of statutory consultation and review, and
- agree private mitigation options with stakeholders.

12.3.1.2 Key dependencies

- clear communication and clarity of the negotiation process for affected parties
- liaison with the private land holder, and
- access to requested information.

12.3.2 Construction and transfer of private infrastructure

June 2017 – December 2022

The key tasks required to plan, design and construct, maintain or upgrade the affected infrastructure are detailed in Figure 8.

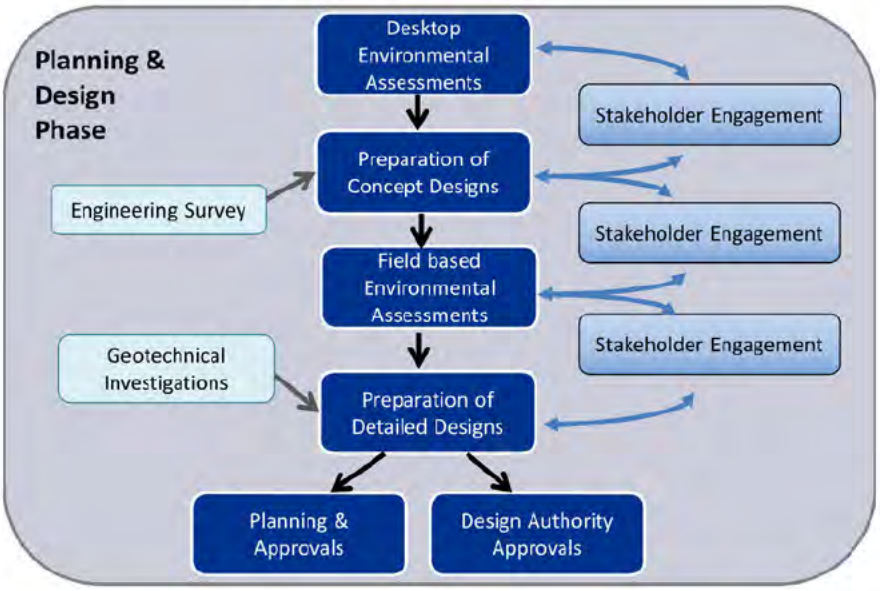

Figure 8: Flow chart demonstrating overall processes for project delivery (JACOBS, unpublished (a)).

12.3.2.1 Key dependencies

This phase would be largely dependent on how the negotiation process occurs and jurisdictional processes, such as approvals which may include additional statutory community consultation and appeal processes.

12.3.2.2 Other factors

The volume of infrastructure work that would be required may directly impact on the resourcing available within the local region. Some regions may already have capacity to manage and build the infrastructure, and other areas may need to access out of region skills. The social and economic impacts of resourcing this program would need to be balanced between achieving value for money considerations, against the broader social and economic benefits the construction works may have to local businesses.

12.3.2.3 Case study

The outline below provides a time scale of the easement establishment process for Hume Dam to Lake Mulwala, from 1996 - 2004. The process was undertaken to allow the regulated delivery of up to 25,000ML/day at Doctor's Point. Below provides an outline of the process to obtain easements on the Murray floodplain directly below Hume Dam.

Emergency releases (1996 – 1999)
• Emergency Releases at Hume Dam
• Recommendation to compensate downstream landholders and establish easements
Exceed channel capacity for environmental watering event (November 2000)
• environmental release to 28,000 ML/day made from Hume Dam to complete a bird breeding event in the Barmah- Millewa Forest.
• minimal damage and little inconvenience. Impacts recorded, ex-gratia contributions to six affected landholders.
• recognised affected floodplain landholders and request easements to confirm right to regulated flow.
• landholders canvassed for attitudes towards the issue of easements.
Surveys and Research (2001- 2002)
• Landholder survey, Site inspection to identify impacts, Aerial photo survey.
• evidence collated to allow more robust estimates of the areas involved.
• inspections carried out by landholders and agency staff together.
Community Consultation (2002 – 2004)
• Hume to Yarrawonga Land Acquisition Group (HYLAG) established.
• Information sharing with landholders.
• Community meetings and Question and answer sessions.
Determining Payment (2004)
• GIS Mapping
• Assessment of flooding impacts
• Land value assessments
Offers for easements (2004):
• 107 offers of easement made[6]

[6] one property was subdivided after initial offer made

- 85 Landholders accepted
- 23 declined.

12.4 Public asset mitigation

January 2017 – October 2022

The key finding of the Public Infrastructure consultancy (by AECOM) is that the preferred mitigation approach for public asset managers (including councils) is the negotiation of mechanisms to provide asset owners additional resourcing to reinstate public assets (roads, parks, crossings and civil infrastructure) after CMS flows.

12.4.1 Negotiations and investigations

January 2017 – March 2021

12.4.1.1 Key tasks

In the public forum there are set processes to follow when funding asset management arrangements between governments and councils. These existing processes can assist in making the negotiations, investigations, construction and contractual obligations streamlined and are likely to be in place earlier than private mitigation.

12.4.1.2 Key dependencies

- clear communication and clarity of the negotiation process for affected asset manager and
- liaison with the public land holders potential affected by impacts to public assets
- legal issues to be addressed through State and Commonwealth frameworks, such as the use of the funding of asset reinstatement works, and
- Jurisdictional processes for negotiations, investigations and other assessments.

This phase would be largely dependent on how the negotiation process occurs and associated jurisdictional processes.

12.5 Operational trials undertaken by environmental water holders

June 2016 – June 2024

Governments may agree to conduct 'operational trials' through existing river management processes. This phase recognises that if higher flows were to be trialled, or natural flows were to occur at rates similar to those proposed in the three River Murray Constraints Measure Business Cases, these events would provide valuable opportunities to refine the knowledge base to inform negotiations and mitigation options for the future delivery of relaxed constraints flows.

12.6 Delivery of relaxed constraint flows

From June 2024

By 2024, it is anticipated that all required mitigation options would be in place.

Maximum regulated heights would only be delivered if:

- there is full mitigation for the target flow

- there is an enduring Governance structure to support the flow
- there is environmental water available
- there are suitable climatic conditions; and
- river operators are comfortable that during delivery, the risk of exceeding the maximum regulated height is negligible.

The delivery of environmental flows under a relaxed constraint scenario would be largely dependent on climatic conditions. Delivery of increased flows would be an incremental process, slowly working towards maximum flow rates over several seasons.

13 Appendix 4 – Stakeholder Engagement Plan 2016-2023

13.1 Purpose

This communication and engagement plan outlines key considerations and tasks for engaging with Hume-Yarrawonga stakeholders during the planning and implementation phase of the Constraints Management Strategy in the Hume-Yarrawonga reach from 2016 through to 2024. Figure 9 (below) outlines the broad phases of work under the Constraints Management Strategy first identified in 2013.

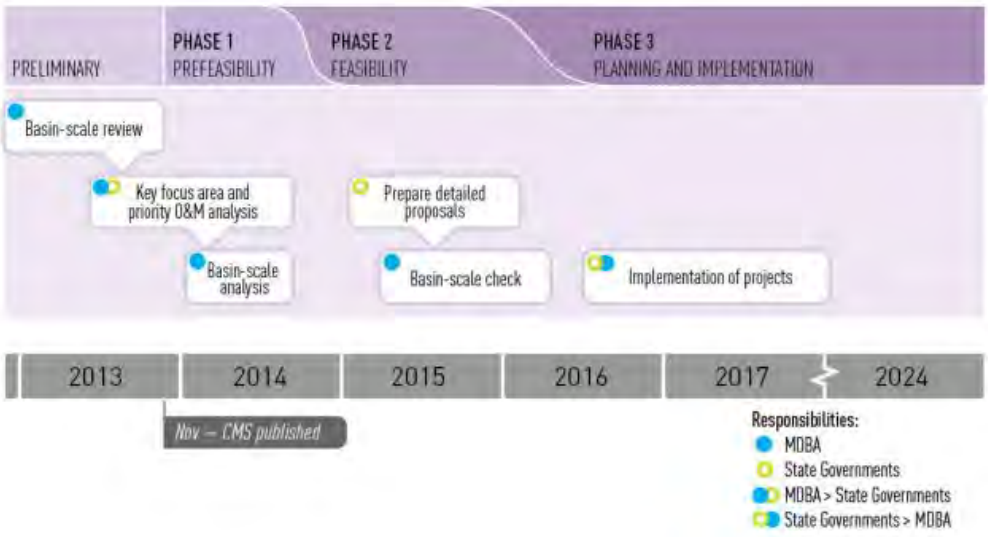

Figure 9: Three broad phases of the Constraints Management Strategy.

Through 2014-15 research was undertaken to investigate whether it would be possible to increase the regulated flow limit from 25,000ML/day at Doctor's Point to 40,000ML/day for the purpose of delivering environmental flows. To understand what this would mean for communities, MDBA used maps that showed the inundation extent of flows to start talking to communities about what relaxing constraints would mean for them, and how the effects of such flows might be mitigated.

In the Hume-Yarrawonga reach the Advisory Group for Hume-Yarrawonga Waterway Management (AGHYWM) has played a key role in helping to inform the understanding of what higher environmental flows could mean for the community. The group meets biannually and includes representatives from most of the affected local councils, state government agencies, and the executive members of the Murray River Action Group (MRAG), a group that represents the interests of riparian landholders in that reach. It is proposed that the AGHYWM should continue to play a key role in future constraints work.

At the conclusion of the second phase of work in 2015, Basin ministers will decide which constraint measures should move ahead to planning and implementation (June 2016).

Implementation of constraints proposals is contingent on confirming that mitigation measures have addressed the effects of relaxing constraints and that communities are fully supportive. Where it is agreed to proceed to next steps, the majority of further investigative work for this measure will include additional consultation with individual landholders about the feasibility of acquiring easements, options

for the upgrade of private infrastructure, such as improved creek crossings or culverts, and options for the reinstatement and capital works to ensure that impacts on public infrastructure are mitigated.

If work moves from feasibility into planning and implementation, states and the Commonwealth need an understanding of the scope of communications and engagement work needed over the next eight years.

The following stakeholders have been involved in work to date and would continue to be involved if the project progresses to implementation.

Government

- Basin state governments
- Commonwealth Government, including the Department of Environment and the Commonwealth Environmental Water Holder.

External

- regional communities in the key focus areas, including potentially impacted landholders and land managers, local governments, business owners/operators and Traditional Owners
- state-based natural resource management organisations
- state water authorities responsible for river operations
- irrigation companies
- conservation groups
- industry and peak bodies
- Basin communities outside the key focus areas.

13.2 Scope and community needs

It is extremely important to set accurate community expectations about the scope (purpose and scale) of engagement being undertaken during different stages of the project, given this is potentially an eight-year proposition of significant complexity.

There are significant uncertainties yet to be resolved, for technical work, policy and of course community needs. For the community, an eight year planning and implementation process leading to a change in river management is likely to be challenging for a number of reasons:

- Another government process hanging over them, especially as it is on the back of a significant period of change (drought and water reform)
- General weariness of reform/change
- Distrust of government and government processes
- Lack of empowerment – 'this is being done to them' and some may find it difficult to identify how they can input to the process and control their individual outcome
- Distrust of technical work (e.g. inundation mapping accuracy)
- In some areas, lack of any recent exposure, 'lived experience' of variable river flows, except for individual and community memories of large scale flood damage
- 'Fear the worst' – someone will 'stuff up' and cause damaging flooding
- Don't see that there is anything wrong with the river and why you would want or need to change current river management. Hard for many landholders to see the need for change, i.e. the why that could help them move towards accepting change
- Extended timeframe and therefore extended uncertainty, which affects things like property sales and planning and investment decisions, and links to community wellbeing.

- Uncertainty about what the future will look like when trying to plan and adapt – for riparian landholders, uncertainty about the process, how big, when and how often overbank flows might happen, what the notice would be, how exactly individuals will be affected in terms of farming/using the river flats, and how do they get swift and fair compensation if something goes wrong.
- Perception that this work is about getting water to fish, frogs and wetlands, but at the expense of hurting individuals, businesses and communities. Perception of harm to upstream communities to get water to downstream areas.
- Likely to be frustration waiting for the level of technical detail to get down to an individual or detailed-design level.
- Water and water reform is always highly charged in the community and politically sensitive.

From the above:

- Engagement needs to be very clear about what people can influence, with significant early and continuing input into expectation management.
- Distrust, fear and political sensitivity means that there should be a commitment across the project to providing accurate and timely information to demonstrate transparency.
- People may need to be able to access independent advice if they don't trust the process or the process is highly technical, and this should be built into those parts of the project where individual negotiations are likely to occur.
- Need efforts to get down to the individual property level as soon as possible to provide accurate information about the process, establish relationships that need to be sustained over the long term, and start fostering a constructive process where people can start to adapt to change.
- Establish ways to support community members getting involved and staying informed about sub-components of the project that require significant development and design over time
- Establish processes for community members to get involved with ground-truthing and improving the accuracy of developing technical work.
- If possible, aside from the focus on 'direct impact' engagement work, include scope for community wellbeing and resilience engagement, allowing those indirectly touched to adapt to change around them.

13.3 Outline of phasing and work themes for 2016-2024

An eight year planning and implementation phase is too unwieldy. It needs to be broken down into a number of phases to better reflect project development as well as provide points in time to evaluate project progress, risks and any need for modification. Similarly a complex project involving public and private land and infrastructure along hundreds of river kilometres needs to be broken down into a number of work themes.

The structure provided in the Implementation Plan (Appendix 3) outlines the broad phases of work that need to be completed to mitigate against the impacts of constraints. The activities detailed in the implementation plan do not fully account for all of the activities that would need to be considered in successfully implementing constraints projects. In particular there is significant scope to work with communities and interest groups that would benefit from both the improved infrastructure assets that may be constructed to address constraints and through the eventual delivery of overbank environmental watering events. Activities to promote the achievement of key milestones, for example the completion of

a new regional bridge, or the delivery of the first overbank flows, provide significant opportunities to promote the work of Basin governments in meeting the objectives of the Basin Plan. Engagement and communication activities relating to the local and Basin-wide benefits of addressing constraints would be considered when the final package of works and detailed timeframes for delivery have been developed.

The Implementation Plan (Appendix 3) outlines the following phases of work that need to be completed to address constraints:

- governance arrangements
- information refinement
- private tenure mitigation options
- public tenure mitigation options
- delivery of increased flows.

By considering the information provision and feedback needs at each of these phases it is possible to broadly map out an approach to communications and engagement with directly affected stakeholders. Table 22 provides some details on important implementation tasks that require communication and feedback from stakeholders directly affected by the implementation work. The party responsible for leading engagement activities has not yet been included, but would be confirmed when the NSW Victorian governments have finalised their preferred governance arrangements if the project proceeds.

Table 20: Key engagement tasks and methods for directly affected stakeholders.

Phase	Task	Engagement aim	Stakeholders involved	Method
Governance arrangements	Confirmation of role of the Advisory Group for Hume-Yarrawonga Waterway Management (AGHYWM) and the establishment of any working groups or subcommittees. The role of the group in regards to implementing constraints measures must be clearly identified and incorporated into the groups' Terms of Reference.	Members of the AGHYWM are aware of their roles and responsibilities with respect to progressing constraints work.	Representatives on AGHYWM (includes councils, MRAG executives which are riparian landholders, state government agencies, MDBA).	Meetings of AGHYWM
	Establish supporting mechanisms for stakeholders to access independent advice on technical, legal or engineering issues	Riparian landholders are confident that they have access to advice to represent their collective interests in understanding the process and outcomes of negotiations about easements.	Riparian landholders as represented by MRAG.	AGHYWM and/or MRAG meetings
Information refinement	Use aerial photography to capture images of a natural (or trial) flow of around 40,000ML/day at Doctor's Point to further refine the inundation mapping.	Riparian landholders are confident that the inundation mapping to be used to establish easement boundaries would adequately reflect the extent of inundation.	Riparian landholders AGHYWM subcommittee on inundation mapping.	AGHYWM subcommittee meetings to discuss any refined inundation mapping.
	Involve a subset of riparian landholders in marking out the boundaries of a natural (or trial) flow of around 40,000ML/day at Doctor's Point to further refine the inundation mapping.	Riparian landholders are confident that the inundation mapping to be used to establish easement boundaries would adequately reflect the extent of inundation.	Riparian landholders AGHYWM subcommittee on inundation mapping.	Engage and provide training to willing landholders at the commencement of the program in readiness for a flow event. AGHYWM subcommittee meetings to discuss any refined inundation mapping.
	Share the finalised flood risk study and	All stakeholders are confident that	AGHYWM	AGHYWM meetings

Phase	Task	Engagement aim	Stakeholders involved	Method
	plans for mitigating flood risk.	risk from flooding has been mitigated to an acceptable level.		
	Refine any remaining or identified costing information in infrastructure, specialist businesses.	All specialist business/activity stakeholders have been consulted with and are confident that the impact on specialist activities can be mitigated.	Specialist business/activity owner/operators and councils or other infrastructure owners where changes to public infrastructure are a component of the mitigation solution.	One-on-one meetings
	Confirmation of landholder ownership	The lead agency has confirmation of property ownership for negotiations.	All riparian landholders	Letters to potentially affected parties
	Surveys – property ground- truthing surveys, development of landholder specific maps, site visits or inspections, inclusion of local knowledge.	Landholders are confident that the area subject to an easement agreement has been accurately mapped out and all on-farm activities that would be affected by higher flows have been considered in the proposed mitigation solutions.	Riparian landholders	One-on-one meetings
	Jurisdictions to work with representative stakeholder groups to develop principles on which to base negotiations for individual land tenure agreements.	A model for engagement and negotiation is negotiated that most riparian landholders would be willing to sign up to.	Riparian landholders	Meetings with a AGHYWM subcommittee.
	Confirm the mitigation actions required with individual landholders.	All parties understand and agree to all components of the mitigation solution.	Individual riparian landholders	One-on-one meetings with landholders.
Land tenure based mitigation options (easements)	Confirm clear communication points and clarity of process for affected parties.	Affected parties (councils, businesses and riparian landholders) know where to go for information and who to talk to if they need clarification of where work is up to or if they have any concerns.	All affected stakeholders	AGHYWM Agency website/s Local media
	Provide funding guidelines and funds to MRAG to enable them to employ independent advisors (i.e. legal and valuation experts) to represent the	MRAG are aware of their obligations in ensuring all affected landholders are aware of the independent (legal/valuation etc) advice sought	Riparian landholders	Meetings with MRAG Executive

Phase	Task	Engagement aim	Stakeholders involved	Method
	collective interests of the group.	by MRAG on their behalf and know how to access this information.		
	Legal items – drafting of contracts	Provide all affected landholders and business owners with draft contracts and associated fact sheets to enhance understanding and sign up to mitigation solutions.	Riparian landholders Affected businesses	Draft contracts provided by letter Some information sessions on the process could be held prior to sending out draft contracts.
Infrastructure based mitigation options- private landholders	Surveys – property ground- truthing surveys, development of landholding specific maps for siting of new infrastructure/upgrading infrastructure.	All landholders (riparian and businesses) are aware of the process for siting and choosing infrastructure.	Riparian landholders Affected businesses	On-ground meetings as required
	Liaise with councils regarding development approval processes for new infrastructure.	Establish a process so that councils are aware of the volume of proposed infrastructure applications and can assign appropriate resources to assessing them.	councils	Meetings
	Confirm structure/s with individual stakeholders, provide a draft of contract including proposed operation and maintenance schedule and diagrams of indicative structure/s.	Landholders have confidence in the process and would agree to the proposed infrastructure solution.	Affected riparian landholders where infrastructure is part of the proposed mitigation solution.	One-on-one meetings
	Work with Traditional Owners to identify any potential issues with cultural heritage sites.	Traditional Owners understand the constraints work and have the opportunity to identify any cultural heritage sites/issues associated with construction projects.	Traditional Owners and consultants involved in cultural heritage assessments.	One-on-one meetings Site surveys
Public tenure (infrastructure)	In –principle agreement with landowner for acquisition of flood easement.	council or agency has confidence in the process for acquiring the flood easement.	Council/agency with affected infrastructure.	Meetings
	Pre-Acquisition declaration published in gazette and local newspaper;	Persons affected know they have the opportunity to apply for reconsideration of declaration before the Pre-Acquisition	General community	Local media and gazette

Phase	Task	Engagement aim	Stakeholders involved	Method
		declaration becomes absolute and relevant Minister authorises acquisition of easement.		
	Establish standard infrastructure diagrams for bridges, low-lying crossings and culverts.	Councils (or other infrastructure owners) have an opportunity to provide input to the infrastructure design.	Infrastructure owners	Email Meetings
	Confirm structures with stakeholders and provide draft contracts including the easement arrangements.	Councils (or other infrastructure owners) agree to the structures including the proposed operation and maintenance schedules and easement agreements.	Infrastructure owners	Email Meetings
	Agency and landowner/s enter into agreement in the form of Deed of Grant of Easement and monies are exchanged.	All parties are clear on their ongoing roles and responsibilities.	Infrastructure owners	Meeting
	Work with Traditional Owners to identify any potential issues with cultural heritage sites.	Traditional Owners understand the constraints work and have the opportunity to identify any cultural heritage sites/issues associated with construction projects.	Traditional Owners and consultants involved in cultural heritage assessments.	One-on-one meetings Site surveys
Delivery of relaxed constraint flows	Confirmation that adequate mitigation activities have been undertaken to allow the delivery of higher environmental flows.	All affected stakeholders are aware that higher environmental flows are possible and have had any outstanding issues resolved.	All affected stakeholders.	Local media stories announcing the potential for higher flows Public meetings to describe process for alerting affected stakeholders of when a higher flow is likely/imminent.
	Develop process for alerting affected stakeholders that a high environmental flow is likely/imminent.	All affected stakeholders are aware that higher environmental flows are likely and are clear of the timeframes for delivery.	All affected stakeholders	AGHYWM
	Provide advice of imminent environmental	All affected stakeholders are aware	All affected stakeholders	TBC with stakeholders

Phase	Task	Engagement aim	Stakeholders involved	Method
	flows to affected stakeholders.	of an imminent environmental flow.		but probably including early alert tools such as text messages and emails.
	Confirm extent of flow events with riparian stakeholders.	Continue to gain the confidence of riparian landholders by confirming the inundation extent reflects the easement footprints.	Volunteer riparian landholders AGHYWM.	On-ground meetings AGHYWM meetings

14 Appendix 5 – High level risk Assessment

A high level assessment of the risks to implementation of the measure is presented in Table 23.

Table 21: Risks to implementing the Hume to Yarrawonga constraints measure.

Risk ID	Risk Description	Risk Category	Raw Risk Likelihood	Raw Risk Consequence	Raw Risk Rating	Mitigation strategies	Risk Treatment	Residual Risk Likelihood	Residual Risk Consequence	Residual Risk Rating
Project development and delivery										
Design Risk										
1	Structural failure during commissioning or operation of infrastructure.	Reputation Financial WHS Stakeholders	Unlikely	Moderate	Moderate	Engage experienced contractors to design capital works and review prefeasibility and feasibility studies. Engage technical consultants as appropriate for further studies about conditions and structural integrity. Employ project management arrangements to ensure construction is to a suitable standard. Commission all new works gradually with stepped approach to progressively test new and/or upgraded infrastructure.	Reduction	Rare	Low	Low
Risk to project completion on time										
2	Delays in building approvals or contractual arrangements leading to project delays.	Reputation Financial	Possible	Minor	Moderate	Clearly define approvals processes during Feasibility Phase. Assign ownership to agencies with experience developing these works and with strong procurement, contract and project management protocols. Include clear roles and responsibilities in implementation plan in business case. Monitoring and evaluation process to evaluate progress.	Reduction	Unlikely	Minor	Low
3	Natural high flow or flooding events delay construction of infrastructure on floodplains.	Reputation	Possible	Moderate	Significant	Plan to undertake construction during summer dry period. Use contractors who are experienced with building on floodplain. Normal project management arrangements to monitor delays.	Reduction	Possible	Minor	Moderate
Inability to deliver the project within budget										
4	Inadequate cost assumptions for potential mitigation strategies.	Financial	Possible	Major	Significant	MDBA to use external professional consultants with experience and expertise in estimating costs of potential mitigation strategies on the River Murray. Consult further with technical experts during Planning and Implementation stages to verify any outstanding issues. Seek clarity on assumptions and how this translates to defining project uncertainty, risk, scope and investment. Include defined contingency for investment decisions to account for costings uncertainty. Verify costings of potential mitigation strategies with impacted parties. Build in more detailed planning and assessments for next phase of the project to refine cost estimates.	Reduction	Possible	Unlikely	Moderate
Legal and Landholder risks										
Risks associated with gaining landholder agreements										
5	Lack of landholder participation in and/or support for landholder easement agreements to inundate land.	Stakeholders	Likely	Major	Significant	Continue communications and stakeholder engagement to involve local community in the process. Engage with effected landholders during planning and implementation phase to ensure appropriate mitigation option selected. Prepare communication principles and maintain consultation register. Develop principles for negotiating and costing voluntary agreements. Engage legal advice/assistance to prepare principles and commence negotiations.	Reduction	Possible	Moderate	Significant

Risk ID	Risk Description	Risk Category	Raw Risk Likelihood	Raw Risk Consequence	Raw Risk Rating	Mitigation strategies	Risk Treatment	Residual Risk Likelihood	Residual Risk Consequence	Residual Risk Rating
						Extensive engagement of landholders in proposal design and implementation. Agencies to closely monitor community sentiment towards easement agreements and devise strategies to ensure overbank flows can still be delivered in the absence of 100% uptake of easement agreements.				
6	Residual litigation risk after implementing voluntary landholder management arrangements.	Stakeholders	Possible	Major	Significant	The Commonwealth, MDBA and Basin states seek legal advice on legislative provisions and potential risks of litigation and mitigation strategies. Undertake legal assessment to identify possible legislation approaches and suite of mitigation strategies. Prepare and implement detailed communications and community engagement strategy with landholders. Increase awareness of river operators and other relevant parties of potential legal and litigation risks of environmental water policies and projects and ensure consistent approaches are implemented.	Reduction	Unlikely	Major	Moderate
Risks of impacts to landholders										
7	Extent of potential mitigation strategies does not adequately address impacts of higher environmental flows leading to exposure to risk during high flow delivery.	Stakeholders	Possible	Major	Significant	Engage external professional consultants with experience and expertise in defining potential impacts and mitigation strategies on the River Murray. Consult other technical experts to verify any outstanding issues. Benchmark potential impacts and mitigation strategies with other areas of the Basin. Seek clarity on assumptions and how this translates to defining project uncertainty, risk, scope and investment. Build in more detailed planning and assessments for next phase of the project to refine cost estimates. Include contingency/buffers in calculation of flow inundation levels for purposes of mitigation measures (eg easements, infrastructure placement). Implement new operating regime with stepped approach to monitor flow impacts.	Reduction	Unlikely	Moderate	Moderate
Risks associated with gaining statutory approvals, changes to legislation and/or delays due to parliamentary processes										
8	Potential legal challenge by landholders or third parties (including native title claims, etc.) to proposed legislative changes or mitigation strategies.	Reputation	Possible	Major	Significant	Ensure all relevant statutory development approvals have been sought and granted. Seek legal clarification on outstanding litigation risks from legal advice. Seek more detailed legal advice on specific issues as required. Include legal principles in the business case to identify possible legislation approaches and suite of mitigation strategies.	Reduction	Unlikely	Moderate	Moderate
Cumulative Impacts										
Risks associated with flow-on effects of implementing the project and the collective impacts of interactive measures										
9	Exacerbated flood risk of unexpected rainfall events during or following the delivery of high flow events resulting from relaxing physical constraints.	Reputation	Unlikely	Moderate	Moderate	Continue multijurisdictional governance arrangements to oversee the development of consistent policy approaches to address exacerbated flood risk of high flow events from relaxing physical constraints. Ensure policy approaches are consistent with flood hazard warning approaches for Basin States. Implement operating regime with stepped approach and ongoing monitoring and evaluation to assess changing flood risk. Continue to engage technical consultants in the delivery of infrastructure assessed against updated modelling and inundation layer maps.	Reduction	Rare	Moderate	Low

Risk ID	Risk Description	Risk Category	Raw Risk Likelihood	Raw Risk Consequence	Raw Risk Rating	Mitigation strategies	Risk Treatment	Residual Risk Likelihood	Residual Risk Consequence	Residual Risk Rating
10	Physical constraints relaxation is not optimised preventing full realisation of anticipated environmental outcomes due to headwater storage release limits, timed release limitations river operator actions.	Environmental	Possible	Moderate	Significant	Involve operators and CEWO through proposal development. Ensure the alignment of new flow limits in all reaches i.e. assess the need to relax upstream constraints if downstream constraints are not sufficiently relaxed. Support changes to provide operators with better legal coverage. Enhanced rainfall and stream-flow gauging networks to improve rainfall-runoff models and improve understanding of system responses, especially in unregulated rivers. Commit to pre-requisite policy measures implementation plans in business case. Continue participation in multijurisdictional governance committees to identify options and processes to address channel capacity sharing.	Reduction	Unlikely	Moderate	Moderate
Environmental/Ecological risks										
[NB: See appendix ** for detailed assessment & management plan of ecological risks]										
Salinity & Water quality										
[NB: See appendix ** for detailed assessment & management plan of ecological risks]										
Cultural Heritage										
Ongoing and once-off implications for significant sites										
11	Potential impacts to indigenous cultural heritage from high flows resulting from infrastructure works associated with relaxing constraints.	Stakeholders	Possible	Major	Significant	MDBA to use external professional consultants with experience and expertise in assessing potential impacts to indigenous cultural heritage on the River Murray. Consult other technical experts within Basin governments to verify any outstanding issues. Build in more detailed planning and assessments for next phase of the project. Ensure communications and engagement plan includes pro-active consultation with Traditional Owners to ensure significant sites are identified prior to commencement of works. Conduct cultural heritage assessment and identify key stakeholders.	Reduction	Unlikely	Moderate	Moderate
Community perception of risk										
Stakeholder acceptance risks; third party impacts										
12	Large natural flood during implementation phase causes increased community/stakeholder concern about damaging floods.	Reputation	Unlikely	Minor	Moderate	Continue to implement communications and engagement plans to include community and landholders in proposal design. Engagement and communications strategy to communicate the lower level of flows being proposed. Take advantage of opportunities to verify flow inundation modelling to increase confidence in assessment of potential impacts and mitigation strategies.	Reduction	Rare	Minor	Low
13	A trial flow during the planning and implementation phase exceeds the specified inundation footprint for the flow leading to a loss of community confidence in the abilities of operators/inundation mapping.	Reputation	Possible	Moderate	Significant	Take advantage of opportunities to verify flow inundation modelling to increase confidence in assessment of potential impacts and mitigation strategies. Form partnerships to engage community in citizen science projects to help improve the quality of inundation maps i.e. couch trials as research to help improve inundation maps. Use a stepped approach to work up to higher flow levels and win the confidence of the community.	Reduction	Unlikely	Moderate	Low
Modelling										
Risks associated with the modelling (assumptions, accuracy of model, accuracy of input data, interpretation of modelling outcomes)										
14	Incorrect flow inundation modelling leads to poor assessments of the scale of potential impacts.	Reputation Financial	Likely	Moderate	Significant	Modelling and GIS analysis conducted by technical experts from the MDBA. Include adequate physical buffer area for assessing scale of potential impacts.	Reduction	Possible	Minor	Moderate

Risk ID	Risk Description	Risk Category	Raw Risk Likelihood	Raw Risk Consequence	Raw Risk Rating	Mitigation strategies	Risk Treatment	Residual Risk Likelihood	Residual Risk Consequence	Residual Risk Rating
						Use most up-to-date datasets on infrastructure and land tenure through technical investigations. Verify spatial data with available satellite imagery. Consult other technical experts to verify any outstanding issues. Seek clarity on assumptions and how this translates to defining project uncertainty, risk, scope and investment. Include defined contingency for investment decisions to account for modelling uncertainty. Verify scale of potential impacts with historical accounts of landholders. Build in more detailed planning and assessments for next phase of the project.				
Operation, Maintenance & Management										
Risks re operation and management of the measure post completion/commissions that may affect the enduring benefits of the measure including any risks to projects that require future regulatory change. This should include ongoing monitoring, evaluation and reporting around the operation and ecological outcomes associated with the project.										
15	Lack of clearly defined roles and responsibilities for operation and maintenance of potential new and upgraded infrastructure.	Financial	Possible	Moderate	Significant	Clearly define roles and responsibilities for operations and maintenance of potential new and upgraded infrastructure with business partners during business case development and implementation. Leverage capital works during negotiations with business partners to offset operations and maintenance costs. Implement communications and engagement strategy.	Reduction	Unlikely	Moderate	Moderate
Security of Funds										
Risks that may affect the security of funds sources for the project to support project implementation into the future										
16	Inability to use Water for the Environment Special Account to fund operations and maintenance / reinstatement costs for physical constraints.	Financial	Likely	Major	Significant	Leverage other funding sources with business partners to fund operations and maintenance costs for potential new and upgraded infrastructure. Explore other opportunities to fund operations and maintenance costs.	Reduction	Possible	Major	Significant

Table 22: Risk Assessment Framework.

		CONSEQUENCE				
IMPACT UPON		**Catastrophic**	**Major**	**Moderate**	**Minor**	**Insignificant**
	WHS	Death and/or major injuries on a significant scale; a notifiable incident under WHS Act.	Major injuries of staff or other parties; a no ifiable incident under WHS Act.	Medical treatment required for staff or other parties; and/or a dangerous incident as defined under the WHS Act potentially a notifiable incident to Comcare under WHS Act.	Only minor injury, if any, to staff or other parties. Comcare not notified.	No injury to staff or other parties. Comcare not notified.
	Financial	Total dollar cost greater than $50m	Total dollar cost in he range $1m to $50m	Total dollar cost in the range $100,000 to $1m	Total dollar cost in the range $1,000 to $100,000	Total dollar cost less than $1,000
	Stakeholders	Key stakeholders suffer severe impact or loss of confidence in he program, and possibly the agency involved, to the extent that its future is in question.	Extensive impact on key stakeholders with major political ramifications and/or extensive community dissatisfaction.	Significant stakeholder impact which requires attention of Senior Officials and has some political ramifications.	Minor stakeholder impact which is dealt wi h in a short timeframe.	Little, if any, stakeholder impact.
	Environmental	Catastrophic environmental impact which has long term consequences and severely impacts on the national economy.	Extensive environmental impact over a prolonged period which has major political and/or economic consequences.	Significant environmental impact but only over a limited period.	Only minor, if any, environmental impact.	No environmental impact.
	Reputation	Irretrievable damage to the reputation of agencies involved to the extent that it fails to have continued political support.	Long term damage to the reputation of agency involved.	Significant damage to the reputation of the agencies involved with short to medium term ramifications.	Some short term damage to he reputation of agencies involved.	Little, if any, reputa ion damage for agencies involved.
	Almost Certain Expected to occur within the next 12 mon hs, or has occurred in he past year.	**High**	**High**	**Significant**	**Significant**	**Moderate**

Likely Will probably occur in most circumstances. Expected to occur in the next 2 years or has occurred within the last 2 years.	**High**	**Significant**	**Significant**	**Moderate**	**Low**
Possible Might occur at some time. Expected to occur within the next 5 years, or has occurred in the last 5 years.	**High**	**Significant**	**Significant**	**Moderate**	**Low**
Unlikely Could occur at some time. Expected to occur within the next 20 years, or has occurred in the last 20 yrs.	**Significant**	**Moderate**	**Moderate**	**Low**	**Low**
Rare May occur only in exceptional circumstances. Expected to occur once every 100 years.	**Significant**	**Moderate**	**Low**	**Low**	**Low**

15 Appendix 6 – Projects commissioned

Independent consultants were engaged to undertake four projects to investigate impacts, mitigation measures and costs. These projects are summarised in Table 25.

Table 23: Projects commissioned.

Project	Consultant(s)	Tasks	Sub-tasks	Methods used
Private agricultural land	GHD	Refine prefeasibility assessment of impacts on agriculture, and the costs of easements that may be required over the land in light of those impacts.	Reassess key assumptions, e.g. land use, land value, impacts, and recalculate costs.	Consultation with informed stakeholders (e.g. local agricultural experts).
			Reassess hydrological assumptions, i.e. frequency/timing/duration of flows, and recalculate costs.	Draw on modelling undertaken by MDBA (refer to Appendix 7).
		Develop local level "story" about how different regions/types of land affected, and appropriate mitigation options (including relationship between easement and infrastructure works).	Detailed consultations with landowners to understand nature of local-level impacts in detail, and appropriate mitigation options.	Case studies with landowners.
		Assess benefits to agriculture, where they exist, and the value of those benefits.	Detailed consultations with landowners to understand nature of any local-level benefits.	Expert analysis building on other findings of project.
		Identify and cost works on private infrastructure.	Assess where private infrastructure works would be required to complement easements, and estimate costs of those works.	Expert analysis, drawing on findings of case studies with landholders.
Public infrastructure	AECOM	Refine assessment of public infrastructure (e.g. roads, crossings, bridges, stormwater), how it might be affected by changes in flows, and mitigation options and costs.	Reassess and refine existing GIS-based datasets.	Expert analysis
			Consult with regional stakeholders to refine understanding of impacts on specific infrastructure items, and works required.	Consult with regional stakeholders
			Estimate costs of infrastructure works.	Expert analysis
Implementation costs	Jacobs	Assess what processes would be required to implement mitigation measures, and	Stocktake of approval and management requirements relevant to implementing mitigation measures.	Expert analysis
			Estimate costs of processes	Expert analysis

Project	Consultant(s)	Tasks	Sub-tasks	Methods used
		estimate costs of those processes.	Prepare advice on implications on potential governance options on CMS infrastructure implementation.	Expert analysis
Specialist activities	Jacobs	Consider specialist activities (e.g. tourist facilities and quarries), how they might be affected by changes in flows, and mitigation measures and costs.	Identify specialist activities which would be affected, and develop methodology for identifying potential impacts and appropriate mitigation measures.	Expert analysis
			Engage with potentially affected businesses and develop story about how affected.	Consult with regional stakeholders
			Develop indicative estimates of costs.	Expert analysis

15.1 Private agriculture

15.1.1 Context and scope

During the CMS prefeasibility phase, GHD was engaged to investigate and estimate the likely costs associated with ensuring passage of environmental flows over private agricultural land. The prefeasibility study focused primarily on the purchase of easements from landholders, but also looked at other potential arrangements. The principal output of the study was a desktop-based model to calculate the likely magnitude of costs associated with the purchase of easements. The model provides an estimate of how changes to the flow regime might have implications for the worth of the affected land[7] as a function of impacts on agricultural activity. The model was applied to a set of different flow scenarios in order to enable comparison between options.

15.1.2 Approach to assessing impacts and mitigation options (2015 feasibility phase)

For the feasibility phase, GHD was engaged to undertake further work. For the purpose of the feasibility study, GHD made further assessment of impacts, mitigation options and costs through two complementary processes:

Firstly, GHD refined the costing model developed during the prefeasibility phase, by:

1. Peer review and refinement of agricultural land worth[8] values. This was done through consultation with qualified rural valuers.
2. Peer review and refinement of agricultural enterprise gross margins and impacts of inundation on productivity. Figures were provided and reviewed by officers from state government departments with primary industry responsibility.
3. Refining and verifying land use classifications for inundated land using satellite imagery. During the prefeasibility phase, GHD had used ACLUM classification at a cadastral level, without ground truthing those classifications. It was acknowledged that this verification process would assist in improving the prefeasibility cost estimate.
4. Updating hydrology assumptions to reflect modelling work undertaken during 2015. The hydrological assumptions used are summarised in Appendix 7.

[7] ***"Worth of affected land"*** is calculated as a function of ***"agricultural land worth"***.
[8] ***"Agricultural land worth"*** is calculated based on the gross value of production relevant to directly affected land.

Secondly, GHD engaged with groups of potentially affected landholders in the form of (i) stakeholder group discussions, and (ii) visits to a set of sample properties.

Landholder meetings and sample property visits

GHD participated in meetings and gave presentations to groups of landholders. This provided opportunity for group discussions about GHDs study methods and local implications. The landholder group meetings also helped identify landholders with whom GHD subsequently could followed up with for sample property visits.

River reach	Landholder meetings held
Hume-Yarrawonga	11 June 2015 – MRAG meeting in Howlong

Following the group meetings GHD visited a number of sample properties. Each visit to sample properties lasted 2-3 hours. During the visits the GHD team completed data sheets regarding impacts and mitigation options based on the information provided by the landholder. The discussion with the individual landholder was aided by GHD bringing property maps that included the modelled inundation extents of the proposed flows. The property visits also enabled the project team to inspect the relevant areas of the property that may be impacted by inundation or interrupted access as a result of the CMS, with particular attention to land use and any affected infrastructure.

To the extent possible (subject to consent by each landholder), landholders were asked if they were willing to let their property feature as an example of a property type in terms of location, land use and impact. Note that only a small number of sample properties were subject to visits and the results are not intended to be representative in a statistical sense[9]. However, the outcomes from the visit provided valuable information to improve the cost estimates calculated at the prefeasibility stage[10].

The sample property visits also proved to be important for communication and stakeholder relations, as it provided landholders with an opportunity to voice their concerns, ask questions and obtain more information about the CMS.

GHD prepared synthesised narratives ("stories") from the sample properties. These narratives were then reviewed by stakeholders with whom GHD had consulted.

Reach	Sample properties consulted
Hume-Yarrawonga	23 June 2015: Reach C (x1) [covering Howlong to Corowa region]
	6-7 July 2015: Reach A, B and D (x1) [covering Hume Weir to Albury, Albury to Howlong, and Corowa to Lake Mulwala]

[9] The function of the information from local landholders is not to feature in calculations of averages for the purpose of statistical analysis. In other words, information provided is not and should not be interpreted as an average that is reflective of the specific circumstances of any actual farm or landholding.

[10] A complete range of circumstances applicable to individual properties would be the subject of a subsequent implementation phase and negotiations in each individual case. For the purpose of estimating costs during the feasibility stage it is sufficient to take account of information about the typical range and magnitude of impacts.

15.1.3 What was taken into account in cost estimates

GHD considered impacts and mitigation options on inundated land and land suffering interrupted access, for the following land use types:

- grazing tolerant pastures
- grazing vulnerable pastures
- cropping
- horticulture

It should be noted that the feasibility cost estimates are not intended to determine negotiations for any given property. Costs relevant to individual landholder circumstances would be subject to negotiation during an implementation phase. Table 26 and Table 27 summarise findings to date on a reach-by-reach basis, and separately present impacts and mitigation that *may typically* apply to inundated land and interrupted access. The mitigation options below therefore identifies *types* of significant and likely costs. While not itemised in detail in the cost calculations, these types of costs are factored into the feasibility phase costing.

Table 24: Impacts and Mitigation Options of Inundated Land.

Impacts	Mitigation options
Tolerant pastures *Loss of grazing due to flooding:* After flood recession, grazing is reduced by silt deposition and inability for stock to traverse boggy ground. Measured as number of foregone grazing days. Foregone grazing days increases as duration of inundation increases and also with later season flooding due to reduced chance of follow-up rain to remove silt prior to late spring senescence. *Weed infestation*: Pastures survive flooding but recovery is delayed unless soil fertility is restored *Deposit of debris*: e.g. logs etc. on paddocks.	Provide alternative grazing for livestock for the period of foregone grazing, or compensation via purchase of easement. Allow for increased weed control. Allow for starter fertiliser application to stimulate. regrowth. Allow for clean-up of debris.
Vulnerable pastures As above, but including the need to partially or completely restore pastures due to death of plants. Note that crops not significant on the floodplain.	As above except that pasture renovation costs, including complete resowing as a result of a flood may be required. Foregone grazing increases due to time needed for resown pasture to become established before grazing.
Livestock husbandry On the assumption that sufficient advanced warning of impending CMS flows is provided, cattle can be moved to land where normal husbandry and marketing operations can proceed.	Recognise additional cost of mustering, otherwise no loss of production so long as alternative grazing is available for the foregone grazing days. There is a significant cost in providing alternative grazing sources, whether these are available on farm or via agistment[11].

[11] Agistment costs are based on review of past tax invoices for agistment and limited industry consultation. The costings rate is set approximately 30% above the current rate to take account of transport costs. It is recognised that agistment rates can vary for a number of reasons, including if there is a sudden demand created by a local event. The impact of higher agistment costs is included in the sensitivity analysis. Foregone grazing days are given a conservative estimate (ie overestimation of impacts). The cost estimates are therefor considered to be higher than what are likely to occur.

Impacts	Mitigation options
Fencing Flows can potentially damage fences due to a build-up of debris and reduction in longevity due to additional flooding of posts and wires.	Recognise the costs to restore fences – removal of debris, straightening posts, restraining. There may be limited opportunity to relocate fences to avoid flood damage and at the same time improve livestock management.
Bridges and crossings Approaches and abutments can be eroded and reduce access. Most of this infrastructure was designed to provide access at flows of 25 GL/day.	Recognise ongoing costs for repairs and maintenance.

Table 25: Impacts and Mitigation Options for Interrupted Access Land.

Impacts	Mitigation options
Pastures Loss of grazing on the assumption that livestock are removed to "safe" land to ensure continuity of husbandry and marketing options. Nil impact on pasture quality and density if interrupted access is for short periods only.	Provide alternative grazing for livestock for the period of foregone grazing or compensation via purchase of easement. Consider cost-benefit of constructing new bridges or crossings that could enable access to be maintained at the 40,000 ML/day flow.
Crops	Not applicable
Bridges and crossings (existing) Inundated for varying periods of time.	Consider cost-benefit of refurbishing existing bridges or crossings that could enable access to be maintained at the 40,000 ML/day flow.

Through consultation with landholders it was assessed that on average, interrupted access land averages 110 percent of the area of inundated area. Consultation also found that the land use in the interrupted access areas was: tolerant pastures 75 percent; vulnerable pastures 20 percent; and annual crop 5 percent.

It was found that impacted properties are subject to periodic flooding on the floodplain due to both natural and managed events, including for the release of environmental water up to 25,000 ML/day. As a result, property management, including type and location of infrastructure, has been refined over time with the aim of limiting impacts of flooding events.

As such, infrastructure such as haysheds, silos and livestock yards are generally located off the floodplain and it is considered there would be minimal impact on both inundated and interrupted access land. The same is the case for water pumps whereby the river, creeks and farm dams supply the vast majority of livestock drinking water although some portable pumps are infrequently used. Irrigation pumps on the river are rare.

Fencing is generally located away from fast flowing sections of the river and are aligned as much as possible in the direction of flow. However flooding could result in a build-up of debris along fences and weaken their structure and reduce longevity. The costs of clearing debris and repairing fences would need consideration.

15.1.4 Infrastructure upgrade costs

Sample property inspections identified that a number of properties have existing infrastructure that would potentially be impacted by the proposed CMS flows. The main types of infrastructure include creek

crossings, bridges and water pumps. While these have been constructed and maintained to standards suitable to the current inundation patterns, upgrades to the infrastructure would be justified if CMS flows are implemented due to the increased frequency, duration and/or height of inundation expected.

For the creek crossings and bridges, upgrades to these also have the potential to enable access to land that otherwise may suffer interrupted access as a result of the CMS flows.

During the feasibility stage it has not been possible to accurately determine the number of properties that would benefit from the upgraded infrastructure nor the extent of the upgrades required. Some property owners either had minimal infrastructure that would be impacted by CMS or considered that CMS flows would have minimal impacts and thus would not warrant upgrading. Others, however, felt that CMS flows would cause significant damage to existing infrastructure or that new infrastructure would be required to reduce the area of interrupted access.

All owners recognised that any refurbishment or new construction would need to meet a benefit/cost assessment and agreed that some instances of interrupted access may not justify upgrades to infrastructure or construction of new infrastructure. For these instances, some other form of compensation such as purchase of easements was seen to be a suitable option.

As a base case, GHD considered an "easement focused" approach to addressing interrupted access. They assumed that infrastructure works would only be justifiable if a minimum area of interrupted access land is made accessible. For example, if an individual property has interrupted access of 122 hectares, there could be justification to build one or more structures totalling $100,000 that would then avoid the cost impacts.

As an alternative approach, GHD also considered an "infrastructure focused" approach, which recognises that there may be circumstances in which landholders express a preference for infrastructure works rather than easements. It is not easy to estimate the extent of such potential infrastructure works, because of uncertainty surrounding the number of properties that may be suitable for infrastructure construction / upgrades, and the specific circumstances of each property.

To provide an indicative estimate of the costs of such an "infrastructure focused" approach, GHD assumed that 50% of properties suffering inundation of more than 10 hectares in each reach may require infrastructure upgrades and that the average cost of upgrades would be $50,000 per property.

The $50,000 average is assumed to comprise a combination of the following estimated upgrade costs. Note that the costs include on-farm works only and do not include any design or approval costs which in many cases are not expected to be required.

Infrastructure upgrade	Approximate cost
Pump Raising	$5,000
Raising of access tracks (0.2-0.5m)	$20,000
Small farm track culverts (low flow culverts)	$10,000
Erosion protection works (around culvert/bridge crossings and/or track batter slopes)	$7,500
Large box culverts (higher flow culverts)	$20,000
Bridge Works (e.g. widening)	$80,000

GHD utilised a number of datasets as part of their analysis:

- SA Landuse data 2008, SA Department of Water, Land and Biodiversity Conservation (DWLBC)
- NSW Landuse data 2009, Department of Environment and Climate Change

- VIC Landuse data 2014, Australian Bureau of Agricultural & Resource Economics & Sciences (ABARES)

15.2 Public infrastructure

15.2.1 Context and scope

During the CMS prefeasibility phase, URS engineering consultants were engaged to investigate the costs associated with potential infrastructure works to mitigate the impacts of higher environmental flows – for example, works on roads or river crossings.

URS developed a desktop-based model which assumed that "unit rates" could be used to estimate the costs of infrastructure work. Desktop-based GIS analysis was used to identify what infrastructure would potentially be affected, through assessment of the intersections between GIS-based infrastructure datasets, and modelled inundation maps at different flow rates. URS also assessed the costs associated with a small selection of specified larger infrastructure items.

In 2015 AECOM was engaged to undertake work during the CMS feasibility phase, to build on and refine the assessment undertaken by URS in 2014. AECOM undertook this work in the following key focus areas: Hume-Yarrawonga, Yarrawonga- Wakool, River Murray in South Australia, Murrumbidgee, and Goulburn.

Note that AECOM considered only **public**[12] infrastructure. Infrastructure on private agricultural land was considered separately by GHD through the private agriculture project.

15.2.2 Approach to assessing impacts and mitigation options

AECOM refined the prefeasibility costing work by:

- creating a spatial (GIS) database of available information
- identifying assets at risk, in consultation with regional stakeholders
- developing responses/treatments for assets at risk
- preparing an estimate of probable cost for response/treatment measures, and
- undertaking an assessment of the total cost for each reach.

A key element of the project was working with on-ground stakeholders to ground truth assumptions and modelled inundation outcomes of infrastructure that would be affected at the specified flow rates. AECOM engaged with the following stakeholders through a combination of phone calls and regional visits:

- Albury City
- Corowa Shire
- Wodonga City

[12] For the purposes of this project "public infrastructure" included:
- transport infrastructure (e.g. roads, crossings, bridges) which is owned or maintained by governments (e.g. local councils)
- stormwater and sewerage infrastructure which is owned or maintained by local councils
- levees which are owned or maintained by local councils and which are used to help manage the effects of higher river levels and/or significant rainfall events
- river operation infrastructure (e.g. locks, weirs, floodgates, regulators) which are publicly owned or maintained
- irrigation infrastructure (e.g. irrigation channels, drainage canals) which is owned or maintained by corporate entities (e.g. irrigation companies), even where those corporate entities are privately owned and operated (e.g. Murray Irrigation Limited).

Similar infrastructure which is owned or maintained by agricultural landowners (e.g. roads, crossings, bridges, levees on private agricultural land, private irrigation pumps) was outside the scope of this project.

- Moira Shire
- Indigo Council
- Greater Hume Council.

15.2.3 What was taken into account in cost estimates

During consultations with local councils and other public asset managers, AECOM found that:

- Substantial capital upgrade works would not be typically required to mitigate against environmental flows. Councils identified that the most efficient approach to mitigate environmental flows is to proactively manage, or directly respond to the impacts of the events. A small number of exceptions for assets requiring upgrade were identified and recorded.
- Very few culverts or bridges require physical repair/replacement after flow events. The typical response was clean up of silt and debris and reinstatement of beaching where materials had been washed away.
- Roads subject to inundation or even water to the road shoulder would not necessarily require works, but experienced greater rates of deterioration in the months after flows.
- Operational costs to enact flood mitigation controls (such as road management/closing and shutting off backflow prevention valves) was a common cost, not captured by asset costing.
- Duration of inundation extending beyond seven days has an amplified impact on damage and costs. The impacts of this have been considered in proposed treatment measures and associated costs, and separate calculations prepared for each outcome.
- Landscaped areas (including manicured grassed parks and sports fields) require rectification.
- Waterside infrastructure (such as jetties, pontoons, boardwalks) often require maintenance and repair.

AECOM considered the following mitigation responses (Table 28) in developing cost estimates:

Table 26: Public Infrastructure Impacts and Mitigation Responses.

Asset Class	Definition / Description	Response	
		Allowance for <7 days	Allowance for > 7 days.
Sealed Road	Sealed roads are typically any roads that have a bound surface finish; primarily asphalt but may also include concrete. Local Government Authorities: Any sealed road with Arterial, Sub-arterial, or Local classification that are owned or maintained by a Local Government Authority. Other Public Asset Owners: Road classes with a Major (assumed Freeway or Highway which are State owned) classification and sealed surface. Any sealed road that are within National or State Forests, or reserves that are not owned or maintained by a Local	Intermittent pothole rectification Allowance: Applied to 100% of the identified impacted sealed roads. Scope: 1 x 1 sqm pothole rectification every 20 m length of affected pavement	Intermittent pothole rectification Allowance: Applied to 90% of the identified impacted sealed roads. Scope: 1 x 1 sqm pothole rectification every 10 m length of affected pavement. Pavement Rehabilitation Allowance: Applied to 10% of the identified impacted sealed roads. Scope: Scarify and overlay 150 mm unbound granular road base with 7 mm to 14 mm 2-coat spray seal.

Asset Class	Definition / Description	Response	
		Allowance for <7 days	Allowance for > 7 days.
	Government Authority.		
Unsealed Road	Unsealed roads are typically roads that are used for regular access to properties or assets, which have a formed earth material pavement (typically crushed rock or other compacted granular material) to a defined engineering standard. Local Government Authorities: Any unsealed road with Arterial, Sub-arterial, or Local classification that are owned or maintained by a Local Government Authority. Other Public Asset Owners: Any unsealed road with Arterial, Sub-arterial, or Local classification that are within National or State Forests, or reserves that are not owned or maintained by a Local Government Authority.	*Road regraded* Allowance: Applied to 100% of the identified impacted unsealed roads. Scope: Regrading of 8 m wide section without crushed rock supplement.	*Road regraded* Allowance: Applied to 100% of the identified impacted unsealed roads. Scope: Regrade 8 m wide section with 30 mm average crushed rock supplement.
Track	Tracks are typically assets which are used for infrequent access to sites or for recreational use (i.e. 4WD tracks), which are of suitable dimensions for vehicle access but possibly not constructed to a defined engineering standard. Local Government Authorities: Any road with a Track classification that is owned or maintained by a Local Government Authority. Other Public Asset Owners: Any road with a Track classification that are within National or State	*Ad-hoc maintenance allowance.* Allowance: Applied to 100% of the identified impacted tracks. Where the value of impacted tracks within a Local Government Authority area is less than $1,000, then no costs are allocated. Scope: $1,000 per 10 km of inundated track. This does not equate to $0.10 cents per metre length of inundated track. The cost allocation, for example, may rectify a number of small defects over a 10 km length of track.	*Ad-hoc maintenance allowance.* Allowance: Applied to 100% of the identified impacted tracks. Where the value of impacted tracks within a Local Government Authority area is less than $1,000, then $1,000 of cost is allocated. Scope: $4,000 per 10 km of inundated track. This does not equate to $0.40 cents per metre length of inundated track. The cost allocation, for example, may rectify a number of small defects over a 10 km length of track.

Asset Class	Definition / Description	Response	
		Allowance for <7 days	**Allowance for > 7 days.**
	Forests, or reserves that are not owned or maintained by a Local Government Authority.		
Shared Path / Walking Track	Shared user paths are walking or cycle paths. These are typically defined paths that are for recreational use and have not been designed for vehicle access. Local Government Authorities: Any road with a Recreational classification that is owned or maintained by a Local Government Authority. Other Public Asset Owners: Any road with a Recreational classification that are within National or State Forests, or reserves that are not owned or maintained by a Local Government Authority.	*Surface repair* Allowance: Applied to 100% of the identified impacted tracks. Scope: 2 sqm crushed rock reinstatement every 50 m of inundated length.	
Bridge	Bridges provide road access over a river or flood plain. They may be associated with Local Government Authorities and Other Public Asset Owner roads.	*Silt/debris removal and rock abutment reinstatement* Allowance: Applied to 100% of the identified impacted bridges. Scope: Clean up bridge columns from gross pollutants (i.e. branches, litter etc) and reinstate 60 sqm of 300 mm rock rip-rap abutment lining.	
Culverts	Culverts are typically a pipe structure that allows water to flow under a road. They generally consist of four main components - a pipe, two headwalls, beaching at each headwall and the road over the pipe. It may be associated with Local Government Authorities and Other Public Asset Owner roads.	*Silt/debris removal and rock beaching reinstatement.* Allowance: Applied to 100% of the identified impacted culverts. Scope: Pressure wash culvert and reinstate 10 sqm rock beaching at each headwall.	*Culvert replacement* *Allowance*: Applied to 1% of the identified impacted culverts. Scope: Replace 1 x 12 m long by 600 mm diameter culvert including headwalls and reinstate of pavement above. *End wall reinstatement* Allowance: Applied to 4% of the identified impacted culverts. Scope: Reinstate headwalls (2 no. off) for 1 x 600 mm diameter culvert with 10 sqm rock beaching at each headwall. *Silt/debris removal and rock beaching reinstatement.* Allowance: Applied to 95% of the identified impacted culverts.

Asset Class	Definition / Description	Response	
		Allowance for <7 days	**Allowance for > 7 days.**
			Scope: Pressure wash culvert and reinstate 10 sqm rock beaching at each headwall.
Fords	Fords are a low area along a river or stream that is used as a road crossing, but designed for inundation/overspill in high flow events. It may be associated with Local Government Authorities and Other Public Asset Owned roads.	No asset reinstatement response applied. The cost of reinstatement of fords is considered to be included within the unsealed road maintenance allowance.	
Landscaped Area	Landscaped areas are grassed areas such as parks and sports fields which require rehabilitation after periods of inundation. These were identified using the land use planning zones which are generally referred to as: PPRZ, Public Park and Recreation Zone (Victoria and NSW); RE1, Public Recreation (NSW); Open Space (SA). These zones are referred to as 'Open Space' for consistency. Response measures would be applied to manicured (regularly mowed and actively used) landscape areas only.	*Silt/debris removal only and Silt/debris removal and re-seeding.* Allowance: 1% of identified Open Space within Local Government Authority areas. If the value of reinstatement of Open Space was less than $10,000; $10,000 was allocated to the Local Government Authority area. If the value of reinstatement of Open Space was greater than $250,000; $250,000 was allocated to the Local Government Authority area. Scope: Two asset reinstatement measures were applied to impacted Open Space for events <7 days: • 80% has silt/debris removal only – based on a hectare rate for scraping 50 mm silt and removing to suitable fill area within 10 km • 20% has silt/debris removal and re-seeding.	*Silt/debris removal and re-seeding.* Allowance: 1% of identified Open Space within Local Government Authority areas. If the value of reinstatement of Open Space was less than $10,000; $10,000 was allocated to the Local Government Authority area. If the value of reinstatement of Open Space was greater than $250,000; $250,000 was allocated to the Local Government Authority area. Scope: Hectare rate for scraping 50 mm silt and removing to suitable fill area within 10 km and hydro-seeding.
Operational Costs	Asset Managers (councils) have incurred additional resourcing costs associated with flood preparations.	Enacting flood mitigation controls (such as road management/closing and shutting off backflow prevention valves) was a common cost, not captured by asset costing.	

AECOM also considered a number of potential infrastructure items which would require capital works, which were identified during the stakeholder consultations:

Capital Cost Item	LGA
Isolated Property Access. Assume 1% of all impacted properties require 100 m per property unsealed road upgrade cost.	All

AECOM also utilised a number of datasets as part of their analysis:

- Collaboration between CSIRO & Murray–Darling Basin Authority (MDBA) 2015, Flow inundation modelling (65K, upper limit extent)
- Collaboration between CSIRO & MDBA 2014, Flow inundation modelling (20K, 35K, and 50K extents)
- Digitised Point crossings, NSW LPI Digital Topographic Database, 2014
- Point Crossings, VICMAP, 2014
- Roads on private land and public land, NSW LPI, 2014
- Roads on private land and public land, Victoria DELWP, 2014
- NSW LPI 2014 Cadastre of Public land
- VICMAP 2014 Crown land Public Land Management (PLM25), Victoria DELWP
- River Murray Water Main Structures and Hydrologic Indicators sites, MDBA 2008.

15.2.4 Peer Review

The MDBA engaged a Principal Engineering Consultant from GHD Pty Ltd, to peer review the draft technical analysis and recommend changes that should be addressed in the final technical report.

Specific issues that were considered in the review included:

- any risks around the engineering assumptions in the project methodology
- identification of potential gaps in the engineering analysis, to ensure that the costing estimates are as robust as possible
- improvement and any extra data required for analysis.
- review of contingencies
- appropriateness of proposed mitigation options
- any other matters of consequence which the consultant considered would have a material impact on the costings.

AECOM considered and addressed the issues raised in the peer review in their final technical report.

15.3 Implementation costs

15.3.1 Context and scope

A key consideration in planning for implementation of CMS mitigation measures is potential engineering, planning and environmental approvals. Jacobs was engaged to provide expert advice regarding the scope and resourcing that might be associated with such implementation requirements. The consultants:

- undertook a stocktake of approvals and engineering requirements for implementing infrastructure works
- quantified additional contingency costs relating to the planning approvals, engineering design work and construction activities, and
- explored how potential governance options could have an impact on the infrastructure delivery of the CMS.

15.3.2 Findings

Jacobs recommended that some considerations be taken into account in the implementation phase, as summarised below. These recommendations were incorporated into the discussion in Section 7.

15.3.2.1 Design, approval and site supervision costs

Jacobs recommended that indicative cost ranges (% of CAPEX) should be applied for design, approvals and contracting/supervision for CMS infrastructure works (see Tables 29, 30 and 31) The rates were developed based on several recent projects involving capital works on floodplain. Jacobs' recent experience has revealed that the approvals/site supervision costs are significantly higher in a rural floodplain areas compared than other regions.

Table 27: Design fee as a % of the capital cost.

CAPEX	Design Fee (Total as % of CAPEX)	Breakdown of Design Fee (%)			
		Feasibility	Concept Design	Preliminary Design	Detailed Design
> $10 million	3.5-4%	10%	15%	30%	45%
$3 – $10 million	4-5%	10%	15%	30%	45%
$1 -$3 million	5-6%	10%	15%	30%	45%
$0.5-$1 million	6 -10%	10%	15%	30%	45%
<$0.5 million	10-30%	10%	15%	30%	45%

Table 28: Approvals as a % of the capital cost.

CAPEX	Regulatory/Design Authority Approvals (% of CAPEX)
> $10 million	5-6%
$3 – $10 million	6-8%
$1 -$3 million	8-15%
$0.5-$1 million	10-50%
<$0.5 million	30-100%

Table 29: Contracting/site supervision as a % of the capital cost.

CAPEX	Contracting/Site Supervision (% of CAPEX)
> $10 million	1.75-2%
$3 – $10 million	2-3%
$1 -$3 million	3-5%
$0.5-$1 million	5-10%
<$0.5 million	10-30%

The quantums in the tables demonstrate that the % of the CAPEX for design, approvals and the contracting/supervision increases significantly for small capital works projects (<$0.5 M). Therefore, bundling of small projects into a package of works would be very important to achieve the scale needed to foster greater efficiencies and cost savings. The size of the work packages would also be very important for the contractors that have the required processes, practices and systems that you would want to bid for these types of works and for generating efficiencies and cost savings in the construction phase.

Works on riparian and floodplain areas: The vast majority of the works proposed to be implemented under the CMS would be located in riparian and floodplain areas that are regularly subjected to flooding. An acknowledgement of this risk would need to be built into the proposed implementation strategies and

a consistent approach to the management of this risk should be developed to ensure that project implementation is not unduly impacted by the inevitable flooding events.

Works on private land: The current program of works for the CMS includes significant numbers of works items that would be constructed on private land on behalf of private landholders. Works completed on private land would be inherently more complex as a result of the need to engage with a diverse range of individual landholders who have varying acceptance of the program.

15.3.2.2 Approvals Considerations

Planning application and approvals process: An integrated approach to design, application, stakeholder consultation and approvals is required for the proposed CMS infrastructure works programs. This would ensure that the implications of any change to the proposed works package are well understood and that there are no surprises as the proposed works are developed. It would also drive cost savings in undertaking planning and environmental assessments.

Flood prone areas of land are in many instances subject to a wide range of planning and environmental protection controls. The application and approvals process for many of the works associated with the CMS would therefore be complex. Specifically, works to be undertaken in riparian and floodplain areas typically retain a range of environmental and heritage values that would require consideration. Consequently the Approvals and Design Phases of the CMS may take several years to complete (see Table 32.

EPBC Act: It would be necessary to gain approval for implementation of the CMS under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act, 1999. A preferred approach to approval under this legislation would need to be developed that considers both construction and operational impacts of CMS implementation. The preparation of referrals for "bundles" of works may be a suitable approach. Determining the extent of "bundling" and hence the scale of any referral would be crucial to maximise efficiencies. A consistent consultation approach would need to be agreed and developed. It is envisaged to sit across all works in all jurisdictions to ensure that there is transparency and equity in interactions with all stakeholders, regardless of jurisdiction and the sub-program.

Table 30: Information requirements for applications and approvals across Victoria, South Australia and New South Wales.

Issue	Information requirement	Scale of duration
Ecological assessment	A review of potential impacts on flora and fauna is required to determine potential impacts on, aquatic environment, native vegetation and other State and National listed species. This assessment may also manages issues associated with obtaining native vegetation offsets. Note: If seasonal surveys are required for particular species this could take up to a year.	2-12 months
Geomorphology assessment	Where works are being undertaken in and along waterways an assessment of the impacts on the stream geomorphology make be needed.	2 months
Aboriginal heritage	Consultation with the relevant Aboriginal groups is recommended and the completion of a cultural heritage survey may also be required depending on the location and extent of works.	2-6 months
European Heritage	A European heritage study may also be required depending on the age and significance of existing assets that may be impacted or replaced.	1-2 months
Surface water/inundation	Studies are required to determine the impact to third party property from inundation, and to manage potential pollution and stormwater runoff appropriately during construction and operation.	1-3 months
Traffic and transportation	Construction may generate significant volumes of traffic. A traffic management plan and route assessment may be required to ensure safe and efficient vehicle movement.	1-2 months.

Issue	Information requirement	Scale of duration
Land division	A survey for land division purposes identifying the location of any easements.	1 month
Stakeholder / community engagement	Undertake meetings to gain feedback on the project, to confirm key risks and determine an approvals strategy. This duration could increase significantly if the works are to be located on private property	See Appendix 4 – Stakeholder Engagement

15.3.2.3 Governance Considerations

Complex scope of works: An extremely diverse range of works are currently being investigated as part of the proposed CMS. Via the State Constructing Authorities the MDBA has an existing operational model for the delivery, operation and maintenance of water infrastructure. However many of the works types proposed as part of the Constraints Management Strategy are atypical of works delivered via the current arrangements (e.g. roads, bridges, etc). Consideration should be made in relation to the use of alternate delivery agencies that have the relevant capability and the necessary capacity to undertake the work. Regardless of what model is chosen for implementation, given the scale and complexity of the likely final works program there needs to be a high level program management approach developed to ensure that there is consistency and transparency across all works categories and jurisdictions.

15.4 Specialist activities

15.4.1 Context and scope

During the CMS prefeasibility phase, some potential costs were not estimated. This included potential costs associated with mitigating impacts on Specialist Activities.[13] Instead, the nature of these impacts was assessed qualitatively (refer to Table 7 of the 2014 Cost Estimates report (Murrray-Darling Basin Authority, 2014g)).

The CMS prefeasibility phase considered the potential impacts on river shacks in South Australia through a separate exercise undertaken by GHD.

Jacobs and RMCG (hereafter referred to as Jacobs) were engaged to inform the CMS feasibility phase by undertaking a more detailed assessment of potential impacts on specialist activities (including river shacks). Jacobs undertook this work in the Hume-Yarrawonga, Yarrawonga-Wakool, River Murray in South Australia, Murrumbidgee and Goulburn reaches (Table 33).

Table 31: Scope of Specialist Activities.

Activity	Activity type	In/Out of Scope
Residential Activity (including River shacks)	Residential activity	In scope
Tourist cabins	Tourism activity	In scope
Caravan park	Tourism activity	In scope
Holiday accommodation	Tourism activity	In scope
Golf course	Recreation activity	In scope
Public park	Recreation activity	Out of scope (considered through separate public infrastructure project undertaken by AECOM)

[13] Broadly defined as land-uses and activities that are not related to broad-scale agriculture or major public infrastructure.

Activity	Activity type	In/Out of Scope
Wineries	Other Primary Industry	In scope
Orchard (*Irrigated modified pastures, perennial tree fruits, perennial vine fruits*)	Other Primary Industry	Out of scope (considered through separate private agriculture project undertaken by GHD)
Turf farms	Other Primary Industry	In scope
Dairies	Other Primary Industry	Out of scope (considered through separate private agriculture project undertaken by GHD)
Nurseries	Other Primary Industry	In scope
Quarries	Other Primary Industry	In scope
Aquaculture	Other Primary Industry	In scope
Forestry	Other Primary Industry	In scope
House boat operators	River based business activities	In scope
Outdoor adventure tourist operators	River based business activities	In scope where CMS impacts on fixed assets

15.4.2 Approach to assessing impacts and mitigation options

Jacobs created a spatial (GIS) data base of available information to identify the type, number and location of affected specialist activities in the reach (see Table 8 in Section 5.1).

Jacobs assessed impacts, mitigation options and costs through two complementary processes of case studies and cost assessment and extrapolation.

Case Studies

Jacobs worked with stakeholders through selected case studies, to "ground truth" assumptions and modelled inundation outcomes (Table 34). The consultants engaged through a combination of phone calls and regional visits to:

- discuss possible impacts from the anticipated flow events
- obtain business data with which to build business cost models
- discuss other similar businesses in the region, and whether the landholder being interviewed thought they would be impacted to a similar degree
- explore possible mitigation options, and
- view the site, and refine mitigation option concepts.

Table 32: List of Specialist Activities Case Study Sites.

Reach	Case Studies
Yarrawonga Wakool	Golf course, NSW
	Caravan park, NSW
	Forestry Operation, NSW
Murrumbidgee	Quarry, NSW
Hume to Yarrawonga	Visitors Centre, NSW
Goulburn	Caravan park, Victoria
	Aquaculture business, Victoria
	Caravan park, Victoria
South Australia	River Murray Shacks, South Australian

Cost Assessment and Extrapolation

Jacobs undertook a spatial analysis to identify potential impacts, mitigation options and costs of each affected Specialist Activities Site. Jacobs considered the following factors in costing impact and mitigation options.

- Any lessons / observations gleamed from the case studies
- An estimate of the financial impact of inundation - using a financial impact assessment model (developed for the project),
- Identification and costing of a Minimum Cost and Infrastructure focussed mitigation options – using standard unit rates agreed as part of the projects cost model. The cost model includes a number of common mitigation measures, such as:
  - levee banks ($ per m)
  - rebuild access track ($ per m)
  - install culverts ($ per number)
  - post flooding clean up ($ per m2)
- Assessment of the residual financial impact on the business based on a partial inundation mitigation option.

Details of impacts and the method for determine mitigation options for affected sites are detailed in Table 35.

Table 33: Impacts and method for determining mitigation options for Specialist Activities in the Hume to Yarrawonga Reach.

Activity Type	Impacts	Recommended Mitigation options
Quarries	Inundation impacts to quarry site Inundation and restricted road access.	Easements
Tourist visitor centre	Inundation and restricted road access.	Easements or Upgrade access
Restaurant/café	Inundation and restricted road access.	Upgrade access road (Note that such mitigation measures were costed by AECOM rather than Jacobs)

15.4.3 What was taken into account in cost estimates

Jacobs used the following information / data to assess impact and mitigation options and costs for this project.

- Modelled flow and inundation extents provided by the MDBA, and State authorities.
- Aerial imagery.
- Property boundary data sourced from various State authorities.
- Unit rate construction costs obtained from Rawlinson's Australian Construction Handbook 2014 (Rawlinsons).
- Refined unit rate for construction costs were identified at specific case study sites and applied to extrapolations (only where appropriate).
- Business profit and turnover data obtained from case study landholders.
- ABS business statistics.

15.4.4 Peer Review

The MDBA engaged a Principal Engineering Consultant from GHD Pty Ltd, to peer review the draft technical analysis and recommend changes that should be addressed in the final technical report.

Specific issues that were considered in the review included:

- any risks around the engineering assumptions in the project methodology
- identification of potential gaps in the engineering analysis, to ensure that the costing estimates are as robust as possible
- improvement and any extra data required for analysis.
- review of contingencies
- appropriateness of proposed mitigation options
- any other matters of consequence which the consultant considered would have a material impact on the costings.

Jacobs considered and addressed the issues raised in the peer review in their final technical report.

16 Appendix 7 – Summary of modelling approach

MDBA modellers undertook the hydrological modelling which informed this business case. The MDBA has long-established hydrological modelling capacity and has been developing models since the 1980s to inform water sharing arrangements in the River Murray System.

The constraints modelling was built on the existing Basin Plan modelling framework. The MDBA's MSM-BigMod platform was used for the River Murray, and NSW's IQQM and Victoria's REALM platforms used for the Murrumbidgee and Goulburn System respectively. These are established modelling platforms and accepted as industry best practice for the Southern Connected System, and were used to inform the Basin Plan in 2011-12.

State hydrological experts provided advice to inform the assumptions used in the modelling.

16.1 Hydrological modelling method

The modelling approach considered the Southern connected system (i.e. the River Murray System, Goulburn and Murrumbidgee) as an inter-connected single hydrologic unit. For the Albury-Yarrawonga reach, flows of up to 40,000 ML/day at Doctor's Point were modelled. For the Yarrawonga-Wakool Junction Reach, flows of up to 65,000ML/day downstream of Yarrawonga Weir were modelled with an alternative scenario of up to 50,000ML/day.

The method applied in the modelling aims to mimic natural flow cues and uses a probability-based approach to calculate environmental demands.

The model uses historical inflow data to determine environmental water delivery based on natural flow cues that reflect dry and wet cycles and natural variability. For the purposes of the model, environmental flow demands for winter and spring seasons are placed at locations throughout the system. The locations are specified based on the delivery patterns to meet the environmental water requirements used to inform the SDLs in the Basin Plan. The contribution of regulated flows is capped at a maximum limit for the delivery of flows within the Southern connected system. These demands trigger water to be released from storages to meet environmental demands, which are limited as in Table 36. The limit provided in the table is an absolute upper limit and is likely to be effectively utilised only during very wet years. For relatively dryer years, this limit is much lower as determined by limit-curve based on percentiles of monthly cumulative natural flows.

The model assumes environmental flows are limited by channel capacity (also set out in Table 36); the maximum allowable limit for each location; environmental water allocation; and other operational constraints.

Environmental demands are then estimated as a fraction of natural (without development) flows at each location. The fraction that is applied is calculated monthly based on percentiles of monthly cumulative natural flow data for the June to May water year. The fractions are relatively higher for the Winter-Spring months in the wetter years than for those months in the relatively drier years. The wetter years and drier years are identified based on monthly cumulative inflows to headwater storages, such as Hume dam in the upper Murray, and Burrinjuck dam in the upper Murrumbidgee. During extremely wet and dry years, particularly the wettest 10% of the years and driest 10-30% of years on record, environmental demands are not applied. The environmental demands are then used as inputs to the model.

The model produces daily estimates of environmental releases from storages, over a modelled 114-year period from 1895 to 2009. The 114-year sequence of daily model outputs was used to inform the business cases through:

- Analysis of statistics of specified types of flow events (e.g. numbers of flow events lasting less than 7 days in length, or more than 7 days in length, in specified time periods). Such statistics informed analysis by GHD, AECOM and Jacobs on the impacts of relaxed constraints for agriculture, public infrastructure and specialist activities.
- Hydrographs created from the model outputs. These hydrographs informed the sections of the business cases on proposed changes to hydrology and the operating regime.

Table 34: Physical constraints and limits applied to environmental demand (ML/day).

Location	Assumed channel capacity when constraints are relaxed	Limit applied to environmental demand
River Murray		
Doctor's Point	40,000	
Yarrawonga	50,000 or 65,000	50,000 or 65,000
Torrumbarry		40,000
Euston		85,000
SA border		80,000
Lower Darling		
Weir 32	9,300	
Burtundy		17,000
Goulburn		
Eildon	15,000	
Molesworth	15,000	
Seymour	30,000	
Shepparton	40,000	40,000
Murrumbidgee		
Gundagai	33,000	
Narrandera		44,000
Maude		20,000
Balranald		12,000

Note that this maximum environmental demand limit is generally applied to the wet years. For dryer years, the maximum environmental demand is capped by limit curve and is much lower.

16.2 Assumed flow regime changes

To inform cost estimates, it was necessary to define a "baseline" flow regime, and a "post-CMS" flow regime, as inputs to the costing methods.

- The "baseline" flow regime was assumed to be represented by modelling outputs from the MDBA's "baseline diversion limit" (BDL) model run. The "BDL" flow regime represents pre-Basin Plan water recovery condition and is a modelled representation of flows in the Basin, taking into account a 114-year climate sequence from 1895 to 2009, and assuming a level of development as per 2009. Refer to MDBA (February 2012) Hydrologic modelling to inform the proposed Basin Plan: methods and results, Section 3.3.
- The "post-CMS" flow regime represents post-Basin Plan water recovery condition and delivery of environmental water by relaxing channel capacity constraints, and was assumed to be represented by modelling outputs from the MDBA's "relaxed constraints" model run (described in the previous section of this document).

The "BDL" flow regime represents the most appropriate baseline for cost estimates, noting that:

1. The costs that would be incurred in implementing mitigation options (e.g. easements or infrastructure works) would reflect the outcomes of negotiations with stakeholders, who would need to agree to those options, and associated funding, before they can be implemented.
2. If mitigation options (e.g. easements and/or infrastructure works) were to be pursued, negotiations over costs would need to be with reference to a "baseline" which stakeholders can relate to (i.e. represents their recent lived experiences).
3. The "BDL" flow regime is an appropriate representation of this baseline. A non-modelled baseline (e.g. actual flows) would not be appropriate as it would not be possible to compare it to the "relaxed constraints" modelled 114-year flow regime.

17 Appendix 8 – Inundation mapping

In order to inform the assessment of impacts, mitigation options and costs it was necessary to estimate spatially how higher managed flows would inundate areas of land. This section describes how inundation maps were produced.

17.1 CMS pre-feasibility phase (2014)

During the CMS pre-feasibility phase *hydraulic models* and *GIS processing* were used to generate inundation extent maps. Two approaches to hydraulic modelling[14] were used in various reaches (see Table 37). Modelled flow levels in combination with geo-spatial information such as digital elevation were used to model the extent of inundation (i.e. derive an "inundation footprint"). The inundation extents were also calibrated and validated against a range of other information, for example known gauge heights, landscape features, and vegetation.

The inundation extent was captured and presented spatially using GIS tools (e.g. raster format transformed to polygon shapes). The use of GIS has two key advantages: access to geo-spatial analytical techniques (for example to identify location, size, and type of tenure or land use for affected properties), and the relative ease of presenting flow rate implications in the form of maps (for example for discussions with stakeholders).

In order to provide a reference point for analysis, and consultations with stakeholders, each inundation extent was related to a specified flow rate at a reference gauge or location. Further details of the methodology is described in the technical report "Flow inundation mapping & impact analysis[15] (MDBA, 2014).

17.2 CMS feasibility phase (2015) – Hume to Yarrawonga reach

To inform the business case, a single inundation extent corresponding to flows of 40,000 ML/day at Doctor's Point was used.

Table 35: Modelled flow inundation extent - feasibility phase.

Reach	Flow extent (ML/day)		Reference location or gauge	Hydraulic model used
	Inundation	Spatial buffer		
Hume to Yarrawonga	40,000	(not applied)	Doctor's Point	MIKE-11

This inundation extent was revised from the inundation extent which had been used in the pre-feasibility phase. It included some revisions proposed by Hassall and Associates as a result of landholder feedback during earlier negotiations for easements to allow managed flows of up to 25,000 ML/day.

Note that the revised inundation extent covered a smaller area of private agricultural land than was incorporated into easement cost estimates for the prefeasibility phase. In particular:

[14] MIKE was commissioned on behalf of the MDBA (and former Murray-Darling Basin Commission). For a more detailed summary, please see the technical report published December 2014 and available from the MDBA website: "Flow inundation mapping & impact analysis. CMS pre-feasibility technical report".
[15] For further details, see above report.

- A property with 230 ha of inundated land with an easement for flooding was excluded.
- The prefeasibility areas included some land that was zoned as residential and industrial. The feasibility study only includes land zoned for primary production, including rural residential land.
- The feasibility assessment excluded Crown Land (especially river frontage land in Victoria) that was included in the prefeasibility estimate.
- The prefeasibility study included inundated land within the main river stem. This was excluded in the feasibility assessment.

17.3 Application of flow inundation mapping to impact, mitigation options and cost analysis

Consultants used the flow inundation extents, overlaid with other geo-spatial information, such as landuse, roads, crossings, tenure, to identify structures and types of land and production that would be affected by different CMS flow options. The information served as a basis for identifying and costing the impacts and potential mitigation options.

In some instances this processing uncovered inaccuracies in the mapping. In addition, the inundation extents were shared and tested with local stakeholders. Where feedback from local stakeholders and GIS processing indicated discrepancies, consultants took account of local knowledge for the purpose of costings calculations (for example by adjusting figures for hectares etc.). Consultants also updated the maps by comparing them with outcomes of remote sensing (e.g. aerial photographs).

The inundation extents were considered fit-for-purpose to assess impacts and estimate costs at a regional scale, and as a starting point for discussions with local stakeholders.

However, it is important to recognise that the extents were not intended to accurately assess impacts or costs at a local or property level. While the impact and cost assessment included case studies at property level, these case studies were intended to inform the regional level assessment, not a property-level assessment. Such assessment would be the subject to an implementation phase, and conducted on a case by case basis.

If the CMS were to progress to implementation, the existing flow inundation mapping would function as a starting point for identifying and contacting property owners who may be directly affected, and for discussions and negotiations. It would also be necessary to update the inundation maps through improved modelling, further analysis of aerial photography, and/or further consultations with stakeholders regarding details of inundation in specific locations.

Table 36: Summary of updates and revision to flow inundation mapping – feasibility phase.

Inundation extent layers at given flow rates	Source of update			
	Revised modelling	Landholder feedback	Remote sensing	Other stakeholder/ local experts
Hume-Yarrawonga		✓	✓	

Figure 10 and Figure 11 provide some examples of the inundation extents used to inform cost estimates in the feasibility phase in an urban and more rural setting.

Figure 10: The inundation extent of flows of 25,000ML/day and 40,000ML/day as measured at Doctor's Point in Albury/Wodonga on the River Murray.

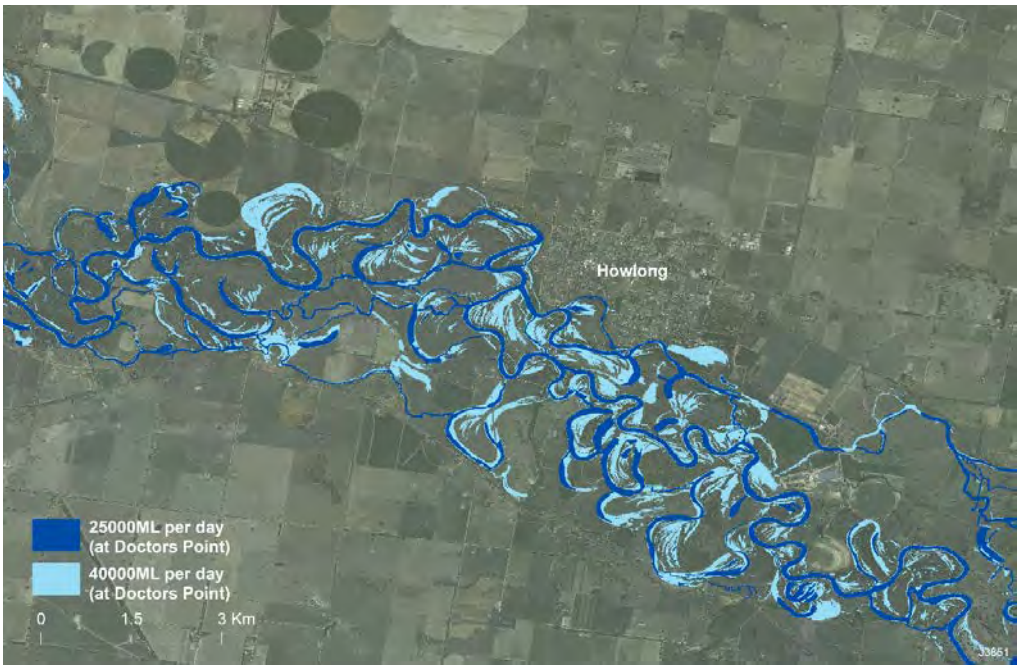

Figure 11: The inundation extent of flows of 25,000ML/day and 40,000ML/day as measured at Doctor's Point near Howlong in the Hume-Yarrawonga reach.