Amendment date: 28 June 2017

1.	**Title of measure**	**SDL offsets in the Lower Murray NSW: Locks 8 and 9 weir pool manipulation Carrs, Capitts, and Bunberoo Creeks connectivity Frenchmans Creek fish passage)**
2.	**Proponent undertaking the measure**	**NSW**
3.	**Type of measure**	**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 It is a new project (not already included in the benchmark conditions).
c)	NSW agrees with the notification	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 supply measures. The identification of affected units does not constitute an agreement between jurisdictions on apportioning the supply contribution, which will be required in coming months.	
6.	**Details of relevant constraint measures**	
	Not directly linked to constraint measures, but implementing the three Murray constraints concept proposals for the Murray River (see separate supply measure notifications) will provide outcomes that are complimentary to this supply measure.	
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 this measure	The purpose of the proposed operational measure and package of works is to deliver benefits for native fish on a regional broader Lower Murray scale. Weir pools can create unnatural inundation of connected wetlands when the river is held artificially high. Lowering the weir pool can be used to return wetlands to a more natural wetting/drying regime, while raising it can allow water to reach areas that would be difficult to water under most conditions. The strategy of raising and lowering the weirs should provide an environmental benefit compared to an artificially constant weir pool level. There are three components to the proposal: a) Locks 8 and 9 weir pool manipulation: this component is an operating rule change to increase the variability of the weir pool height at both Locks 8 and 9 within and between seasons with the objective to promote a range of environmental outcomes and potentially make a small evaporative water saving; b) Carrs, Capitts and Bunberoo Creeks system connectivity: this component involves environmental works to restoring high flows and hydro-dynamic diversity to creeks isolated by earlier works at Lock 9, by providing regulators and fishways at existing fixed weirs; and

		c) Frenchmans Creek fish passage: this component involves construction of a fish passage around the inlet regulator between Frenchmans Creek and Lake Victoria. The location of proposed modifications is shown in Figure 2-2 in and described in Section 2.3 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*	Yes
c)	Geographical location of the measure	The measure is in the lowland reaches of the River Murray and Darling Rivers in south west NSW. It is within the Riverland-Chowilla Floodplain hydrologic indicator site under the Murray Darling Basin Plan, which includes the Riverland Ramsar site and The Living Murray Chowilla Floodplain and Lindsay-Wallpolla Islands icon site. See Section 2.1 and Figure 2-1 and 2-2 in **Attachment A.**
d)	Spatial data describing the inundation extent associated with the operation of the measure	*This measure will generate inundation associated with the weir pool raising and lowering at Locks 8 and 9, and through the provision of flows along the Cars, Capitts, and Bunberoo Creeks system, both of which are described in section 7.4 of **Attachment A**.* The area of inundation associated with the operation of the Lock 8 raising, Lock 9 raising and CCB works have been added to other necessarily concurrently operated works measures (Mulcra and Wallpolla Island works) for scoring in the ecological elements method. As such the ecological elements scoring for these projects has been accounted for through the Mulcra and Wallpolla Island scores. The lock 8 & 9 raising areas were generated by hydrodynamic modelling undertaken by NSW and the CCB area was generating by digitising a figure in the appendix of the phase two business case provided by NSW. **Project** — **Total Inundated Area (Ha)** Lock 8 raising — 1236 Lock 9 raising — 2994 Carrs, Capitts & Bunberoo — 46
e)	Representation of the measure in the MDBA modelling framework	The MDBA has undertaken hydraulic modelling of weir pool inundation for Locks 8 and 9. It is anticipated that modelling of the measure by the MDBA will be based on this work.

<table>
<tr>
<td>f)</td>
<td>Representation of the project in the MDBA assessment framework</td>
<td>

Level-volume-area relationship

Additional inundation due to raising Lock 8 has been captured in the model as a part of implementing Mulcra works. There are three wetlands represented separately to model additional inundation including NSW Retention, Vic Retention and Lock 8 Wetland. The relationships are already described in the Notification Imperfection Register (NIR) for Mulcra Island.

For Lock 9 raising, no specific wetlands is modelled given its small impact on increased inundation area. However, additional inundation is included for the CCB system for scoring calculation which is presented in section 8d) *Spatial data describing the inundation extent associated with the operation of the measure*.

Interaction between river flows and site inflow

In- and outflows from Lock 8 Wetland are described using inlet capacity depending on lake levels as below.

$$Inflow = \max\left(0, capacity\sqrt{level\ at\ Lock\ 8 - Level\ at\ lake}\right)$$

If level at Lock 8 > level at lake

$$Outflow = \max\left(0, capacity\sqrt{level\ at\ lake - Level\ at\ Lock\ 8}\right)$$

If level at Lock 8 < level at lake

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The inlet capacity is described at Table 7 in the Mulcra NIR.

Flows to the other two retention areas are implemented using special codes 209 and 205. The special codes are designed to bring the retention areas to an equilibrium status with Lock 8 for NSW Retention and Potterwalkagee weir pool for Vic Retention.

Surface water loss relationships

A standard evaporation loss is applied by MSM-Bigmod with evaporation and rainfall calculated using monthly data from the Lake Victoria climate station and a pan evaporation factor of 0.660.

</td>
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<tr>
<td>g)</td>
<td>Representation of each operating strategy in the MDBA modelling framework.</td>
<td>

The operating strategies proposed for weir pool manipulation are based on the trials conducted to date, and a generalised flow regime are described in section 9.2 of **Attachment A**.

Modelling of the measure by the MDBA will be based on this work. This model representation of the operating strategy is summerised below.

<table>
<tr><th>Operating strategy</th><th>Frequency</th><th>Weir pool manipul-ation</th><th>Equivalent natural flow</th></tr>
<tr><td>Lock 8 raising</td><td>1 in 2 yrs</td><td>Up to 25.7 mAHD</td><td>20,000 ML/d</td></tr>
<tr><td>Lock 9 raising</td><td>1 in 2 yrs</td><td>Up to 27.7 mAHD</td><td>20,000 ML/d</td></tr>
</table>

</td>
</tr>
</table>

Attachments:

A	NSW DPI Water, August 2015	Business Case for SDL offsets in the Lower Murray NSW: Locks 8 and 9 weir pool manipulation Carrs, Capitts, and Bunberoo Creeks connectivity Frenchmans Creek fish passage

Department of Primary Industries
Water

Business case for SDL offsets in the Lower Murray NSW:

Locks 8 and 9 weir pool manipulation
Carrs, Capitts and Bunberoo Creeks connectivity
Frenchmans Creek fish passage

Final business case

August 2015

Document review and authorisation

Doc. Version	Final/Draft	Date	Authors	Reviewed by	Quality check	Release approved by	Issued to	Copies
1 0	Draft	30/03/15	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1e
2 0	Draft	9/04/15	[redacted]		[redacted]	[redacted]	[redacted] - for distribution to SC members	1e
3 0	Final draft	17/04/15	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1e
4 0	Final draft v2	4/06/15	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	1e

Notes: * Ecological Associates ** Alluvium

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More information

www.dpi.nsw.gov.au

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This report has been prepared by RMCG, Alluvium and Ecological Associates.

Front cover: Bunberoo Creek (James Val, NSW OEH)

[Insert Reference number]

Contents

Abbreviations

AHD	Australian Height Datum (m)
Basin Plan	The Murray-Darling Basin Plan adopted by the Commonwealth Minister under section 44 of the *Water Act 2007* (Cth) on 22nd November 2012.
CAMBA	China Australia Migratory Bird Agreement
CCB	Carrs, Capitts and Bunberoo Creeks system: an interconnected group of floodplain waterways isolated from the main Murray channel in the 1920s by fixed crest weirs on the Lock 9 weir pool.
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
DELWP	Victorian Department of Environment, Land, Water and Planning
EPBC	Environment Protection and Biodiversity Conservation Act (1999)
EVC	Ecological Vegetation Class
GST	Goods and Services Tax
Guidelines	Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases
ISO	International Standards Organisation
JAMBA	Japan Australia Migratory Bird Agreement
Left / right bank	The convention used to describe the banks of a creek or river channel, assuming looking downstream in the direction of the water flow.
MDBA	Murray-Darling Basin Authority
MDBA OAG	Murray Darling Basin Authority Operational Advisory Group
MWWG	Murray Wetlands Working Group
MER	Monitoring, evaluation and reporting
NOW	New South Wales DPI Water
ROKAMBA	Republic of Korea Australia Migratory Bird Agreement
SDL	Sustainable Diversion Limit
SDLAAC	Sustainable Diversion Limit Adjustment Assessment Committee
SEWPAC	Department of Environment, Water, Population and Communities
TLM	The Living Murray

Executive Summary

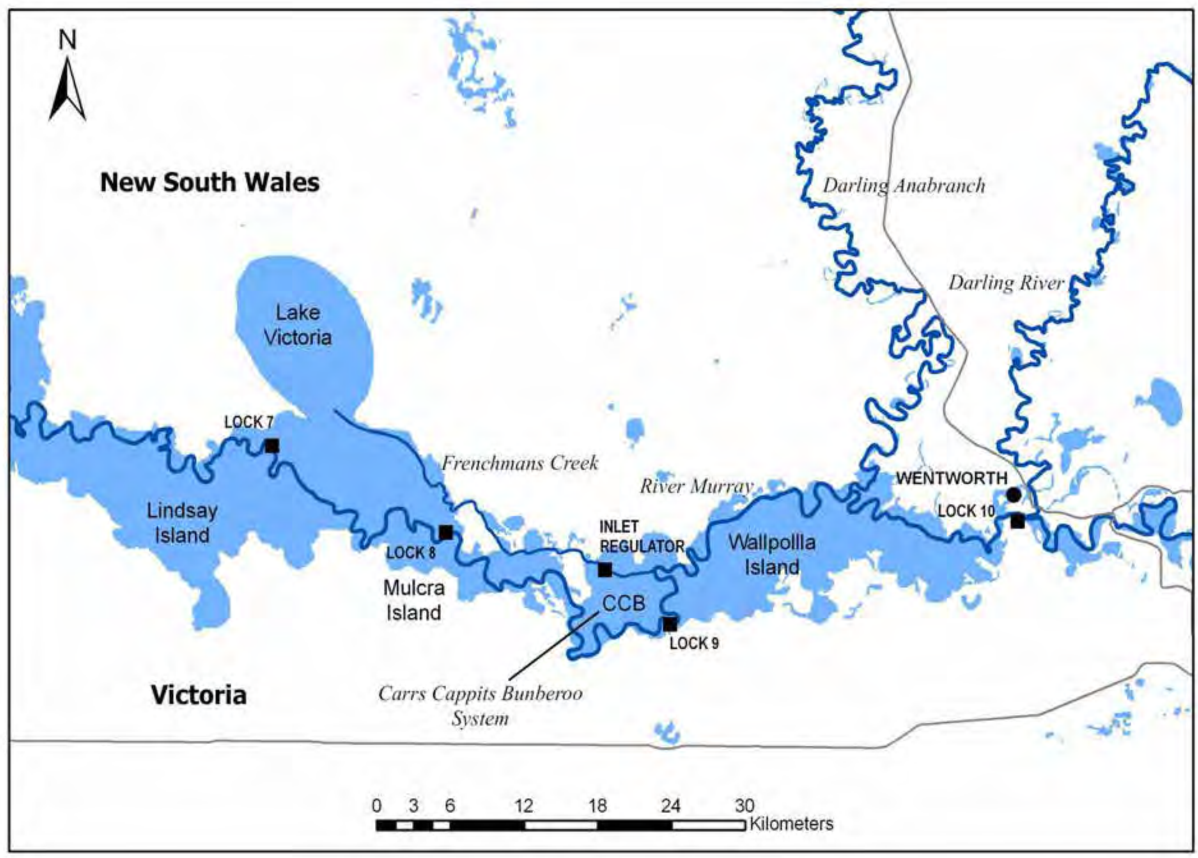
This business case proposes an integrated package of works to restore and enhance river habitat in the Lower Murray region of New South Wales (NSW). The works will generate significant environmental benefits that will be additional to those assumed in the benchmark model in the Basin Plan whilst using less water. The works proposed are simple and robust with low risk. The proposal is therefore a strong candidate for the Sustainable Diversion Limit (SDL) adjustment program as a supply measure. For a relatively small investment on the NSW floodplain, further value will be added to the investment already committed to environmental water projects in the Lower Murray.

ES1. The location

The program area is in the lowland reaches of the River Murray and Darling Rivers in south west NSW. The project is within the Riverland-Chowilla Floodplain hydrologic indicator site under the Murray Darling Basin Plan, which includes the Riverland Ramsar site and The Living Murray (TLM) Chowilla Floodplain and Lindsay-Wallpolla Islands icon site (MDBA 2012a).

There are significant synergies between the proposed works and parallel projects at regional sites under the The Living Murray (TLM) and other SDL initiatives. However, the benefits and outcomes assessed under this initiative are separate from the outcomes sought at these other locations.

Figure ES-1-1: Project location – Locks 8 and 9 and Lake Victoria



ES2. The proposal

The proposal covers three main components:

- **Component 1: Locks 8 and 9 weir pool manipulation.** This operating rule change would increase the variability of the weir pool height at both Locks 8 and 9 within and between seasons. The objective is to promote a broader riparian and littoral zone of macrophytes which will increase productivity and habitat quality, promote habitat use by aquatic fauna and waterbirds as well as fish growth and reproduction. An option of holding the weir pool at a lower height over summer also reduces water losses from evaporation. This project builds on the enhanced connections now possible along the River Murray reach from Lock 1 to Lock 15.

  Trials over the last three years have proven the operational and risk profile of the proposal. There are current design limits to the extent of surcharge and drawdown achievable which will be addressed under this project via capital works and consideration of the functionality of existing fishways on Locks 8 and 9 in operational strategies.

- **Component 2: Carrs, Capitts and Bunberoo Creeks system connectivity (CCB Creeks).** This environmental works measure involves restoring high flows and hydro-dynamic diversity to creeks isolated by earlier works at Lock 9, by providing regulators and fishways at existing fixed weirs. The project will increase the diversity and quality of aquatic habitat, promote fish populations by providing regionally important spawning and nursery areas and support bird breeding events through habitat and food provision.

  Much of the land affected by the CCB Creek project is traditional Tar-Ru lands. Phase 1 of this project involved early consultation with Tar-Ru Lands Aboriginal Traditional Owners who are providing advice on the impending Tar-Ru Lands Transfer. A Tar-Ru Lands Board of Management will be established under the Barkandji Native Title Group Aboriginal Corporation who has been nominated to take ownership of the Tar-Ru Lands.

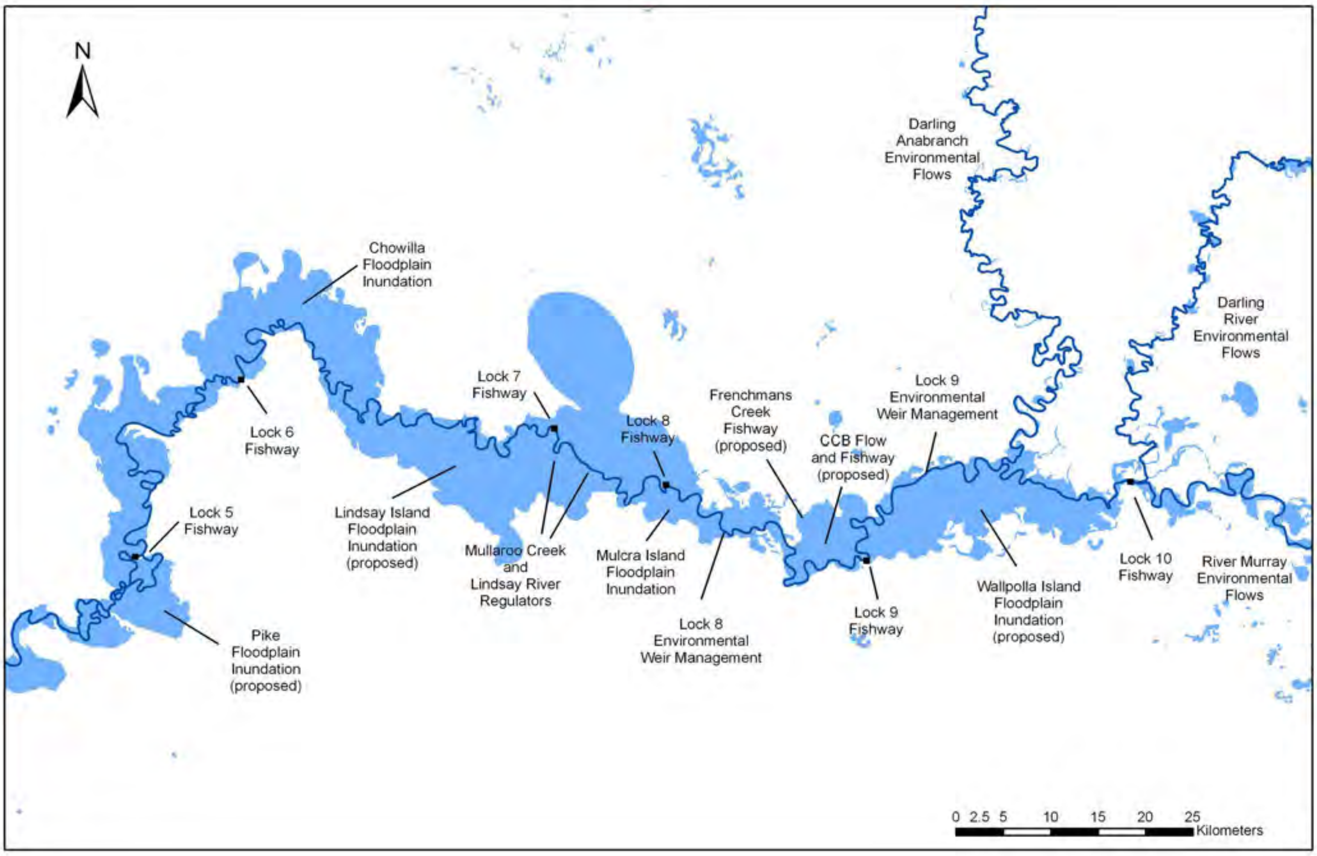
- **Component 3: Frenchmans Creek fish passage.** This proposal involves the construction of a fish passage around the inlet regulator between Frenchmans Creek and Lake Victoria. The inlet regulator is one of the last major barriers to fish passage along the River Murray and blocks fish passage upstream from Lake Victoria which is an important breeding site for native fish species. The fish passage will promote connectivity between breeding sites, feeding grounds and migratory routes along the River Murray and so generate benefits at a regional scale.

Taken together the suite of measures provide a rare opportunity to restore habitat for native fish as the pre-existing creek system has the characteristics required to support all stages of fish recruitment, spawning and self-supporting mature life cycles for Murray cod and golden perch.

The investment will also provide opportunities to support the engagement of local Indigenous groups in land and water management to meet cultural heritage objectives.

There are significant interactions between the proposed works and parallel projects at regional sites under TLM and proposed SDL initiatives. The location of the three project components in relation to these other initiatives is shown in Figure ES-2. For a relatively small investment on the NSW floodplain the beneficial outcomes from existing TLM investment in the Lower Murray will be enhanced.

Figure ES-2: Funded environmental water project in the Lower Murray



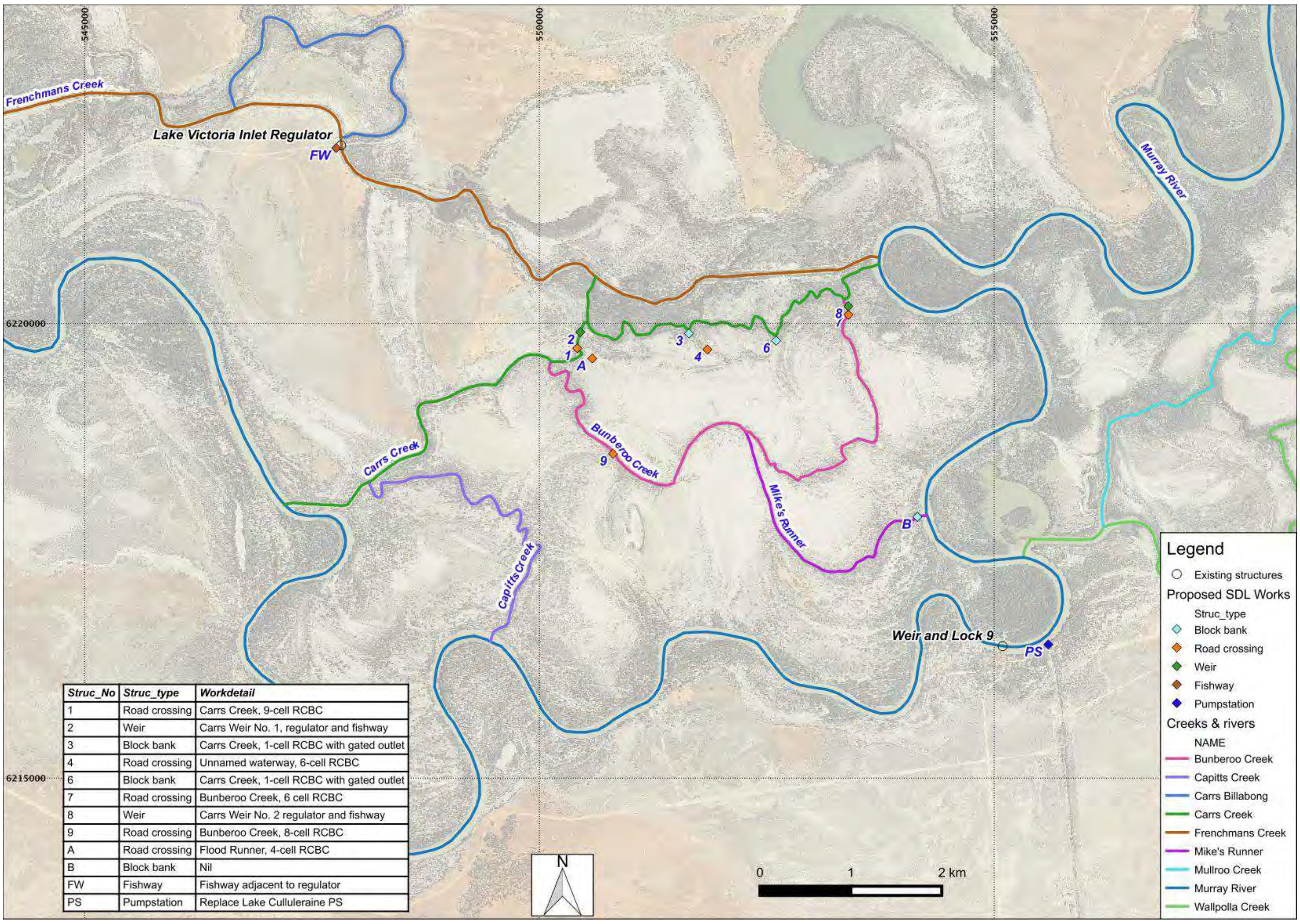
ES.3 Works and costs

The works required are simple and robust:

- Weir pool manipulation: this is an 'operating rule change' so there will be limited capital costs incurred. The NSW DPI Water and MDBA have run joint trials over the last three years testing the operational issues and outcomes of the approach so they have good evidence on all aspects of the proposal. The project includes relocation and replacement of the Millewa pump station at Lake Cullulleraine (in Victoria) used for bulk water supply and other minor works that will include construction of several low level banks and crossings to better manage small areas of inundation in the vicinity of Lock 9. These works involve a capital construction cost of [redacted].
- CCB Creeks works: this involves standard engineering works to provide regulators and fish passage on all current weirs and blockages. The works will involve capital construction of [redacted] including detailed design, planning and contingency. There will be limited call on the environmental water as any additional flows down the creeks will be largely offset by reductions in flows over Lock 9.
- Frenchmans Creek fishpassage: a vertical slot fishway is proposed because this is a low risk, well proven design and will involve a total project cost of [redacted]. However, further work is required to validate the detail of the approach, given the characteristics of the site with a highly variable head to tail water distance.
- The three components combined gives an overall capital construction cost of up to $28.6 million including appropriate contingency allowance and project management costs, including commissioning.

The location of each element of the works package is shown in Figure ES-3.

Figure ES-3: Location of the works package for the Lower Murray NSW project
[Source: RMCG using imagery from Victorian Government]



Struc_No	Struc_type	Workdetail
1	Road crossing	Carrs Creek, 9-cell RCBC
2	Weir	Carrs Weir No. 1, regulator and fishway
3	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
4	Road crossing	Unnamed waterway, 6-cell RCBC
6	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
7	Road crossing	Bunberoo Creek, 6 cell RCBC
8	Weir	Carrs Weir No. 2 regulator and fishway
9	Road crossing	Bunberoo Creek, 8-cell RCBC
A	Road crossing	Flood Runner, 4-cell RCBC
B	Block bank	Nil
FW	Fishway	Fishway adjacent to regulator
PS	Pumpstation	Replace Lake Cullulleraine PS

In summary, the proposal includes the following works:

Component 1: Locks 8 and 9 weir pool manipulation

- Relocation and replacement of the Millewa pump station at Lake Cullulleraine (in Victoria)
- Several low level banks and crossing near Lock 9

Component 2: Carrs Capitts Bunberoo Creeks connectivity

- Replacement of Carrs 1 and 2 fixed weirs with new structures encompassing regulators with overshot gates and vertical slot fishways
- Two block banks requiring installation of gated reinforced concrete box culverts (RCBCs)
- Five road crossings requiring RCBCs to provide flow continuity and maintain vehicle access

Component 3: Frenchmans Creek fish passage

- A vertical slot fishway adjacent to the inlet regulator on Frenchmans Creek.

ES.4 Risk management

A rigorous risk management assessment was completed that identified the following priority issues and effective mitigation measures:

- Construction: There should be limited risks from construction as:
  - The Locks 8 and 9 weir pool management initiative is an operating rule change with few associated works. Existing fishways will need to be monitored to ensure their functionality is not being compromised.
  - Many of the sites along the CCB and Frenchmans Creeks are sensitive in terms of cultural heritage significance. There has been good engagement with the Barkandji Traditional owners and the Tar Ru Lands Board of Management who are supportive of the project proposals. A full survey will be completed and protocols observed to minimise impacts.
  - The CCB Creeks works are standard engineering structures within land of mixed tenure. This includes land owned and managed by the MDBA/SA Water and land that is currently held by the Minister administering the National Parks and Wildlife Act 1974 and due to be transferred to the Barkandji Native Title Group Aboriginal Corporation. Contingency has been included to account for risks of inclement weather and flooding
  - The Frenchmans Creek fish passage has a small footprint within an area already owned and managed by SA Water
- Operation: This project involves the provision of enabling infrastructure to support environmental objectives. Flexibility is built into the project through the development of operating plans to optimise outcomes with minimal third party impacts.
  - The main adverse ecological risk is that the various works promote pest fish recruitment such as carp. There are few effective mitigation options but the risk is acceptable given the significant benefits for native fish and bird species
  - The operational limits of existing fishways at Locks 8 and 9 require validation and monitoring their funtionality will be included in the operational plan.
  - Through ongoing trialling and monitoring, weir pool manipulation scenarios will be developed that will balance the ecological requirements of macrophytes in the littoral zone and connected wetlands, floodplain vegetation communities and fish
  - The lower weir pool level at Lock 9 may impact on the effectiveness of the pump off-take operated by Lower Murray Water as a bulk water supply to the Millewa waterworks district and irrigators at Lake Cullulleraine. Works would be required to relocate this off-take if the full potential of the weir pool manipulation is to be exploited
  - The risks around the functional effectiveness of the proposed fishway for Frenchmans Creek will be managed through the proposed detailed design and staged commissioning process, as well as the system operating and maintenance procedures adopted by SA Water.
- Design and development:
  - The governance of the project is well established (Section ES.5) and provides confidence in the effective development and implementation of the design and construction program.
  - This business case is based on indicative concept designs. The business case has costed the detailed design and supporting investigations still required to firm up a ‘shovel-ready’ project.
  - Several supporting investigations are in the process of being commissioned to generate the required additional evidence to validate these proposals and these include: collection of more

detailed hydraulic information for the CCB project component (including an on-ground survey of the creeks including bathymetry), physical modelling of flows at the Frenchmans Creek inlet regulator to assess the optimum location of the fishway entrance, and geotechnical and cultural heritage surveys in proximity to the proposed worksites.

ES5. Governance

Strong existing governance arrangements will ensure effective project delivery:

- The NSW DPI Water is the project proponent.
- Locks 8 and 9: The weir pool management initiative is co-ordinated through an MDBA Operational Advisory Group with representatives from all relevant agencies and interested parties. This group meets on an as-needs basis under the auspices of the *Lindsay Mulcra Wallpolla Operations Group*, currently chaired by the Mallee CMA.
- CCB Creeks and Frenchmans Creek works: The MDBA is the owner and SA Water the manager of the relevant assets. These partners have a proven track-record of effective project development and implementation. SA Water would take responsibility for managing the construction and operation of any new assets.

1 Introduction

1.1 Overview

This business case for the *SDL offsets in the Lower Murray NSW* project has been developed in accordance with the Phase 2 Assessment Guidelines for Supply and Constraint Measure Business Cases (the Guidelines). This project falls within two categories in the guidelines: an *environmental works and measures at point locations* and an *operating rule change*.

The project area is in the lowland reaches of the River Murray and Darling Rivers between Locks 8 and 9. It includes environmental assets associated with Lake Victoria and Frenchmans Creek, the Carrs, Capitts and Bunberoo (CCB) Creeks systems in NSW, and the Mulcra and Wallpolla Island areas on the Victorian floodplain. The project area forms part of the Chowilla Floodplain ad Lindsay-Wallpolla Islands icon site, identified under The Living Murray initiative (TLM).

An integrated package of works is proposed including operating rule changes for Locks 8 and 9 weir pool manipulation and the installation of regulators and fishways on existing fixed crest weirs to restore flows, connectivity and hydrodynamic diversity in the CCB Creeks system. In response to feedback on the project feasibility proposal the scope was expanded to include the construction of a fishway at the Frenchmans Creek inlet regulator to restore fish passage between Lake Victoria and the River Murray.

The project will be managed through collaboration between all relevant stakeholders in NSW, SA and Victoria to deliver ecological outcomes across considerable reaches of the River Murray floodplain. The project will be managed in conjunction with proposed changes in river operations and existing environmental infrastructure (e.g. TLM works at Mulcra Island) to deliver environmental outcomes set under the Basin Plan, using less water.

1.2 Eligibility

The works proposed for the *SDL offsets in the Lower Murray NSW* project meet the eligibility criteria for Commonwealth supply measure funding as a ‘new measure’. Firstly, the projects meet the definition of a 'supply measure' under the Basin Plan as they are additional to the measures included in the benchmark conditions of development under clause 7.02 of the Plan. Secondly, the proposals are not ‘pre-existing’ Commonwealth funded projects, and have not been approved for funding by another organisation, either in part or in full, other than through financial support to develop this business case.

Thirdly, the operation of the measures will:

- 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;
- provide equivalent environmental outcomes with a lower volume of held environmental water than would otherwise be required to be achieved;
- have no detrimental impacts on reliability of supply of water to holders of water access rights that are not offset or negated; and
- be designed, implemented and operational by 30 June 2024.

This business case demonstrates how each eligibility requirement in the Phase 2 SDLAAC Guidelines is met. However, the ultimate outcomes of the proposal will depend on the modelling of different combinations of SDL offset proposals to be completed in 2015 by the Murray-Darling Basin Authority.

2 Project details

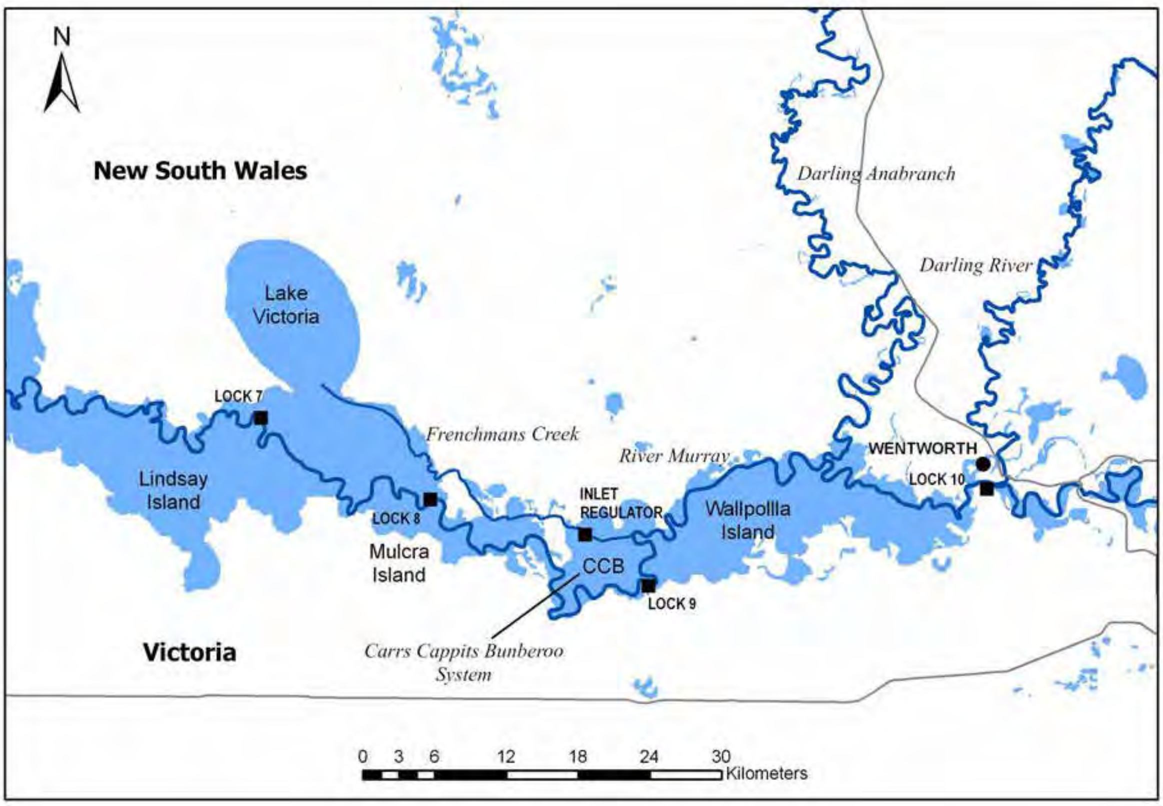
2.1 Locality

The proposal provides direct benefit to the environmental assets associated with two Surface Water Resource Management Units, namelythe NSW Murray and Lower Darling (SW8), Victorian Murray (SW2).

The project area is in the lowland reaches of the River Murray and Darling Rivers. The River Murray flows mainly from east to west through a broad valley up to 10 km wide (Walker & Thoms 1993). The Darling River and its anabranch flow towards this area from the north east, joining the River Murray at Wentworth.

The proposal brings ecological benefits to environmental assets associated with the River Murray near Lake Victoria including Lock 9, Lock 8, Frenchmans Creek, Mulcra Island, Wallpolla Island and the Carrs, Capitts and Bunberoo (CCB) Creeks system (Figure 2-1). A package of works in addition to weir pool manipulation on Locks 8 and 9 has been recommended for these floodplain areas as part of this proposal.

Figure 2-1: Project area – Lower Murray floodplain downstream of Wentworth, NSW



The project is within the Riverland-Chowilla Floodplain hydrologic indicator site under the Murray Darling Basin Plan, which includes the Riverland Ramsar site and The Living Murray (TLM) Chowilla Floodplain and Lindsay-Wallpolla Islands icon site (MDBA 2012a).

The floodplain features a range of hydrological environments that contribute to the diversity of habitats present and the species they support. The main hydrological environments are permanently inundated wetlands, permanent and temporary watercourses, intermittently flooded wetlands, river red gum and black box forests and woodlands and alluvial plains supporting chenopod shrublands and grasses. Each of these zones is associated with particular soil types, groundwater conditions and flooding histories.

The majority of the New South Wales floodplain is privately owned and managed for agricultural production, recreation and to some extent, for conservation. Significant Crown land areas in the CCB Creeks area are vested with the National Parks and Wildlife Minister (comprising the former Moorna, Wangumma and Lake Victoria State Forest areas) for transfer to the Barkandji traditional owners. These areas comprise parts of the Tar-Ru Lands. Although Lake Victoria lies in New South Wales, its associated assets are owned by the Murray-Darling Basin Authority (MDBA) and operated by SA Water as the constructing authority.

Public land areas on the Victorian floodplain between Lock 10 and Lock 7 are managed for conservation and recreation. The Murray-Sunset National Park encompasses most of Wallpolla Island and Mulcra Island. Other floodplain areas include the proposed River Murray Park and leasehold and freehold areas. Freehold land includes Kulnine, Neds Corner and Kerra Stations, making up a considerable proportion of land between Locks 8 and 9.

The project exists within the semi-arid zone of Victoria and New South Wales. The climate is hot and dry, with an average annual rainfall of 270 mm in Mildura. Average maximum temperatures are around 32°C in summer and 16°C in winter, with high evaporation rates throughout the year. The River Murray therefore represents an important source of water for the floodplain ecosystem (MDBA 2012b).

2.2 Significance

The project is located within a high conservation floodplain environment that has a relatively high diversity of terrestrial and aquatic habitats (MDBC 2006). The Riverland-Chowilla Floodplain anabranch environments support significant populations of native fish, including Murray cod and golden perch (Zampatti et. al 2008; Newall et al. 2009). Reinstating flows and fish passage into the CCB Creeks system aims to create similar habitat and hydrodynamic characteristics to Mullaroo Creek (at Lindsay Island), an area supporting one of a few self-sustaining anabranch populations of Murray cod in the Lower Murray. The provision of fish passage between Lake Victoria and the River Murray, via Frenchmans Creek, will provide the critical linkage between a main recruitment site (for golden perch) and a significant length of improved habitat upstream. Large numbers of golden perch and bony herring are expected to migrate upstream from nursery habitats in Lake Victoria through the proposed fishway on the inlet regulator. These fish are expected to recolonise hundreds of kilometres of the River Murray and anabranch habitats, enhancing the regional population. In 2001 the *Sea to Hume Fish Passage* program identified the inlet regulator on Frenchmans Creek as one of the highest priority fish barriers requiring reconstruction to permit fish passage (MDBC 2008). The project also creates opportunities to enhance the outcomes of nearby environmental watering initiatives e.g. habitat for golden perch recruitment and migration triggered by environmental watering in the lower Darling system.

The area directly influenced by the proposed works includes three distinct aquatic environments within and adjacent to the Lake Victoria floodplain and Mulcra and Wallpolla Islands:

- Several floodplain wetlands and flood runners adjacent to the River Murray in New South Wales and within Wallpolla Island and Mulcra Island in Victoria. High value wetlands influenced by the project include The Bong (Wallpolla Island), Purda Billabong (off Frenchmans Creek), Lock 8 wetland (within NSW) and Thegoa Lagoon (adjacent to Lock 10 near the Darling River confluence).
- More than 200 km of riparian (littoral) zone along the River Murray, Frenchmans Creek and the lower reaches of the Great Darling Anabranch.

- The instream environment of the Carrs, Capitts and Bunberoo (CCB) Creeks systems (where approximately 12 km of dewatered habitat will be reinstated) and Frenchmans Creek, connecting Lake Victoria and the River Murray upstream of Lock 9.
- More than 1,000 hectares of high value and high quality Frenchmans Creek floodplain area.

Over 40 vegetation associations representing 340 plant species have been identified in the broader Riverland-Chowilla Floodplain hydrologic indicator site (MDBC 2006). The diverse range of habitats supports a total of 179 bird species (including 63 wetland-dependent species), 17 mammal species, 9 species of frog and 16 species of fish (Newall et al. 2009).

More than 20,000 waterbird individuals have been recorded at the indicator site, including freckled duck (*Stictonetta naevosa*), red-necked avocet (*Recurvirostra novaehollandiae*) and red-kneed dotterel (*Erythrogonys cinctus*), which represents more than 1% of their estimated global population (Carpenter 1990; Newall et al. 2009). The area provides critical habitat for both nomadic and migratory waterbirds during times of drought in central and eastern Australia, including being stop-over habitat for migratory species listed under international agreements (JAMBA, CAMBA, ROKAMBA) (MDBA 2012a).

2.3 Proposed works package

The purpose of the proposed operational measure and package of works is to deliver benefits for native fish on a regional and broader Lower Murray scale. The combination of works and the weir pool manipulation will provide intermittent inundation and exposure of wetlands, macrophyte beds and floodplain vegetation, as well as restore fish passage, fast-flowing habitat reaches and connectivity within the CCB Creeks system. The provision of fish passage from Lake Victoria back up into the River Murray will provide benefits for native fish populations throughout the Lower Murray region.

The advantage of the proposed approach is its simplicity and minimal operational risks.

A short description of the operational measure and the package of works is provided below with further detail provided in Section 11 and costing in Section 13. The supply measure project has three components.

2.3.1 Component 1: Locks 8 and 9 weir pool manipulation

The weir pool manipulation proposal is an "*Operating rule change*". It involves confirming an amended protocol for weir pool management that assumes increased variability in weir pool height within and between seasons. The amended rules would establish agreed triggers and scenarios that would specify when weir pools are raised or lowered to meet environmental outcomes, within river operating constraints and risk mitigation measures.

The primary aim of this measure is to meet the water requirements of a small but important component of the ecosystem: the littoral and riparian zone of wetlands and watercourses, and flowing water habitat. The objectives are to promote a broader zone of macrophytes, to increase productivity and habitat quality, to promote habitat use by aquatic fauna and waterbirds and to promote fish growth and reproduction.

The initiative involves few costs as the rule change can be implemented largely as an administrative decision. However the project includes the relocation and replacement of the Lower Murray Water Millewa bulk water pump station at Lake Cullulleraine (in Victoria) and other minor works that will include construction of several low level banks and crossings in order to better manage small areas of inundation in the vicinity of Lock 9.

The project generates minimal socio-economic impacts as few water users reliant on the weir pools will be impacted. Operators and river managers will have the flexibility to adapt the temporal pattern of the weir pool levels to match the multi-objectives of river operations and ecological restoration, a process which is already undertaken and has well-established protocols and responsibilities.

The proposed changes have been proof tested through a series of pilot trials over three years (2013 to 2015). This has allowed the practical feasibility of the proposals to be explored, the potential impacts to be confirmed and interested parties to adjust their activities.

The operating strategy will be determined through adaptive management and be refined to ensure that potential negative impacts to fish communities will be managed through timing of operations. The proposed weir pool manipulation strategy will also be developed in conjunction with Mulcra Island TLM watering and the proposed Wallpolla Island supply measure works put forward by the Victorian Government in 2014.

2.3.2 Component 2: Carrs, Capitts and Bunberoo Creeks system connectivity

The CCB Creeks investment represents an "*Environmental works and measure at a point location"*. This involves the provision of infrastructure measures to deliver environmental outcomes which will allow the same outcomes to be achieved with a lower volume of held environmental water.

The underlying proposal for the CCB Creeks system is straightforward. Flows in the creeks were blocked as part of the construction of Lock 9, to prevent flows from the weir pool and Frenchmans Creek. As a result the creeks have been depleted of water. This proposal provides the ability to restore flows along the creeks past the existing Carrs 1 and 2 fixed crest weirs and related block banks.

The works include:

- Replacement of existing weirs with regulators to restore flows, connectivity and hydrodynamic diversity
- Culverts on block banks to provide flows and connectivity (and maintain vehicle access)
- Fish passages on weirs and regulators to promote connectivity

The project will increase the diversity and quality of aquatic habitat, promote fish populations by providing regionally important spawning and nursery areas and support bird breeding events through habitat and food provision. Almost all projected flows will remain within the existing creek channels so there will be few impacts on neighbouring properties in terms of access or use.

This component has been developed over several years by a local non government organisation, the Murray Darling Wetlands Working Group (MWWG), and is well founded in logic and preliminary designs.

2.3.3 Component 3: Frenchmans Creek fish passage

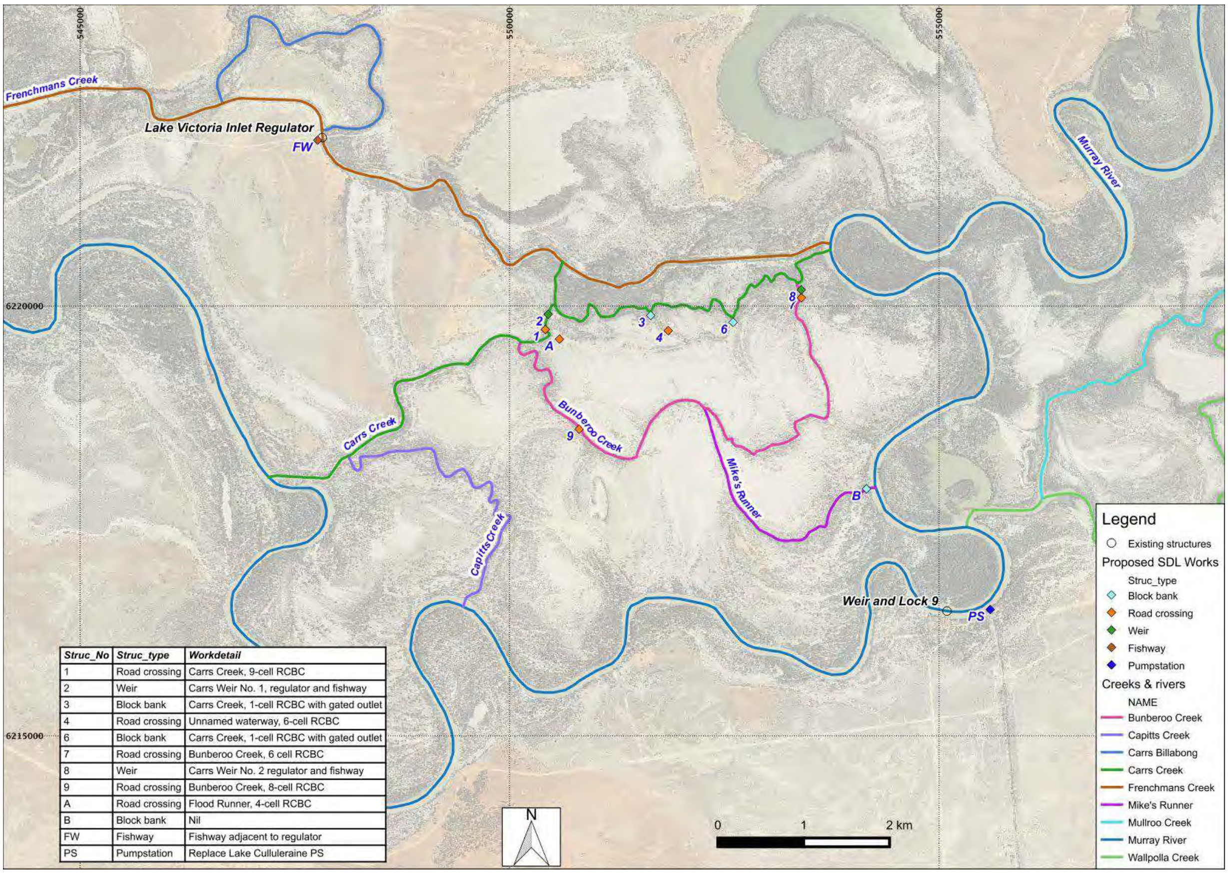
Frenchmans Creek is the main flow path from the River Murray to Lake Victoria. The lake is one of the major storages on the River Murray and is used, in particular, to ensure minimum passing flows to South Australia during the height of summer when there are constraints on supply from the River Murray itself. The Frenchmans Creek inlet regulator fully impedes fish passage upstream and the undershot gates cause significant turbulence and sheer stresses so that downstream passage for small fish and larvae is severely compromised. These effectively isolate over 1,000 hectares of high value Frenchmans Creek floodplain together with Lake Victoria itself, from the River Murray. The Lake Victoria inlet and outlet regulators are among the last major barriers to fish passage along the River Murray (Baumgartner et al. 2014).

This project involves drafting a feasibility concept design and costing for the provision of an appropriate, fit-for-purpose fish passage that will restore fish passage between Lake Victoria and the River Murray. Once again this is an "*Environmental works and measure at a point location".* The project also seeks confirmation of the benefits of this connectivity for regional fish populations.

The Frenchmans Creek inlet regulator site and related creeks are important locations for local Indigenous groups. There are therefore risks of disturbance to sensitive cultural heritage sites. However, the construction sites will be within the existing footprint of the inlet regulator and related roadway so there should be few impacts. The main project imperative will be to design and operate a highly functioning structure that fish will use.

The location of works to deliver ecological outcomes in the project area is shown in Figure 2-2.

Figure 2-2: Location of the works package for the Lower Murray NSW project
[Source: RMCG using imagery from Victorian Government]



Struc_No	Struc_type	Workdetail
1	Road crossing	Carrs Creek, 9-cell RCBC
2	Weir	Carrs Weir No. 1, regulator and fishway
3	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
4	Road crossing	Unnamed waterway, 6-cell RCBC
6	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
7	Road crossing	Bunberoo Creek, 6 cell RCBC
8	Weir	Carrs Weir No. 2 regulator and fishway
9	Road crossing	Bunberoo Creek, 8-cell RCBC
A	Road crossing	Flood Runner, 4-cell RCBC
B	Block bank	Nil
FW	Fishway	Fishway adjacent to regulator
PS	Pumpstation	Replace Lake Culluleraine PS

2.3.4 Overview of site hydrology

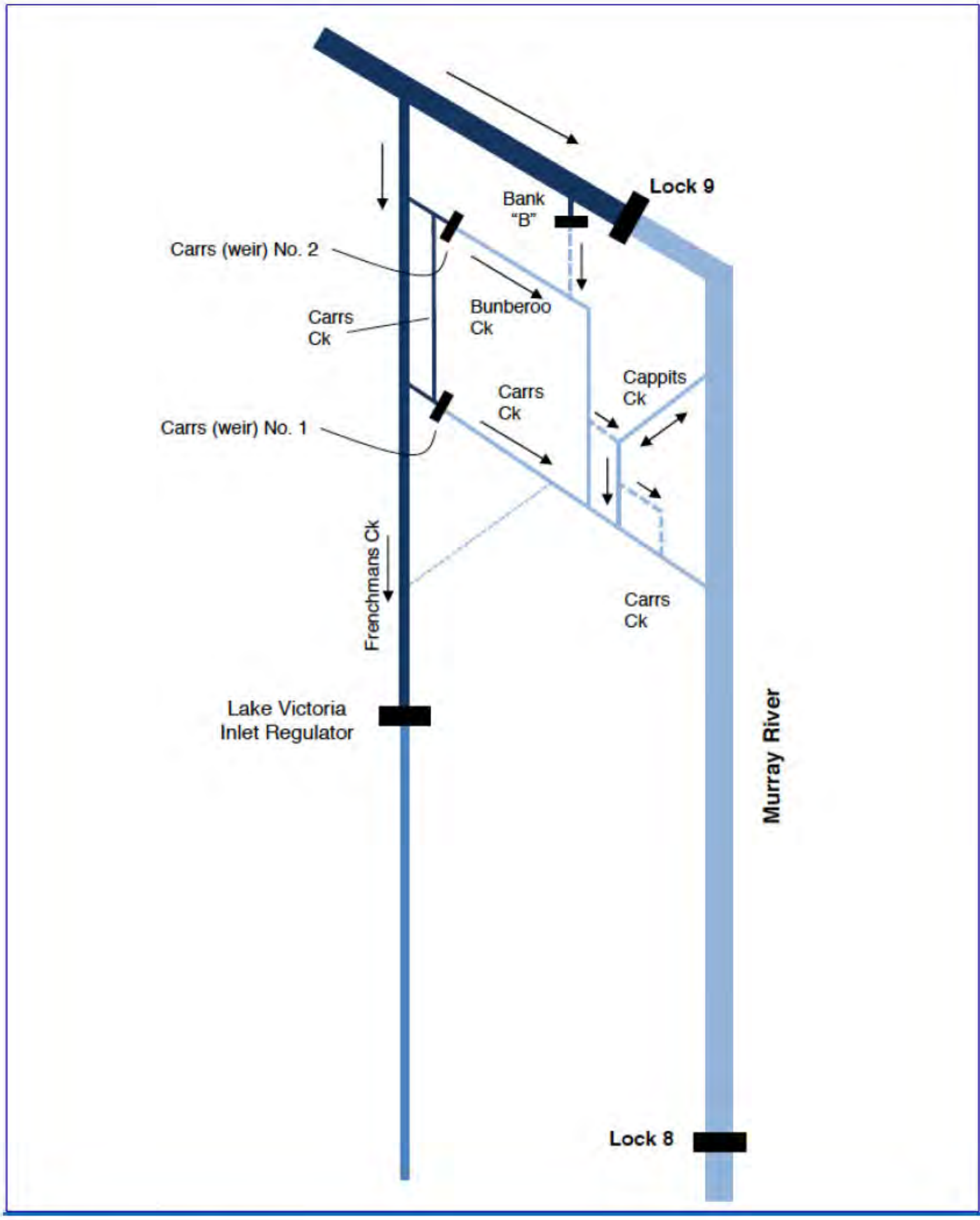
A description of the site hydrology is provided over the page and Figure 2-3 illustrates the interaction between the three project components: Lock 8 and Lock 9 weir pools, the CCB system and Frenchmans Creek inlet regulator.

Frenchmans Creek diverges from the River Murray upstream of Lock 9 which raises the river level to provide gravity feed to Lake Victoria, with flow controlled at the inlet regulator. The creek flows approximately parallel to the river in a channel that has been straightened and enclosed by levees to deliver water more efficiently. Regulated flow into Lake Victoria can often exceed the passing flow in the River Murray below Lock 9. Levees on the south side of Frenchmans Creek limit the spread of water to the floodplain.

The CCB Creeks system is a network of floodplain anabranches within the upstream part of the Lake Victoria Floodplain to the north of Lock 9. Block banks prevent water spilling to the creeks and wetlands from the Lock 9 weir pool in Frenchmans Creek and fixed crest weirs are located at the two major inlets at Carrs No. 1 and Carrs No. 2, while a block bank (B) is located on a higher level flood-runner that flows into Bunberoo Creek. The Lock 8 weir pool permanently inundates the lower reaches of the CCB system.

Figure 2-3: Schematic diagram of the three project components

The Lock 9 weir pool is shown in dark blue and the Lock 8 weir pool is shown in light blue. [Source: NSW Public Works - FCS 2013.]



2.4 Summary of costs and proposed schedule

2.4.1 Project costs

The estimated capital construction cost for the Lower Murray NSW supply measure project is in the order of $28.6M (GST exclusive). The main cost elements of the project are summarised in Table 2-1.

[redacted]

2.4.2 Project schedule

Table 2-2 provides a high-level program schedule for the project. The works will be fully operational prior to 2024.

Table 2-2: Project schedule

Stage	Year 1	Year 2	Year 3	Year 4
Business case development				
Planning and concept designs				
Detailed design phase				
Approvals				
Procurement				
Construction works				
Commissioning				

2.5 Proponent and proposed implementing entity

The NSW DPI Water is the project proponent on behalf of the New South Wales Government and has prepared this business case in consultation with SA Water, NSW National Parks and Wildlife Service, NSW Office of Environment and Heritage, Fisheries NSW, MWWG, MDBA and Victorian Government authorities, through funding from the Australian Government.

NSW DPI Water is the project owner and will have oversight responsibility for project implementation pending confirmation of construction funding. Further information regarding the proposed governance and project management arrangements for implementation is provided in Section 16. The assets would be owned by the MDBA and operated and maintained by the State Constructing Authority, SA Water River Murray Operations (RMO) Group, who are contracted by the MDBA to operate and maintain Locks 1 to 9, Lake Victoria works and the five Murray Mouth barrages.

3 Values of the site

3.1 Ecological values overview

Diverse hydrological environments are provided across the project area including permanently and intermittently inundated wetlands, permanent and temporary watercourses, river red gum forests, black box woodlands, lignum shrublands and alluvial plains supporting chenopods and grasses (Ecological Associates 2013). These areas perform important ecological functions and provide habitat that support many water-dependent communities and species, some of which are listed under Commonwealth and/or New South Wales legislation.

This section identifies important conservation values of the area based on a search of database records and recent surveys of Lindsay and Wallpolla Islands and the broader Riverland-Chowilla Floodplain hydrologic indicator site. This summary is representative of the entire region, but does not comprehensively review flora and fauna records and their conservation status in all three states. Species lists for flora and fauna and their conservation status are provided in Appendix 2.

3.2 Listed flora and fauna

3.2.1 Flora

The study area has a diverse flora and supports numerous plant species of conservation significance. A recent vegetation survey (Australian Ecosystems 2013) reported 228 indigenous plant species, of which 44 are floodplain species that are rare or threatened under the Victorian Advisory List of Threatened Plants (Appendix 2, Table A2-2). One species, *Eleocharis obicis*, is vulnerable in Victoria and listed vulnerable under the Commonwealth EPBC Act. Many of these species are found near to the project site e.g. Wallpolla Island supports 30 flora species of conservation significance (Ecological Assoc. 2014). Soda bush (*Neobassia proceriflora*), is endangered under the Victorian Advisory List of Threatened Plants and in Victoria is known only from Wallpolla Island and Lindsay Island (Ogyris 2013).

3.2.2 Fauna

There are 70 fauna species of conservation significance listed under international agreements, Commonwealth and state legislation within the broader Riverland-Chowilla Floodplain hydrologic indicator site (MDBA 2012a).

Fish

The anabranch environments of the study area are located within the broader Riverland-Chowilla Floodplain hydrologic indicator site, have been identified as supporting significant populations of native fish, including provision of valuable habitat for conservation significant Murray cod (Zampatti et al. 2008; Newall et al. 2009; Zampatti et al. 2011, NSW Public Works-FCS 2013).

The Frenchmans and CCB Creeks environments are predicted to contain threatened aquatic species listed as part of the Lowland Murray aquatic ecological community (as determined by the Fisheries Scientific Committee, NSW Department of Primary Industries). The listing of this aquatic ecological community provides all native fish and other aquatic animal life the status of endangered species. The community includes 23 native fish species and over 400 recorded native invertebrate species (NSW DPI 2007). This proposal contributes to some of the recovery actions for this ecological community. For example, removing barriers or installing fishways and allocating environmental flows.

The native fish of the River Murray are often considered in two groups: small-bodied species and large-bodied species. The smaller species tend to be wetland specialists, though many are also found in main river channels and many have a close relationship to aquatic vegetation beds. Larger bodied fish such as Murray cod have, in general, a preference for larger, strong flowing main river channels, especially where there is high quality snag habitat. The native catfish (*Tandanus tandanus*) is a larger species and spends time in deep channel habitat but occurs predominantly in wetlands during breeding seasons.

Most of the small-bodied native fish are common and widespread. Commonly occurring species in the study area include carp gudgeon, flathead gudgeon, unspecked hardyhead, Australian smelt, Murray-Darling rainbowfish and bony bream. Rare species include pygmy perch, Murray hardyhead, olive perchlet and purple-spotted gudgeon (Ellis and Suitor 2004, Reid et al. 2009; Gilligan, 2008).

Historically, Frenchmans Creek and Lake Victoria supported an important commercial fishery, largely based on golden perch, Murray cod, bony herring, freshwater catfish and silver perch. The fishery for Murray cod and golden perch was still active until the mid 1990s and peaked at approximately 20 tonnes of golden perch per annum. More recently, the large and medium-bodied native fish species (e.g. golden perch, Murray cod, silver perch and freshwater catfish) generally occur in low abundances in the region (Sharpe and Rehwinkel 2011). However, from fishway monitoring work, many golden perch and Murray cod move through the region from local and distant sources during a spring/summer flow event.

Twelve native fish species are encountered regularly in the study area and a further nine are known to occur within the hydrologic indicator site (Sharpe and Rehwinkel 2011; Reid et al. 2009; Ellis and Meredith 2005; Gilligan 2008; Ellis and Sharpe 2012; Henderson et al. 2013, Lloyd 2012) (Refer to Appendix 2, Table A2-3).

Fast-flowing habitat in Mullaroo Creek and Chowilla Creek support the only two known self-sustaining anabranch populations of Murray cod in the lower River Murray (Mallen-Cooper et al. 2008; Saddlier et al. 2008). The high quality of fish habitat in these creeks also contributes to healthy populations of golden perch, Australian smelt and freshwater catfish.

In the Lower Murray, the majority of golden perch spawning appears to take place upstream of Lake Victoria, in the River Murray channel and the Darling River above Menindee (ref?). This is significant because with large portions of flow being diverted at Lock 9, the majority of drifting larvae and downstream dispersing juveniles will be transported down Frenchmans Creek, through the inlet regulator and into Lake Victoria, and is supported by a highly productive Frenchmans Creek floodplain and Lake Victoria Lake system. At present the lake is acting as a ‘sink’ for native fish, with little passage out.

For this reason, Lake Victoria is an important and highly productive nursery habitat, particularly for golden perch and bony herring, with larvae drifting in from Murray and Darling rivers’ spawnings (Sharpe 2011). Floodplain lakes, such as Lake Victoria and the Menindee Lakes on the Darling River, are major recruitment sources, particularly for golden perch and there are subsequent major juvenile fish dispersal events and these fish recolonise hundreds of kilometres. The fish from Lake Victoria form an important regional source population.

In spring and summer, when many fish leave Lake Victoria and attempt to recolonise the Murray River; large aggregations of fish beneath the inlet structure are often observed and these are prone to significant mortality from anglers and birds. Species which accumulate include, young-of-the-year bony herring, adult and juvenile golden perch, Murray cod, unspecked hardyhead, Australian smelt, Murray Darling rainbowfish, carp gudgeons and non-native carp and goldfish.

The Frenchmans Creek and Lake Victoria area has largely acted as a terminal system where both the inlet and two outlet structures have severely limited fish movement. Fish accumulations are exacerbated because inflows to Frenchmans Creek can be much higher than flows in the Murray River which potentially attracts fish away from the mainstem fishways (Stuart et al. 2008; Baumgartner et al. 2010). Hence, there is an opportunity to restore the system to a flowing anabranch with fish passage at the three major regulating structures. The long-term ecological benefits of creating an anabranch system are likely to be self-sustaining native fish populations which acts as a recruitment source to enhance the broader regional fish population.

Flowing creek habitats (e.g. Carrs, Cappits, Bunberoo) are also important for regional fish ecology, with Murray cod and small-bodied fish targeting these habitats. Murray cod particularly favour fast-flowing reaches (>0.3 m/s) with high hydraulic complexity and hence restoring flows and connectivity among these habitats will enable native fish re-colonisation. Bunberoo Creek has potential to provide high quality fish habitat (Figure 3-1).

Figure 3-1: Bunberoo Creek [Source: James Val, NSW OEH]

Amphibians and reptiles

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs. Ten amphibians and reptiles of conservation significance have been recorded in the Riverland-Chowilla Floodplain indicator site (MDBA 2012a). This includes the Environmental Protection and Biodiversity Conservation (EPBC) Act-listed Southern Bell frog (*Litoria raniformis*) (known as growling grass frog in Victoria) (Figure 3-2) and striped legless lizard (*Delma impar*) (Ecological Assoc. 2014; MDBA 2012a). A recent survey by Biosis (2013) recorded 21 reptile species at Wallpolla Island and 28 reptiles have been reported on Lindsay Island, including five species of conservation significance (Appendix 2, Table A2-6). Six frog species occur at Lindsay Island including the growling grass frog (GHD 2014a). The Southern Bell frog was recorded at 5 out of 6 watered wetland sites in the Bunberoo Creek area following environmental watering in 2006 (Val et al. 2007). Known populations are present downstream of the project area which are supported by environmental watering events.

Figure 3-2: EPBC listed Southern Bell frog *(Litoria raniformis*) [Source: James Val, NSW OEH]

Birds

The study area has a highly diverse bird fauna with 196 bird species reported, of which 35 have conservation significance at the state and national level, and four are protected under international migratory bird agreements (Appendix 2. Table A2-4). Three are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth); e.g. regent parrot (*Polytelis anthopeplus monarchoides*) (Ecological Assoc. 2007; MDBA 2012b). A recent bird survey conducted in 2013 on Lindsay Island observed 93 species (GHD 2014a).

Wetlands provide habitat for dabbling, diving and filter feeding ducks, while small fish will provide prey for piscivorous waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Flooded woodland and lignum shrubland provide nesting sites for waterbirds including waterfowl and colonial nesting species. Broad areas of shallow flooding in alluvial plains and wetlands provide feeding areas for waterbirds, including migratory species which visit Lindsay Island in summer and early autumn.

Flooding promotes plant productivity and will increase the food resources for bush birds that depend on fruit, seeds, nectar and insects. Understorey complexity will increase the availability of vertebrate prey species such as lizards and will provide sheltering and nesting sites for bush birds.

Mammals

A recent survey by Biosis (2013) identified 22 mammal species in the local area (Wallpolla Island), while the broader Riverland-Chowilla Floodplain indicator site supports three mammals of conservation significance (MDBA 2012a).

The bat fauna of the study area is diverse, with nine species observed in the vicinity of the project area (Appendix 2, Table A2-5). The bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey while trees provide roosting habitat in bark, crevices and hollows.

The open plains and grassland provide habitat for kangaroo species while watercourses and wetlands provide habitat for water rat. Understorey vegetation, including lignum shrublands, is an important habitat component for Giles' planigale.

3.3 Aquatic environments

3.3.1 Overview of significant areas

This section describes the high values of the area that will benefit from watering under the project. Various aquatic environments exist across the project site, some of which are described below.

The *Lock 8 and Lock 9 weir pools* extend along the River Murray for 39 km and 63 km, respectively. The pools upstream and downstream of Lock 8 equalise at River Murray flows of 37,000 ML/day and at Lock 9 equalise at flows of 49,000 ML/day (MDBA 2010). Up to this point, the weirs are operated to maintain a stable water level upstream so that the natural variability in the water level is removed. This provides a stable water habitat similar to permanent wetland environments and provides conditions ideal for flora species that are adapted to permanent inundation (e.g. submerged aquatic plants such as *Myriophyllum* spp.) or prolonged exposure (e.g. grasses such as *Sporobolus mitchellii*) (Ecological Assoc. 2013). Large numbers of native fish migrate through the fishways at Locks 8 and 9 especially during a spring river rise (Stuart et al. 2008).

Wallpolla Island features persistently inundated wetland habitats including Wallpolla Creek, Horseshoe Lagoon and The Bong that provide reliable aquatic habitat and refuge from regional drought (Ecological Assoc. 2014). **Mulcra Island** includes the Potterwalkagee Creek, which has a perennial flow through part of its length due to Lock 8 (Ecological Assoc. 2013) and the Mulcra Horseshoe – a wetland with an intermittent water regime (Mallee CMA 2009).

Several floodplain wetlands also exist on the New South Wales side of the River Murray including Purda Billabong (north of Frenchmans Creek) and Thegoa Lagoon (further upstream near Lock 10) that will be watered through raising the Lock 9 weir pool. Other wetlands include Wombalano, Grand Junction and Six Mile Creek. The floodplain billabongs provide backwater habitats along the River Murray when river levels first begin to rise and then through flow environments at higher River Murray flows (Ecological Assoc. 2013). They provide valuable aquatic habitat for a range of species.

Anabranches dissecting the Lindsay–Wallpolla and Lake Victoria floodplains provide diverse aquatic habitats, including deep and shallow sections with varied flow velocities and both steep and sloping banks. Re-instating flows into the Carrs, Capitts and Bunberoo Creeks has high potential to restore hydrodynamic diversity including fast-flowing habitats (NSW Public Works FCS 2013). Dense stands of aquatic macrophytes are supported and significant amounts of instream woody debris are present. The diversity of habitats within anabranches has significant potential to support fish, aquatic invertebrates, frogs and birds, including some that are threatened or uncommon (MDBA 2012b).

Reinstating flows into the CCB Creeks can potentially provide the flow and habitat conditions which prevail in the nearby Mullaroo Creek (Sharpe and Rehwinkel 2011), noting that these conditions are otherwise absent from the rest of the system. Mullaroo Creek is considered to be an important spawning and nursery area for Murray cod in the lower River Murray (Saddlier et al. 2008). It supports one of the most significant populations of Murray cod in the lower River Murray and Victoria, exhibiting significantly better age structure and population size than in any other Victorian system (Saddlier et al. 2008; Sharpe et al. 2009). It is the robustness of the Mullaroo Creek population that makes it of particular importance to the sustainability of broader regional populations (Sharpe et al. 2009). A robust Murray cod population may also exist in Capitts Creek, but is yet to be confirmed by survey (Ellis and Sharpe 2012)

Frenchmans Creek and Lake Victoria hosts an important source population of larval, juvenile and adult golden perch that will be able to move upstream into the River Murray following the provision of fish passage at the inlet regulator on Frenchmans Creek along with a flow management plan to enhance fish passage.

3.3.2 Water dependent vegetation communities

A range of water dependent vegetation communities are present across the project area.

The weir manipulation component of the project will enable wetting and drying of shallow wetlands and the riparian zone along several watercourses including the River Murray and various floodplain flood runners. The delivery of environmental water to the Carrs, Capitts and Bunberoo Creeks will also result in wetting of the littoral zone along these waterways.

Vegetation communities have been mapped and classified differently on either side of the River Murray. In Victoria, Ecological Vegetation Classes (EVCs) are the standard vegetation classification unit, which groups vegetation occurring across biogeographic ranges within specific environmental niches. In New South Wales, vegetation is mapped according to Vegetation Classes (Keith 2004).

The vegetation communities within the inundation footprint and their conservation status (Victorian communities only) are identified in Table 3-1.

Table 3-1: Vegetation communities in the inundation area within the project area

State	Vegetation community	Conservation Status
Victoria	EVC 103 Riverine Chenopod Woodland	Depleted
	EVC 104 Lignum Swamp	Vulnerable
	EVC 106 Grassy Riverine Forest	Depleted
	EVC 806 Alluvial Plains Semi-arid Grassland	Vulnerable
	EVC 808 Lignum Shrubland	Least Concern
	EVC 810 Floodway Pond Herbland	Depleted
	EVC 811 Grassy Riverine Forest/Floodway Pond Herbland Complex	-
	EVC 813 Intermittent Swampy Woodland	Depleted
	EVC 818 Shrubby Riverine Woodland	Least Concern
	EVC 819 Spike-sedge Wetland	Vulnerable
	EVC 823 Lignum Swampy Woodland	Depleted
New South Wales	PCT 8 River Red Gum	-
	PCT 11 River Red Gum	-
	PCT 12 Shallow Marsh Wetland	-
	PCT 13 Black Box Lignum Woodland Wetland	-
	PCT 15 Black Box Open Woodland Wetland	-
	PCT 16 Black Box Open Woodland Wetland	-
	PCT 17 Lignum Shrubland Wetland	-
	PCT 41 River red Gun Open Woodland Wetland	-
	PCT 240 River Coolbah Tall Shrubland Wetland	-

Source: Victoria: DELWP 2015 website accessed 15/3/15 Bioregional Conservation Status list for each BioEVC. NSW Plant Community Types (PCT): Extracted from VIS Classification 20 May 2013.

3.3.3 Water regime classes

Water regime classes are a way of grouping vegetation based on their respective hydrological requirements. They provide a practical way of defining the water requirements needed to achieve the ecological objectives and targets of a project. Five water regime classes occur in the project's potential inundation area (as a result of weir pool manipulation), noting that EVC mapping does not cover waterways.

Table 3-2 outlines the estimated increase in area of inundation for Lock 8 for two illustrative weir height adjustments for two Murray River flow rates. Raising Lock 8 by a maximum of 1.0 m will mostly flood Red Gum Forest and Woodland (approximately 260 ha from a flow of 20,000 ML/d). Little additional vegetation is inundated at higher river flows because the weir and the regulator dominate floodplain inundation at Lock 8 (Ecological Assoc. 2013).

Table 3-2: Increase in area (hectares) of vegetation inundation from normal operating levels at Lock 8 weir (Source: Ecological Assoc. 2013)

Water regime class	10,000 ML/d		20,000 ML/d		50,000 ML/d
	25.1 m AHD (+0.5 m)	25.6 m AHD (+1.0 m)	25.1 m AHD (+0.5 m)	25.6 m AHD (+1.0 m)	Weir not operating
Low Intermittent Wetlands	26	40	27	41	51
Red Gum Forest or Woodland	132	252	134	264	345
Lignum shrubland	39	137	39	141	41
Black box woodland	19	51	21	58	60
Alluvial Plains	48	88	57	90	81
Total	**264**	**568**	**277**	**594**	**578**

Table 3-3 outlines the estimated increase in area of inundation for Lock 9 for one illustrative weir height adjustment for two Murray River flow rates. Raising Lock 9 by its maximum limit of 0.3 m will mostly flood Red Gum Forest and Woodland (up to approximately 240 ha from a flow of 20,000 ML/d). In contrast to Lock 8, weir raising during higher flows will substantially increase the area inundated for all water regime classes (more than three-fold).

Table 3-3: Increase in area (hectares) of vegetation inundation from normal operating levels at Lock 9 weir (Source: Ecological Assoc. 2013)

Water regime class	10,000 ML/d	20,000 ML/d	50,000 ML/d
	27.7 m AHD (+0.3 m)	27.7 m AHD (+0.3 m)	Weir not operating
Low intermittent wetlands	30	64	138
Red gum forest or woodland	85	237	625
Lignum shrubland	18	86	235
Black box woodland	18	101	248
Alluvial Plains	11	56	232
Total	**163**	**544**	**1,478**

In summary, weir pool manipulation will provide the ability to inundate approximately 500 ha of river red gum Forest or Woodland, 150 ha of black box woodland and 200 ha of lignum shrubland. This is expected to improve the health of the canopy trees and the diversity of flora within these vegetation communities. Water regime classes have been mapped within the floodplain areas between Locks 9 and 10 (Figure 3-3) and Locks 8 and 9 (Figure 3-4).

Figure 3-3: Water regime classes of the Lower Murray SDL project area between Locks 9 and 10
[Source: Spatial data provided by NSW DPI Water and Mallee CMA; map prepared by Ecological Assoc. 2015]

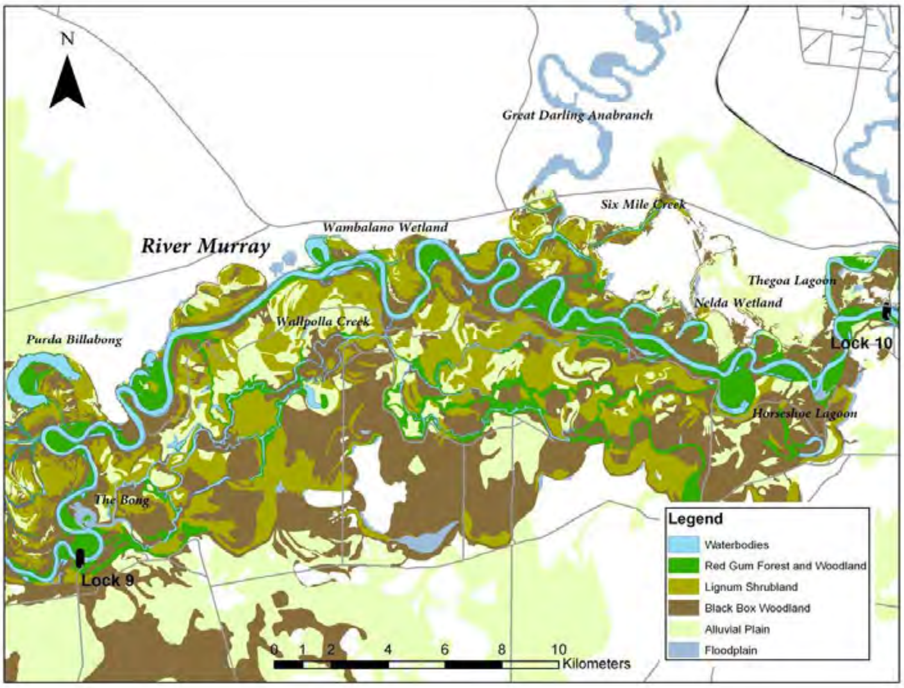
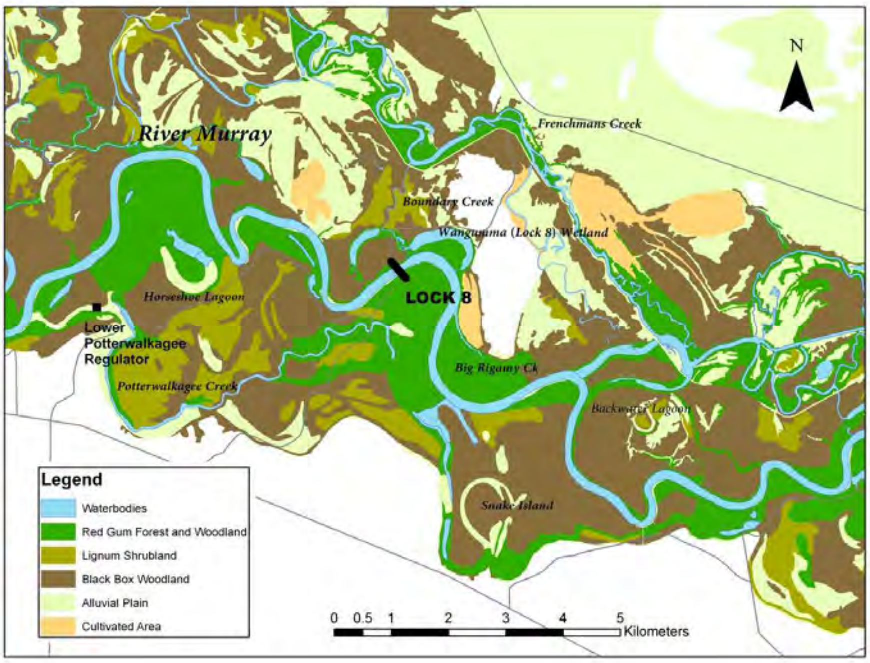


Figure 3-4: Water regime classes of the Lower Murray SDL project area between Locks 8 and 9
[Source: Spatial data provided by NSW DPI Water and Mallee CMA; map prepared by Ecological Assoc. 2015]



3.3.4 Ecosystem functions

The diverse hydrological environments across the project area perform many ecosystem functions at a local and regional scale. These functions support invertebrates, fish and birds through (but not limited to):

Food provision through carbon and nutrient cycling – The hydrological connection between watercourses and their associated floodplain wetlands provides for the exchange of carbon and nutrients (Thoms 2003). During dry periods, organic matter such as leaf litter and grasses, is slowly decomposed by bacteria, releasing carbon and nutrients that accumulate in the soil. On re-wetting, decomposition accelerates and carbon/nutrients are released from the soil where they enter the water and become available for aquatic plants and animals. The release of energy and nutrients results in a very rapid increase in productivity with a proliferation of bacteria and invertebrates. These organisms are food for larger animals and support an increase in their abundance and diversity e.g. frogs, small fish (Ecological Assoc. 2013).

Transfer of water between the main river channel and floodplain areas inundates wetlands and billabongs, supplies nutrients and sediments from the river and accelerates the breakdown of organic matter. Any water returning to the river from these areas will provide the main river channel with organic matter (MDBA 2012a). The connections are considered essential for the functioning and integrity of floodplain-river ecosystems (MDBA 2012a). The provision of large woody debris in waterways and wetlands provides a surface for biofilms to establish which then supplies food to aquatic macroinvertebrates.

Habitat provision and maintenance – Aquatic vegetation provides shelter, nesting habitat and nesting materials for many aquatic fauna. For example, dense macrophyte beds are important for cryptic waterbirds like Australasian bittern, purple swamp hen and black-tailed native hen. Dense reed beds provide nesting habitat for the Southern Bell frog. As water levels drops, mudflats are exposed which provide conditions for herbland plants□to establish. These are then grazed by wading birds such□as the great egret (*Ardea alba*), greenshank (*Tringa nebularia*) and the red-necked stint (*Calidris ruficollis*), all of which are listed under the Japan–Australia, Republic of Korea–Australia and the China–Australia Migratory Bird agreements (MDBA 2012b). The provision of large woody debris in waterways provides habitat for large-bodied native fish and helps contribute to variability inflow velocity and turbulence within anabranch streams. The diversity in velocity, turbulence, width and depth conditions within waterways provides a number of habitat niches that enables the support of several life-stages of native fish – nursery areas, juveniles and adults (NSW Public Works & FCS 2013).

Migration/dispersal/recolonisation – The connectivity between aquatic environments enables the movement of aquatic organisms within and between these systems e.g. longitudinally along waterways and rivers, and laterally between waterways and floodplain environments. This transfer of individuals is required to promote genetic diversity and therefore resilience of populations and communities. The CCB Creeks system in particular has the potential to be a nursery ground for Murray Cod, which could provide source individuals to boost the regional native fish community (NSW Public Works & FCS 2013).

Regarding weir pool manipulation, the wetting and drying of the littoral zone will consolidate soils, allow sedimentation processes to occur, mineralise organic matter, support microbial and planktonic productivity and promote overall biodiversity in the long-term.

Fish movement will also occur between the CCB Creeks system and the Murray River and hence with upgraded block banks and regulators, golden perch and Murray cod will move between Frenchmans Creek and the Murray River (Saddlier et al. 2008). Linking Lake Victoria, Frenchmans Creek, Carrs-Capitts-Bunberoo Creeks and the Murray River provides connectivity among highly important and diverse aquatic habitats. Hence, restoring connectivity among these habitats is an important opportunity to enhance regional fish populations.

Fishways on the main stem of the Murray River at Locks 7, 8, 9 and 10 provide passage to large numbers of small and large bodied fish (Stuart et al. 2008; Baumgartner et al. 2010). For the Frenchmans system there is also an expectation that large numbers of golden perch and other native fish would also use fishways to move among habitats.

3.4 Social and economic values

Frenchmans Creek is an important recreational fishing area and land on the NSW floodplain area has a long history of pastoral use. Most of the area of influence for the CCB Creeks connectivity proposal is located on Crown land that is in the process of being transferred to Barkandji Native Title Aboriginal Corporation. Following the transfer, the land will be managed by a Tar-Ru Lands Board of Management (to be established in the near future). This area was previously public land held by State Forests and then NSW National Parks and Wildlife Service with limited access or development. There is a small amount of leasehold land (long-term grazing licences, Western Lands Division) in the north of the CCB area around Purda Billabong and east of Carrs Creek.

Being close to Mildura and Wentworth, recreational use of the site is substantial, especially riverboats passing through, and recreational canoeing and fishing. Tourism in the Mildura region generates more than $210 million annually, and is the third largest industry in the region (Mildura Development Corporation 2009), with tourist numbers in the tens of thousands every year (B. Rogers, pers. comm. 2010). Sites such as the Murray–Sunset National Park are major attractions contributing to the tourism industry and local economy. The island floodplains are also popular recreation sites for the local communities of Millewa and Sunraysia, Victoria and the Riverland in South Australia. Camping (especially in spring and autumn), boating, canoeing, bird and wildlife watching, photography, fishing and four wheel driving are all popular pursuits (MDBA 2012b).

3.5 Cultural values

Indigenous Australian occupation across the project area dates back thousands of years and was sustained by the rich productivity of the floodplain woodland and wetland systems. Only a very small area of the Chowilla Floodplain and Lindsay-Wallpolla Islands icon site has been surveyed for areas of cultural significance, largely because of its isolation. Surveys show the area was once densely populated by Indigenous peoples, who maintained spiritual, cultural and emotional links with its land, waters and traditional resources such as native species used for food and medicine (MDBA 2012b). The land and waterways are associated with cultural learning, which is still being passed onto new generations today (MDBA 2012b).

An assessment of cultural heritage sites conducted within the Tar-Ru Lands on the NSW floodplain during June / July 2013 found the area to be rich with Aboriginal heritage. The survey was focused on the area of the former Moorna State Forest and includes the CCB and Frenchmans Creek project areas. A survey team involving the NSW Office of Environment and Heritage (OEH) and Aboriginal members of the Tar-Ru Negotiating Team, identified and mapped areas of significance and identified priorities for remedial works and immediate site protection works. A total of 95 sites were recorded including burials, scar trees (Figure 3-5) artefacts, shell midden sites and fireplaces. (NSW OEH 2013.)

Earlier more extensive archaeological research around Lake Victoria and Rufus River identified large numbers of Aboriginal burials and other relics in sandy landforms throughout the area. Large-scale reclamation work has been undertaken in collaboration with the Barkindji community (MDBA 2011).

Figure 3-5: Scar tree located within the Tar-Ru Lands [Source: NSW OEH 2013]

On the Victoria floodplain many signs of Indigenous life still remain at the Mulcra and Wallpolla Islands, including diverse archaeological site-types and complexes closely associated with floodplain features (SKM 2004). The floodplain contains many registered sites of cultural heritage, within each of which may be multiple items of significance such as burial sites, shell middens, hearths, stone artefact scatters and culturally scarred trees (Bell 2010; Kelton 1996).

3.6 Threats to values

Due to the extent of River Murray regulation, the predominant threats to the values of the project area are hydrological in nature. The natural variability of the River Murray provided intermittent inundation of riparian, wetland and floodplain habitats, including anabranch waterways. Flora and fauna of the river have adaptations to accommodate, make use of, and rely on, variability in water levels. Without the provision of a suitable water regime many species are unable to complete their life cycles (Ecological Assoc. 2013).

By storing water and reducing variability in river levels, weirs have had significant ecological impacts including (Ecological Assoc. 2013):

- Loss of flowing-water habitat and disruption to lateral and longitudinal connections e.g. the Carrs, Capitts and Bunberoo Creeks are hydrologically disconnected from the main stem of the River Murray due to the construction of Lock 9 and the associated fixed crest weirs and block banks on the inlets of the CCB creeks system. There are extensive slow-flowing and still reaches within the CCB creeks system due to the low flow rate through these waterways (NSW Public Works & FCS 2013).
- Permanent inundation of the river channel, backwaters and wetlands
- Increased sedimentation in weir pools, backwaters and wetlands
- Increased erosion in tailwater zones

- Contraction of riparian and littoral vegetation communities
- Reduction in water-level triggers for fish spawning
- Raising groundwater tables leading to floodplain salinisation

The fixed crest weirs at the upstream ends of the Carrs and Bunberoo Creeks provide no upstream passage of fish and little downstream passage. The various road crossings also block passage for most of the time except in very high flows when they are submerged (NSW Public Works & FCS 2013).

The flows within the CCB creeks system are very low, except at very high headwater levels when the influence of Lock 9 is removed. Flow variability has also been greatly reduced. The key component for large-bodied native fish habitat that has been lost from the system is the fast-flowing (>0.3 m/s) complex reaches. The CCB system requires a much greater base flow and variability of flows for rehabilitation of the aquatic habitat (NSW Public Works & FCS 2013).

The inlet regulator on Frenchmans Creek is one of the last major barriers to fish passage along the River Murray. Currently a large amount of biota, including fish, is being siphoned into Lake Victoria and unable to re-enter the River Murray system. The addition of a fishway at the Lake Victoria inlet regulator will provide a critical linkage between a major recruitment site for golden perch and a significant length of improved habitat upstream (Lock 9 weir pool and CCB Creeks system).

Other potential threats to the values of the project area are land management practices such as domestic stock grazing and pest plants and animals. These are discussed in Section 12.2.

4 Ecological objectives and targets

4.1 Overarching goal

The overall objective of water management in the study area is:

"to protect and restore the key species, habitat components and functions of the ecosystem by providing the hydrological environments required by indigenous plant and animal species and communities".

This will be achieved by:

- Supporting a regional self-sustaining population of golden perch
- Enhancing Murray cod habitat by improving the productivity of connected riparian zones and wetlands while maintaining fast-flowing habitat
- Maintaining resident populations of frogs and small bodied fish in wetlands
- Improved aquatic and littoral vegetation communities
- Providing reliable feeding habitat for waterbirds, including colonial nesting species.

Ecological objectives will be achieved by providing ecosystem water requirements in key areas of the study area. Importantly, the objectives reflect the ecological outcomes that are possible within the scope of the project works.

The three project components are:

- Locks 8 and 9 weir pool manipulation operational measure: wetting and drying of intermittent floodplain wetlands and the littoral zone of waterways influenced by the weir pools
- CCB Creeks connectivity works: restoring flows and improving hydraulic diversity and connectivity within the Carrs, Capitts and Bunberoo Creeks
- Frenchmans Creek fish passage works: restoring fish passage between Lake Victoria and the River Murray

The following describes the ecology and water requirements of the main biological communities within each component.

4.2 Ecological objectives and targets

A series of objectives have been developed based on important aquatic values and processes within the project area that are critical to the achievement of the overarching project goal. Background information including the rationale for the values and processes chosen for the objectives is available in Ecological Associates (2013) – see Appendix 1 Supporting Documents.

4.2.1 Aquatic macrophytes

The primary targets are the water requirements of a small but important component of the ecosystem: the littoral and riparian zone of wetlands and watercourses, and flowing water habitat. The objectives are to promote a broader zone of macrophytes, to increase productivity and habitat quality, to promote habitat use by aquatic fauna and waterbirds and to promote fish growth and reproduction.

Stable water levels promote communities dominated by species at the lower and upper range of this continuum, i.e. species that are adapted to permanent inundation or prolonged exposure. The habitat for species that exist between these extremes, and depend on intermittent wetting and drying, is greatly reduced. The extent of these communities is severely impacted by stable water levels. Prior to the construction of the weirs, water levels varied over a range of more than 3 m over the course of most years. The exposure of damp wetland fringes in spring / summer provided a broad zone in which emergent macrophytes grew.

Weir pool manipulation provides the scope to vary water levels to meet the water requirements of emergent aquatic macrophytes in the littoral zone of weir pools and connected wetlands. This includes both raising and drawdown of pools. Ecological objectives for aquatic macrophytes are outlined in Table 4-1.

Table 4-1: Weir pool management objectives for aquatic macrophytes

Action	Inundation of: 6 to 12 months, every year (lower extent of macrophytes) 2 to 6 months, every 1 to 2 years (upper extent of macrophytes)
Process	– inundation in spring – gradual exposure of riparian zone over late spring and summer
Direct Objectives	– increased width of aquatic macrophyte beds – increased aquatic macrophyte diversity – increased red gum overstorey as a component of macrophyte beds
Indirect Objectives	– waterbird breeding – small bodied fish habitat – frog habitat

4.2.2 Floodplain vegetation

The principal floodplain vegetation types that may be influenced by weir manipulations are red gum and black box woodlands and shrublands. Floodplain vegetation in the study area has been mapped as Ecological Vegetation Classes in Victoria and Benson Vegetation Classes in NSW.

Red gum and black box woodlands and shrublands have an important role in providing structural habitat for aquatic and floodplain fauna, particularly snags used for grazing and shelter by fish and invertebrates, fallen woody debris provides shelter for small mammals, ground foraging birds, and many reptiles, and in providing tree hollows and nesting sites. Insects that fall from the canopy are consumed by frogs and small fish. Floodplain vegetation contributes to the overall productivity of the floodplain by providing much of the organic matter, through leaves, woody debris, nectar and seeds, on which aquatic and floodplain food webs depend.

Weir pool manipulation provides the scope to vary water levels to meet the inundation and drawdown requirements of floodplain vegetation. Ecological objectives for floodplain vegetation are outlined in Table 4-2.

Table 4-2: Weir pool management objectives for floodplain vegetation

Action	Inundation of 1 to 4 months, every 1 to 5 years
Process	– inundation in spring or summer
Direct Objectives	– increased woodland and shrubland vegetation productivity (including tree health)

	– increased woodland and shrubland vegetation diversity
Indirect Objectives	– increased floodplain fauna abundance and diversity

4.2.3 Organic matter processing and supply

The microbial decay of plant material is an important route for energy and nutrients to enter the riverine food chain (Young et al. 2001).

During dry periods, organic matter such as leaf litter and grasses is slowly decomposed by bacteria, releasing carbon and nutrients which accumulate in the soil. On re-wetting, decomposition accelerates and becomes more efficient. Carbon and nutrients are released from the soil and enter the water where they become available for aquatic plants and animals. The release of energy and nutrients results in a very rapid increase in productivity with a proliferation of bacteria and invertebrates. These organisms are food for larger animals and support an increase in their abundance and diversity.

Weir pool manipulation (both raising and drawdown) provides an opportunity to increase the processing and supply of organic matter. Ecological objectives for the processing and supply of organic matter are outlined in Table 4-3.

Table 4-3: Weir pool management objectives for organic matter processing and supply

Action	Inundation of: 2 to 6 months, every 1 to 2 years (wetter limit) 1 to 2 months, every 2 to 3 years (drier limit)
Process	– inundation in spring or summer – inundation and exposure intervals of between 1 and 3 years
Direct Objectives	– increased dissolved organic matter in wetlands – increased particulate matter concentration in wetlands
Indirect Objectives	– increased macroinvertebrate production – increased fish and waterbird foraging

4.2.4 Biofilms

The composition of biofilms and their nutritional value has been related to water regimes.

Weir pool manipulation (both raising and drawdown) provides an opportunity to increase the availability of bacteria dominated biofilms. Exposing and inundating substrates such as plant stems and woody debris under a range of frequencies and durations will promote diversity in biofilm succession and provide a more diverse and nutrient-rich food source for grazing invertebrates (Ecol. Assoc. 2013).

Ecological objectives for biofilms are outlined in Table 4-4.

Table 4-4: Weir management objectives for biofilms

Action	Inundation of: more than 6 weeks, 1 to 3 times per year
Process	– exposure and re-inundation
Direct Objectives	– bacteria-dominated biofilms

	– increased biofilm production
Indirect Objectives	– increased macroinvertebrate production – increased fish and waterbird foraging

4.2.5 Waterbird abundance and foraging

Wetlands and low-lying floodplain woodlands provide significant habitat for waterbird foraging.

Flooding of wetland and floodplain vegetation in spring and summer provides a source of food, refuge from predators and nesting sites and materials (Kingsford and Normal 2002). Food availability is greatly enhanced in wetlands that have been subjected to dry periods of one or more years prior to filling (Briggs et al. 1997). The decomposition of organic matter between floods provides readily available carbon to the food web and supports production by plants and invertebrates. Receding water levels in summer provide shallow open water and mudflats which are important foraging habitat for wading birds.

Weir pool manipulation has the potential to improve the poor bird foraging opportunities which result from the low productivity of permanently inundated wetlands, the poor health and limited extent of littoral vegetation and the low frequency of events that inundate floodplain and wetland vegetation (Table 4-5).

Ecological objectives for waterbird foraging are outlined in Table 4-5.

Table 4-5: Weir pool management objectives for waterbird foraging

Action	Inundation of macrophyte beds in spring / summer for: 2 to 4 months, every year Inundation of floodplain vegetation in spring / summer for: 2 to 4 months, every 2 to 3 years Exposure of mudflats in summer for: 2 to 4 months, every year
Process	– inundation of macrophyte beds and floodplain vegetation – gradual exposure of riparian zone over summer
Direct Objectives	– waterbird foraging in flooded macrophyte beds – waterbird foraging in flooded woodland vegetation – waterbird foraging in open water habitat – waterbird foraging in mudflats

4.2.6 Small-bodied native fish

Weir pool manipulation, restoring flows into the CCB Creeks system and introducing fish passage between Lake Victoria and the Lock 9 weir pool will enhance habitat and improve access to spawning grounds and preferred habitat, and reduce barriers to the movements of migratory fish species.

Small-bodied native fish species include Murray-Darling rainbow fish, carp gudgeons, flatheaded gudgeons, unspecked hardyhead and Australian smelt. All of these fish migrate in fishways and their ecology is enhanced by providing hydraulic diversity via restoring flow variability.

These species feed on biofilms, zooplankton, small macroinvertebrates and organic debris. They are often associated with aquatic vegetation. As well as contributing to the diversity of the fish community, these species are an important part of the diet of large-bodied fish, including Murray cod, and of many waterbirds.

Locks 8 and 9 weir pool manipulation

Weir pool manipulation has the potential to enhance habitat for small fish by providing more productive aquatic habitat, promoting the growth of aquatic macrophytes and providing access to flooded vegetation and woody debris. Weir pool manipulations also provide enhanced hydraulic diversity (fast and slow flowing water). The ecological objectives of weir pool management, for small-bodied native fish are outlined in Table 4-6.

Table 4-6: Weir pool management objectives for small-bodied native fish

Action	Permanent inundation of wetland refuge habitat Inundation of macrophyte beds in winter / spring / summer for: 4 to 8 months, every year Inundation of woodland habitat in spring / summer for: 2 to 4 months, every 2 to 3 years
Process	– feeding, sheltering and breeding opportunities in aquatic macrophyte vegetation – increased feeding and breeding opportunities in inundated floodplain vegetation – increased wetland connectivity – increased wetland and floodplain productivity – increased hydraulic diversity
Direct Objectives	– increased small bodied fish community diversity – increased small fish abundance

CCB Creeks system connectivity

The CCB Creeks works will help meet the habitat requirements of small-bodied native fish by providing a permanent aquatic habitat with access to flooded riparian vegetation on in-channel benches and backwaters through spring and summer. The ecological objectives of restoring flows and fish passage at the Carrs weirs, for small-bodied native fish are outlined in Table 4-7.

Table 4-7: CCB Creeks objectives for small-bodied native fish

Action	A minimum base flow that will provide low stable flows for recruitment of small-bodied generalist fish species Seasonal inundation of in-channel benches and backwaters Inundation of the channel perimeter
Process	– maintenance of slow-flowing water habitat for a period in warmer months to promote dense plankton for small-bodied native fish recruitment – increased connectivity between the CCB Creeks and the Lock 9 weir pool – initiation of seasonal growth of littoral and riparian plants that provide habitat for macroinvertebrates, small fish and larvae – increased levels of biological activity
Direct Objectives	– to support / re-establish a diverse community of abundant small-bodied fish

Frenchmans Creek fish passage

The Frenchmans Creek works will meet the passage needs of small bodied fish by providing optimal hydraulic attraction and passage conditions. From nearby fishways, at Lock 8, it is expected that large numbers of small fish (from 20+ mm long) will attempt to migrate (Stuart et al. 2008). Reconnecting Lake Victoria, Frenchmans Creek, CCB Creeks and the River Murray will have major ecological benefits for small-bodied fish populations.

The ecological objectives of restoring fish passage at the inlet regulator on Frenchmans Creek (for small-bodied fish) are outlined in Table 4-8.

Table 4-8: Frenchmans Creek objectives for small-bodied native fish

Action	Restore fish passage at the Frenchmans Creek inlet regulator via a fishway
Process	- restore connectivity for small bodied fish such as gudgeons, hardyhead, Australian smelt and Murray-Darling rainbowfish - enable dispersal migrations of small-bodied fish from Frenchmans Creek and Lake Victoria to CCB Creeks habitats and the River Murray - reduce predation of small-bodied fish below the inlet structure by larger fish and birds
Direct Objectives	to enhance a diverse community of abundant small-bodied fish

4.2.7 Large-bodied native fish

The project site species are Murray cod, golden perch, silver perch, freshwater catfish and bony herring. With the exception of bony herring, these species are predators and consume fish, frogs, yabbies and shrimps. Bony herring eat algae and micro-crustaceans and are a significant prey for the large Murray cod and golden perch.

For many native species, movements over long distances are an important part of their life cycle. Golden and silver perch will often travel over hundreds of kilometres, with adults often swimming upstream in response to flow related spawning cues. Juvenile golden perch are also highly migratory and respond to even small changes in river flows. Other species including bony herring and Murray cod, may move long distances to access food or to colonise new areas. Barriers to fish passage also fragment habitat. Isolated habitats may not be recolonised after disturbance, so that overall fish populations decline. Barriers also isolate breeding populations and inbreeding occurs, reducing the genetic diversity of fish populations and reducing their long-term viability (Schiller & Harris 2001).

Prior to the construction of weirs, fast-flowing water was a normal characteristic of the River Murray channel, even at low discharges. The decline of fast-flowing habitat has contributed to the decline of native fish populations in the River Murray below Lock 10. The hydraulics of natural channels is complex and involves spatial and temporal variation associated with channel form, debris, vegetation and variable discharge. As a general guide to managing flow for large-bodied native fish, mean cross-sectional velocities of between 0.3 and 0.5 m/s are targeted as fast-flowing habitat (Ecol. Assoc. 2013).

The habitat requirements of Murray cod are the core focus of water management in the CCB Creeks, based on the significance of this threatened species and evidence from other sites that healthy Murray cod populations are associated with healthy populations of other native fish species. However, the particular habitat requirements of other fish will also be included in the design and operation of the system.

Restoration of fish passage between Lake Victoria and the River Murray will enable a vital linkage between a major recruitment site for golden perch and the resulting improved habitat upstream. Large numbers of golden perch and bony herring are expected to migrate upstream from nursery habitats in Lake Victoria through the proposed fishway on the inlet regulator. These fish are expected to recolonise hundreds of kilometres of the River Murray and anabranch habitats, enhancing the regional population.

Locks 8 and 9 weir pool manipulation

Weir pool manipulations will promote conditioning of large bodied species by stimulating more biofilms production that will support increased growth and therefore improve the reproductive potential of mature large bodied native fish such as Murray cod, freshwater catfish and golden perch. Ongoing trialling of the impact of weir surcharge and drawdown on large bodied species is occurring at Locks 8 and 9.

Ecological objectives of weir pool management for large-bodied native fish are outlined in Table 4-9.

Table 4-9: Weir pool management objectives for large-bodied native fish

Actions	Connection between permanent aquatic habitat to wetlands: 1 to 2 months, every year Inundation of emergent macrophyte vegetation for: 2 to 4 months, every 1 to 2 years Inundation of woodland habitat in spring / summer for: 2 to 4 months, every 2 to 5 years Trialling revised weir pool operations that best suit fish including spring time drawdown of pools to enhance flowing water habitats and release of spring pulses to condition large bodies species.
Process	– access to connected wetland and floodplain habitat – feeding, sheltering and breeding opportunities in wetlands – increased feeding and breeding opportunities in inundated littoral and floodplain vegetation – increased wetland and floodplain productivity – spring flow pulse to stimulate pre-spawning migrations
Direct Objectives	– conditioning of large bodied species – increased large-bodied fish community diversity – increased small-bodied fish abundance
Indirect Objectives	– increased piscivorous waterbird abundance

CCB Creeks system connectivity

The CCB Creeks works aim to create similar habitat and hydrodynamic characteristics to Mullaroo Creek (at Lindsay Island) together with Pipeclay and Slaneys Creek areas, supporting one of few self-sustaining anabranch populations of Murray cod in the Lower Murray.

Murray cod are associated with fast-flowing water, particularly velocities between 0.3 and 0.5 m/s, which attract cod, maintain oxygenated conditions and provide diverse and abundant prey species. As predators, Murray cod depend on high levels of ecosystem productivity to provide small-bodied fish, macroinvertebrates and other prey. This depends on the availability of flooded riparian habitat and high nutrient availability, which are promoted by seasonally variable flow regimes. Murray cod breed annually between spring and summer and adult fish can undertake local migrations in the order of tens of kilometres between breeding events, and benefit from structures that permit upstream fish passage (Saddlier et al. 2008).

Freshwater catfish form local populations in permanent slow flowing habitats and depend on stable water levels that keep nests inundated during spring and summer. Golden perch and silver perch will benefit from the diverse and abundant prey species that the CCB Creek system will support. It is expected that larvae drifting into the CCB Creeks system will access food and find protection from predators in riparian vegetation, woody debris and the reinstated diverse hydraulic environment. The ecological objectives of restoring flows and fish passage at the Carrs weirs, for large-bodied native fish are outlined in Table 4-10.

Table 4-10: CCB objectives for large-bodied native fish

Action	A minimum base flow during autumn and winter that will provide pool connections flows, a minimum pool depth (e.g. 2 m) and the minimum extent of fast-flowing habitat A spring fresh (up to 1500 ML/d at Carrs 1, and 500 ML/d at Carrs 2) over a 4 to 6 month period starting in early August Seasonal inundation of in-channel benches and backwaters Inundation of the channel perimeter
Process	– increased reaches of fast-flowing water habitats; providing velocities between 0.3 and 0.5 m/s (for Murray cod) – increased deep pools, more than 1.5 m in channels and backwaters (for freshwater catfish) – increased connectivity between the CCB Creeks and the Lock 9 weir pool – increased levels of biological activity
Direct Objectives	– to restablish and support a diverse community of abundant large-bodied fish – support resident populations of Murray cod – support Murray cod recruitment – support Murray cod dispersal and migration – support local populations of freshwater catfish – support the survival and growth of juvenile golden perch, silver perch, catfish and cod – provide productive habitat for visiting adult golden perch and silver perch

Frenchmans Creek fish passage

The Frenchmans Creek works will redress the problem of the large amount of biota, including fish that are currently being siphoned into Lake Victoria and unable to re-enter the River Murray system. The addition of a fishway at the Frenchmans Creek inlet regulator will provide a critical linkage between a major recruitment site for golden perch and a large amount of improved habitat upstream (Lock 9 weir pool, Lower Darling, Lower Darling Anabranch and CCB Creeks system). The Frenchmans Creek, due to variable water levels and flow regimes through river operations used to fill Lake Victoria provides for a high value and productive floodplain. This project will provide connectivity between the high quality floodplain of the Frenchmans creek (1000 plus hectares) to the main stem of the Murray River.

The large-bodied fish are expected to be dominated by golden perch (adults and juveniles) and bony herring (juveniles and some adults) with smaller numbers of Murray cod to 1.2 m long. Large-bodied fish will move from early August to April each year, especially as flows rise when Lake Victoria is being filled. Fish will recolonise the CCB Creeks and also the River Murray where they will disperse long distances upstream and downstream.

The ecological objectives of restoring fish passage at the inlet regulator on Frenchmans Creek (for large-bodied fish) are outlined in Table 4-11.

Table 4-11: Frenchmans Creek objectives for large-bodied native fish

Action	Restore fish passage at the Frenchmans Creek inlet regulator via a fishway
Process	- restore connectivity for large-bodied fish such as golden perch, bony herring, silver perch and Murray cod - enable dispersal migrations of juveniles of large-bodied fish from Lake Victoria nursery habitats to CCB habitats and the River Murray - reduce predation of fish below the inlet structure by anglers and piscivorous birds
Direct Objectives	To enhance a diverse community of abundant large-bodied fish

4.3 Summary ecological objectives and targets

Overall, weir pool manipulation presents an opportunity to restore components of the riverine ecosystem by providing intermittent inundation and exposure of wetlands, macrophyte beds and floodplain vegetation (Figure 4-1 and Figure 4-2). The key elements of this restoration are:

- increasing the availability of nutrients and energy in the food web through greater plant productivity, mineralisation of organic matter and bacteria-dominated biofilms
- increased extent, diversity and productivity of emergent macrophyte vegetation
- increased diversity and productivity of floodplain vegetation
- increased opportunities for feeding, breeding and sheltering from predators for birds, fish, frogs and other aquatic fauna in flooded wetland and woodland vegetation
- wading bird habitat in summer mudflats

Weirs can be operated to achieve these outcomes by providing:

- annual inundation and exposure of macrophyte beds and woody debris
- intermittent connections between permanent water bodies and temporary wetlands
- annual or inter-annual inundation of floodplain vegetation
- provision of shallow-water habitat or mudflats in summer
- provision of flow cues by means of drawdowns at strategic times
- freshening of local water tables.

Reinstating flows and fish passage into the CCB Creeks system will provide habitat characteristics that aim to replicate the habitat characteristics for a self-sustaining population of Murray cod and other native fish species.

The key elements of this restoration are the provision of:

- increased reaches of fast-flowing water habitats; providing velocities between 0.3 and 0.5 m/s (for Murray cod)
- increased deep pools, more than 1.5 m in channels and backwaters (for freshwater catfish)
- increased connectivity between the CCB Creeks and the Lock 9 weir pool through the provision of fishways on Carrs Weirs 1 and 2.

The provision of fish passage between Lake Victoria and the Murray River via Frenchmans Creek will provide the critical linkage between a main recruitment site and a significant length of improved habitat in the CCB Creeks and the broader River Murray, which can provide significant benefits to the Lower Murray Darling regional native fish populations.

Specific ecological objectives and targets have been developed to measure progress towards the overarching ecological objective for the Lower Murray (NSW) SDL project.

The targets generally define the endpoint for each objective, rather than measuring the change from a benchmark. However, a defined baseline or benchmark will be identified for each to help refine targets where necessary and inform reporting of progress against targets.

A detailed monitoring and evaluation plan will be developed if the proposed works proceed. This will include testing and refining the targets during the operation phase.

The timeframe for target achievement is 2040, which takes into account the time required for the project to be operational and the expected time-lag between implementation of the works and an ecological response being observed through monitoring. The ecological objectives and targets are outlined in Table 4-12.

Figure 4-1: Mid Carrs Creek – effects of Lock 8 weir pool drawdown: exposure of diverse structure and bed material [Source S. Jaensch, April 2015]

Figure 4-2: River Murray – Lock 8 weir pool drawdown event (left): exposure of dry silts for reconsolidation [Source S. Jaensch, April 2015]

Table 4-12: Ecological objectives and targets for the proposed project

<table>
<tr><th>Ecological objectives</th><th>Draft targets</th><th>Flow-on benefits</th></tr>
<tr><td colspan="3">Aquatic macrophytes</td></tr>
<tr><td>Increase the width of aquatic macrophyte beds.</td><td>Average width of aquatic macrophyte beds doubles from 2016 benchmark.</td><td rowspan="3">Improved habitat availability for waterbirds, small native fish and frogs.
Waterbird breeding.</td></tr>
<tr><td>Increase aquatic macrophyte diversity.</td><td>Three species of aquatic macrophyte characteristic of each of the following habitats are recorded each year – infrequently flooded, moderately flooded (regular flooding and exposure) and permanently flooded.</td></tr>
<tr><td>Increase the river red gum overstorey as a component of the macrophyte beds.</td><td>10 macrophyte beds with a sparse river red gum overstorey.</td></tr>
<tr><td colspan="3">Floodplain vegetation</td></tr>
<tr><td>Increase the productivity of woodland and shrubland vegetation.</td><td rowspan="3">>75% of surveyed trees with ‘healthy’ canopy condition - crown condition index score of 4 or greater (Crome 2004).
>75% of flora species expected to occur for the vegetation communities inundated through the project are recorded over a five year period.</td><td rowspan="3">Increased floodplain fauna abundance and diversity.</td></tr>
<tr><td>Increase the woodland and shrubland vegetation diversity.</td></tr>
<tr><td>Improve the tree health within floodplain vegetation.</td></tr>
<tr><td colspan="3">Organic matter processing and supply</td></tr>
<tr><td>Increase the dissolved organic matter in wetlands.</td><td>100% increase in dissolved organic carbon sampled from wetlands within 2 weeks of refilling.</td><td rowspan="2">Increased aquatic macroinvertebrate production.
Increased fish and waterbird foraging.
Improved body condition and reproductive potential in fish.</td></tr>
<tr><td>Increase the particulate organic matter in wetlands.</td><td>100% increase in dissolved organic carbon sampled from wetlands within 2 weeks of refilling.</td></tr>
<tr><td colspan="3">Biofilms</td></tr>
<tr><td>Bacteria-dominated biofilms present.</td><td rowspan="2">Bacterial biomass exceeds algal biomass in biofilms on large woody within the seasonally inundated zone
Scraping invertebrates (e.g. snails) increases as a proportion of total macroinvertebrate biomass</td><td rowspan="2">Increased aquatic macroinvertebrate production.
Increased fish and waterbird foraging.</td></tr>
<tr><td>Increase biofilm production.</td></tr>
<tr><td colspan="3">Waterbird abundance and foraging</td></tr>
<tr><td>Increase waterbird foraging in open water, mudflats and flooded macrophyte beds and woodland vegetation.</td><td>One quarter (12) of the 49 water-dependent birds species are observed foraging in open water, mudflats and flooded macrophyte beds annually.</td><td>Waterbird breeding.</td></tr>
</table>

Ecological objectives	Draft targets	Flow-on benefits
Small-bodied native fish		
Increase the diversity of the bodied native fish community.	6 species of small-bodied native fish recorded annually (Un-specked hardyhead, Carp gudgeon complex, Australian smelt, Murray rainbowfish, Flathead gudgeon and Dwarf flathead gudgeon) (NSW Public Works & FCS 2013).	Increased piscivorous (fish eating) waterbird abundance. Increased large-bodied fish abundance.
Increase the abundance of the small bodied native fish community.	Annual surveys record Un-specked hardyhead, Australian smelt and Murray rainbowfish are common (>50 individuals recorded) and Carp gudgeon complex and Flathead gudgeon are present (10-50 individuals recorded)*.	
Large-bodied native fish		
Increase the diversity of the large bodied native fish community.	5 species of large-bodied native fish recorded annually (Bony herring, Murray cod, golden perch, Silver perch and Freshwater catfish) (NSW Public Works & FCS 2013).	Increased piscivorous (fish eating) waterbird abundance.
Increase the abundance of the large bodied native fish community.	Annual surveys record Bony herring is abundant (>100 individuals recorded), Murray cod and golden perch are common (51-100 individuals recorded) and Silver perch and Freshwater catfish are present (10-50 individuals recorded).	

*Note: Dwarf flathead gudgeon are expected to remain rare (NSW Public Works & FCS 2013).

4.4 Interdependencies

There are interdependencies between the proposed weir pool manipulation at Locks 8 and 9 and delivery of environmental water to the CCB Creeks system and parallel environmental works and measures and water delivery processes, including constraints measures. This project provides an opportunity to use environmental water in transit to the Lower Lakes by briefly storing the water in the elevated weir pools and/or diverting it through the CCB Creeks system before releasing it into the River Murray for continued use downstream.

If this occurs in conjunction with other flow events, then the cumulative area of inundation may also create environmental cues for breeding events. The cumulative effect of the combined works and measures will lead to greater connectivity between the River Murray and floodplain resulting in improved vegetation health, fish passage and an enhanced exchange of nutrients and carbon. As a result, the project will complement existing consumptive and environmental water delivery in the region, and in doing so, will enhance the ecological outcomes that can be attained across the lower Murray River.

Specific examples of the interactions with other sites and watering events include:

The Living Murray works

A suite of works have been developed for the Chowilla Floodplain and Lindsay-Wallpolla Islands icon site that aim to achieve the ecological objectives set under TLM, such as increasing the diversity and abundance of wetland vegetation and maintaining the current condition and extent of river red gum (*Eucalyptus camaldulensis*) communities. The works in close proximity to this proposed project include (MDBA 2012b):

- Regulators and ancillary works on Mulcra Island that enable inundation of the floodplain when Lock 8 is raised at regulated flows. This enables watering of 800 ha of floodplain and increased flows through 20 km of Potterwalkagee Creek. The Lock 8 wetland has also recently had a new regulator constructed to enable controlled watering through weir pool manipulation.
- Regulator at Horseshoe Lagoon (Wallpolla Island) that can enable flooding by the Lock 9 weir pool and drying of the wetland as would have occurred under natural conditions. The wetland can also be surcharged using temporary pumps to water the large fringing river red gums.

Operation of these works will include maintaining base flows and providing spring freshes in anabranches on Mulcra Island (Potterwalkagee Creek), broadscale floodplain inundation at Mulcra Island and managing the water regime of regulated wetlands (Wallpolla Horseshoe Lagoon, Mulcra Horseshoe Lagoon) (MDBA 2012b).

The proposed project will complement the works under TLM by providing additional anabranch habitat for native fish breeding and recruitment, as well as providing habitat for birds, frogs and turtles.

Environmental watering in the Darling Anabranch

The Darling Anabranch is located in south-western NSW, extending approximately 460 km from its junction with the Darling River south of Menindee, to the River Murray downstream of Wentworth. Commonwealth and NSW environmental water has been used to maintain ecological health and resilience in the Darling Anabranch system.

55 GL of Commonwealth and NSW environmental water was used in 2013-14 to contribute to in-channel flows within the Anabranch during spring to reconnect residual pools and provide through-flows to the

River Murray (Department of the Environment 2014). This watering action contributed to river flows to achieve the following expected outcomes (Department of the Environment 2014):

- Support the dispersal of plants and animals residing in refuge pools along the Darling Anabranch, enabling fish, such as Murray cod and golden perch, to disperse, and reconnect with populations in the River Murray.
- Support improved condition of riparian and floodplain native plants, particularly river red gums that line parts of the channel.
- Provide habitat for native birds and other animals such as frogs.
- Enable the transfer of nutrients and energy between the Anabranch and the River Murray, supporting both longitudinal connectivity (i.e. connectivity along a watercourse) and lateral connectivity (i.e. connectivity between the river channel and riparian zones).

Assuming environmental water deliveries will continue in the lower Darling system including the Darling Anabranch in coming years, this project will be particularly important for improving the health and productivity of the lower River Murray and CCB Creeks system to support the recruitment of large-bodied native fish (e.g. Murray cod and golden perch). Eggs and larvae from spawning events further upstream will drift into the project area and will benefit from the improved habitat and food availability within the riparian and instream zones, whilst also being able to move between the systems and complete important migratory runs for breeding.

Environmental watering in floodplain wetlands

The Murray-Darling Wetlands Working Group have submitted a proposal to the Commonwealth Environmental Water Office for a pilot environmental watering of floodplain wetlands to the west of the CCB system, south of Frenchmans Creek and within the influence of the Lock 8 weir pool for 2015/16. It is planned for siphons to be placed over the Frenchmans Creek levee to water wetlands on the NSW side of the River Murray that fall outside the reach of weir pool manipulation.

Wallpolla Island SDL proposal

A separate SDL proposal has been submitted by the Victorian government for Wallpolla Island – the *Wallpolla Island Floodplain Management Project*.

Proposed supply measure works at Wallpolla Island comprise three main components and provide beneficial impacts to three defined areas on the floodplain. Each area has a different target inundation water level and the three areas – Mid (component 1 works), Upper (component 2 works), South (component 3 works) – are designed to cascade water down to lower floodplain areas to extend the inundation benefits by reusing water.

Parts of the Wallpolla Island proposal can benefit from raising and lowering the Lock 9 weir pool. The weir pool manipulation can create further floodplain inundation and better flowing habitat in Wallpolla Creek as well as draw out backwaters and expose considerable areas of creek bed and flats to enable better cycling of nutrients and carbon.

For example, the Wallpolla options report (Alluvium 2013) proposed that releases from Mid Wallpolla and South Wallpolla be timed to coincide with Lock 9 water levels being raised by up to 0.5 m to maximise the area inundated through the releases in the Lower Wallpolla area. Water from the Mid Wallpolla area could be released through two regulator structures, further increasing the area of black box vegetation community that could benefit from the Mid Wallpolla watering event. Reductions in the Lock 9 weir pool elevation of up to 0.5 m would contribute to drying, and flowing water habitat in the Lower Wallpolla water management area. Watering of the Lower Wallpolla water management area is not reliant on such changes to the Lock 9 operation but would benefit from such changes (Alluvium 2013). The works have therefore been designed to work in conjunction with weir pool manipulation, but are not dependent on it (Mallee CMA 2014).

4.5 Contribution to Basin Plan objectives

The project will contribute to the following Murray-Darling Basin Plan objectives, as shown in Table 4-13:

Table 4-13: Contribution of the project to Basin Plan objectives

Basin Plan environmental objectives relevant to the project*	Contribution of project to Basin Plan objectives
Overall environmental objective a) to protect and restore water-dependent ecosystems of the Murray-Darling Basin	
Water-dependent ecosystems that depend on Basin water resources and support the life cycles of species listed under the Bonn Convention, CAMBA, JAMBA or ROKAMBA continue to support those species.	The aquatic habitats within the project area support 8 listed species – White-bellied sea-eagle (*Haliaeetus leucogaster*), Sharp-tailed sandpiper (*Calidris acuminate*), Red-necked stint (*Calidris ruficollis*), Greenshank (*Tringa nebularia*), Glossy ibis (*Plegadis falcinellus*), Eastern great egret (*Ardea modesta*), Curlew sandpiper (*Calidris ferruginea*), Caspian tern (*Sterna caspia*) (MDBA 2012a).
Water-dependent ecosystems are able to support episodically high ecological productivity and its ecological dispersal.	The wetting and drying of more than 200 km of littoral riparian zone results in a very extensive and rapid increase in aquatic productivity as energy and nutrients are released and result in an abundance of bacteria and invertebrates that drive the water-dependent food web (Ecological Assoc. 2013). More than 20,000 waterbird individuals have been recorded (MDBA 2012a).
Water-dependent ecosystems that support the life cycles of a listed threatened species or listed threatened ecological community, or species treated as threatened or endangered (however described) in State law, are protected and, if necessary, restored so that they continue to support those life cycles.	The project will restore aquatic habitats that support 41 listed threatened flora species and 70 listed threatened fauna species – see Appendix 1 (MDBA 2012a).
Overall environmental objective b) to protect and restore the ecosystem functions of water dependent ecosystems	
Protect and restore connectivity within and between water-dependent ecosystems, including by ensuring that: (a) the diversity and dynamics of geomorphic structures, habitats, species and genes are protected and restored; and (b) ecological processes dependent on hydrologic connectivity (i) longitudinally along watercourses; ii) laterally between watercourses and their floodplains (and associated wetlands); and (iii) vertically between the surface and subsurface; are protected and restored. (f) barriers to the passage of biological resources (including biota, carbon and nutrients) through the Murray-Darling Basin are overcome or mitigated.	The project will restore the hydrodynamic diversity of the CCB Creeks system (including variable velocity, turbulence, depth and width) to provide conditions ideal for the EPBC listed Murray cod. Through weir pool manipulation, the project will provide a diversity of aquatic plant habitat that changes over time in response to water level dynamics. Through improved fish passage and inundation of wetlands and flood runners connected to the River Murray channel, the project will enhance aquatic connectivity across the project area. This will facilitate ecological processes such as native fish migration to access food and habitat resources and as part of spawning and recruitment processes e.g. Murray cod and golden perch. The inundation of floodplain wetlands will enable the transfer of carbon, nutrients and biota between the two habitats. The project will overcome barriers on Frenchmans Creek, at the upstream end of the Carrs and Bunberoo Creeks and at 2 block banks and 5 road crossings within the CCB Creeks system.

Basin Plan environmental objectives relevant to the project*	Contribution of project to Basin Plan objectives
Support habitat diversity for biota at a range of scales (including, for example, the Murray-Darling Basin, riverine landscape, river reach and asset class).	The project will provide habitat diversity within the river reach scale – through the manipulation of water levels to promote a range of aquatic macrophytes. It will also provide diversity at the Riverine landscape scale by enabling the delivery of water to floodplain wetlands and flood runners, as well as the main channel of several waterways.
An objective is to protect and restore ecosystem functions of water-dependent ecosystems that maintain populations (for example recruitment, regeneration, dispersal, immigration and emigration) including by ensuring that: (a) flow sequences, and inundation and recession events, meet ecological requirements (for example, cues for migration, germination and breeding); and (b) habitat diversity, extent, condition and connectivity that supports the life cycles of biota of water-dependent ecosystems (for example, habitats that protect juveniles from predation) is maintained.	Through the provision of habitat diversity, the project will enable many ecosystem functions to eventuate and subsequently maintain populations of water-dependent species. For example, by providing a range of flow conditions within the CCB Creeks system, the project will support spawning and recruitment by large-bodied native fish (a nursery ground), development of juveniles and resident populations of adults. This area will then be an important source population for the broader lower River Murray fish community (NSW Public Works and FCS 2013). The diversity of aquatic macrophytes that is expected to result through weir pool manipulation will also support a range of waterbird feeding guilds and provide many nesting and breeding opportunities.
Protect and restore ecological community structure, species interactions and food webs that sustain water-dependent ecosystems, including by protecting and restoring energy, carbon and nutrient dynamics, primary production and respiration.	The wetting and drying processes that will occur within the riparian zone and floodplain wetlands/flood runners under the project, will promote carbon and nutrient cycling, biofilm development and primary production by a range of aquatic plants. These in turn will provide energy to support aquatic fauna including macroinvertebrates, crustaceans, frogs, turtles, fish and birds, as well as fauna that opportunistically use such food supplies and habitats e.g. reptiles, bush birds, mammals.
Overall environmental objective c) to ensure that water-dependent ecosystems are resilient to climate change and other risks and threats	
Provide wetting and drying cycles and inundation intervals that do not exceed the tolerance of ecosystem resilience or the threshold of irreversible change.	The wetting and drying cycles and water regimes identified for the various aquatic habitats influenced by the project are within the range that would be experienced under natural conditions.
Mitigate human-induced threats (for example, the impact of alien species, water management activities and degraded water quality).	This project focuses on mitigating the impacts of river regulation, particularly the influence of the Locks 8 and 9 weir pools and the artificial barriers within Frenchmans Creek (regulator) and at various points along the Carrs, Capitts and Bunberoo Creeks (fixed weirs, block banks and road crossings).
Minimise habitat fragmentation.	The project will improve the longitudinal and lateral connectivity within the project area. In doing so, it will reduce some of the existing aquatic habitat fragmentation that has occurred as a result of river regulation (e.g. the CCB Creeks system being hydrologically disconnected from the main stem of the River Murray).

* From Basin Plan Chapter 8, part 2.

5 Anticipated ecological outcomes

5.1 Current condition

The Lower Murray-Darling Region received minimum inflows during a long period of drought between 2000 and 2010. Drought combined with river regulation and existing consumptive water use had a significant adverse impact on the condition of the riverine environment (CEWO 2013). The authority's second Sustainable Rivers Audit report (MDBA 2012d) concluded that both the Darling and Lower Murray River valleys were in poor ecosystem health. Positive ecological responses were measured in Lindsay-Wallpolla Islands following drought-breaking inflows during 2010-11 and follow-up high inflows in 2011-12. For example, a positive response was recorded for native vegetation (river red gum and black box) on Lindsay and Wallpolla Islands and an increase in fish diversity and abundance, and increased nutrient and salt export (CEWO 2013).

Since 2012, climate conditions have dried in the Lower Murray region with rainfall being below average coinciding with above average temperatures. Environmental water has been provided through The Living Murray program to parts adjacent to the main study area and preliminary evidence suggests success in promoting spawning of native fish (particularly golden perch) and lateral movement between fringing wetlands and the River Murray channel (CEWO 2013).

The ecologically significant adverse effects of the current infrastructure and operating rules compared to the natural hydrology have been to (Ecological Assoc. 2013):

- largely eliminate flowing water habitat under normal regulated flows;
- permanently inundate wetlands, the river channel and low-lying floodplain areas in the vicinity of the weir pools; and
- reduce the frequency and duration of floods that reach higher-level wetlands and floodplain areas.

These changes to the flooding regime have affected the condition of the local floodplain ecosystem. For example, the Carrs Creek has low water velocity and a lack of hydrodynamic diversity and deep pools (Ellis and Sharpe 2012). The key component for large-bodied native fish habitat (fast-flowing complex reaches) has been lost from the system (NSW Public Works & FCS 2013). Longitudinal and lateral connectivity has been degraded through blockages to the passage of biota and reduced inundation of floodplain wetlands.

Stable weir levels upstream of Locks 8 and 9 have promoted vegetation communities dominated by either species suited to persistently flooded areas (e.g. *Schoenoplectus validus, Myriophyllum* spp*. Vallisneria americana* and *Typha domingensi*s) or species that are adapted to prolonged exposure (e.g. *Sporobolus mitchellii* and *Duma florulenta*) (Reid et al. 2009; Ecological Assoc. 2007). The habitat has been greatly reduced for species that depend on intermittent wetting and drying (Ecological Assoc. 2013). Therefore there is currently a reduced presence of such species within the riparian zone of the Lock 8 and 9 weir pools, which has resulted in an overall reduction in the biodiversity of aquatic plants at the site. This has implications for the provision of specific habitat niches required by aquatic fauna such as waterbirds.

For ten years prior to 2010, the reduction in flooding caused by river regulation was compounded by extended drought (MDBA 2012b).

In 2008, monitoring of selected NSW wetlands associated with Lock 8 and 9 weir pools found an abundant and relatively diverse native fish community existed in the wetlands including nine native fish species and more than 62,000 fish sampled over a one year period (Murray-Darling Freshwater Research

Centre 2009). A total of 55 aquatic plants were recorded and in general, the tree canopy condition was moderately stressed for river red gums and black box across all sites. Water quality parameters were within expected levels for wetlands (Murray-Darling Freshwater Research Centre 2009).

The widespread rainfall in spring 2010 generated high flows throughout the Murray-Darling system. Flows downstream of Lock 9 began to rise in late August 2010, reaching 30,000 ML/d in October 2010. This inundated low lying wetlands along the river channel and generated flows through a number of anabranches across the Mulcra and Wallpolla Islands, as well as the Carrs, Capitts and Bunberoo Creeks (Ellis and Sharpe 2012; MDBA 2012b). Flow rates rose steadily from early November and exceeded 60,000 ML/d in mid-January 2011. This flooded most wetlands across the floodplain in the project area (MDBA 2012b).

The condition of the project area today reflects the hydrological changes that have occurred over time. There has been substantial disturbance as evidenced by indicators such as the low numbers of large-bodied (predatory) native fish in the local system due to flow and habitat alterations (Ellis and Sharpe 2012). For example, Carrs Creek does not currently provide favourable Murray cod habitat and the latest fish survey failed to find Murray Cod in this system (Ellis and Sharpe 2012). There is also currently limited emergent and submerged aquatic vegetation within the CCB Creeks system, possibly due to scouring of aquatic macrophytes during the 2010/11 flood event (Ellis and Sharpe 2012) and impacts from carp..

However, the recent flooding has provided evidence of the system's resilience (e.g. native fish such as carp gudgeon breeding events in spring/summer 2012) and the opportunity for further improvements in order to achieve ecological objectives (e.g. the strong Bony herring population in the CCB system would be expected to provide a food source (Baumgartner 2007) to enhance recruitment of Murray cod and golden perch in this region) (Ellis and Sharpe 2012).

5.2 Past water management activities

Mulcra and Wallpolla Islands were made part of the Murray–Sunset National Park in June 2010. The islands have traditionally been used for grazing, apiary, timber harvesting and water extraction, as well as for broadacre and irrigated cropping (MDBA 2012b).

Wallpolla Creek is used for irrigation and domestic extraction. In 2012, there was a small amount of stock and domestic extraction from Wallpolla Creek as part of Kulnine Station operations and irrigation as part of Keera Station. Water extraction from Potterwalkagee Creek on Mulcra Island ceased when Trust for Nature purchased the adjacent property, Ned's Corner, and decommissioned the dam and channels (MDBA 2012b).

Previous water related management activities include:

- Small volumes of environmental water have been delivered to NSW floodplain wetlands to the west of the CCB Creeks system, south of Frenchmans Creek and within the influence of the Lock 8 weir pool in the past using temporary pumps and siphons over the Frenchmans Creek levee.
- For example, selective environmental watering of wetlands occurred within the Moorna State Forest in 2006 during the Millennium drought. Siphoning water (at a rate of 30 ML/day) into 12 wetlands covering 60 ha (including 13 km of narrow creeks) in the Bunberoo Creek system, led to significant ecological benefits. Immediate responses were recorded from aquatic vegetation and frogs, including the threatened growling grass frog recorded at 4 out of 5 watered sites (Val et al. 2007).

5.3 Expected benefits

The project is expected to result in a range of ecological benefits as discussed below and within the earlier Table 4-13 Contribution to Basin Plan objectives. These will work towards “improving aquatic processes and the health of ecological communities” in line with the overall goal of the project.

Ecosystem functions

The wetting and drying processes that will occur within the riparian zone and floodplain wetlands/flood runners under the project, will promote carbon and nutrient cycling, biofilm development and primary production by a range of aquatic plants. These in turn will provide energy to support aquatic fauna including macroinvertebrates, crustaceans, frogs, fish and birds, as well as fauna that opportunistically use such food supplies and habitats e.g. reptiles, bush birds, mammals.

The project will provide a diverse range of habitats including waterways with variable instream environments suitable for supporting native fish at different life stages, riparian aquatic plants across the full water regime spectrum and shallow floodplain wetland systems. A variety of niches will be made available over a large area to facilitate a diverse water-dependent ecosystem through the provision of food, shade and shelter, nesting materials and connectivity between suitable environments. This in turn will facilitate processes necessary for the longevity of fauna communities including migration, recruitment and recolonisation.

Further information on the types of ecosystem processes expected to eventuate under the project is provided in Section 4.5.

Biofilms

Biofilms are communities of bacteria, algae and fungi that grow on submerged surfaces such as wood, rocks, plants and sediments. They are an important food source for a number of grazing invertebrates including snails (Sheldon and Walker 1997) and decapods (Burns and Walker 2000), which in turn are important food sources for fish and waterbirds (Ecological Assoc. 2013).

The composition of biofilms is important to aquatic fauna because the carbon to nitrogen ratio in bacterial biofilms is much lower than in algae, making them more nutritious to grazers. It has been suggested that macroinvertebrate productivity of the River Murray has decreased as a result and has been specifically linked with the decline of the river snail (*Notopala sublineata hanleyi*) (Sheldon and Walker 1997).

The composition of biofilms and their nutritional value has been related to water regimes. Bacteria are the primary colonisers when degradable substrates are first flooded and will dominate the biofilm community, consuming the nutrients made available by the preceding dry conditions. Over time autotrophic algae increase in abundance and become dominant. Permanent inundation of wetlands, backwaters and benches by weirs has promoted algae in biofilms while bacterial biofilms have declined (Sheldon and Walker 1993). Disturbance such as exposure and drying for periods exceeding 40 days (Burns and Walker 2000) and scouring flows (Burns and Ryder 2001) can re-establish bacteria as the dominant component of biofilms.

Weir pool manipulation provides an opportunity to increase the availability of bacteria dominated biofilms. Exposing and inundating substrates such as plant stems and woody debris under a range of frequencies and durations will promote diversity in biofilm succession and provide a more diverse and nutrient-rich food source for grazing invertebrates (Ecological Assoc. 2013).

Vegetation

The project will target a specific habitat niche focused on shallow floodplain wetlands/flood runners and the instream and littoral zone of several waterways. As a result, vegetation benefits under the project are focused on typical communities and flora species that eventuate in these environments. These are discussed below.

Aquatic macrophytes

Aquatic vegetation is made up of species across a range of flooding tolerances. These are ordered along the banks of wetlands and waterways from the deepest, most persistently flooded areas to the higher, intermittently flooded areas (Blanch et al. 1999).

Typically, arid zone floodplain wetlands are sites of high biodiversity and may support both aquatic and terrestrial plant communities, depending on inundation status (Henderson et al. 2009). For example, when inundated, wetlands such as the Mulcra Horseshoe Lagoon host aquatic flora species grown from both dormant seeds and propagules present in the lakebed, as well as those washed in (Ecological Assoc. 2007). As the lake dries, aquatic vegetation will give way to wetland herb communities (Ecological Assoc. 2007).

The variation in water level provided by the project within the relevant wetland and riparian environments (approximately 200 km of riparian zone and 100 ha of low intermittent wetland) will promote aquatic plants across the full range of the inundation continuum.

The recession of water levels from a peak in the winter/spring period will expose a broad zone of shallow water or damp soils during the spring/summer period. This environment is the habitat for a range of emergent aquatic plants including *Pseudoraphis spinescens, Eleocharis acuta, Phragmites australis* and *Bolboschoenus caldwellii,* as well as seedlings of *Eucalyptus camaldulensis*. The deepest areas are the last to be exposed and form open mudflats before they are opportunistically colonised by herbland plants such as *Centipeda cunninghamii* and *Senecio cunninghamii* (Ecological Assoc. 2013).

The extensive and complex riparian vegetation will benefit a number of fauna including turtles, avian herbivores, cryptic waterbirds such as crake and bittern, frogs that lay eggs on flooded vegetation and shelter from predators in reeds, and small fish such as Murray-Darling rainbowfish and gudgeon which occur predominantly in aquatic vegetation. Reed beds provide nesting materials for swans and grebes and nesting sites for a wide range of bird species. Inundated littoral vegetation is also an important source of organic matter in the aquatic food web (Ecological Assoc. 2013).

Floodplain vegetation

Weir pool manipulation will provide the ability to inundate approximately 500 ha of river red gum Forest or Woodland, 150 ha of black box woodland and 200 ha of lignum shrubland (Ecological Assoc. 2013). This is expected to improve the health of the canopy trees and the diversity of flora within these vegetation communities. In doing so, a range of flow-on benefits will be provided as discussed below.

River red gums occur mainly in riparian and floodplain zones along the River Murray channel and on the edges of waterways and wetlands. They line sections of Moorna Creek, Finnigans Creek and Wallpolla Creek on Wallpolla Island and Carrs, Capitts and Bunberoo Creeks in NSW (Ecological Assoc. 2013). These trees will provide an important source of habitat and a food resource for many fauna, including birds, reptiles and mammals, and will be critical to the successful recruitment of many species (MDBA 2012b). They will also provide submerged woody habitat to anabranches through limb-drop or complete topples (Water Technology 2009; Ecological Assoc. 2007). Submerged woody habitat is a source of food and shelter for fish and aquatic macroinvertebrates. Similarly, limb-drop is a source of organic matter used to fuel primary productivity in the aquatic system (MDBA 2012b).

Black box occurs commonly throughout the floodplain (MDBA 2012b). It occurs at higher elevations in less frequently flooded areas than red gum. Black box woodland has a diverse shrubby understorey that includes *Atriplex* spp., *Einadia nutans, Enchylaena tomentosa* and a range of terrestrial grasses. Aquatic plants that appear during or shortly after flooding would include *Marselia drummondii, Eleocharis acuta* and *Sporobolus mitchellii.* Tree recruitment and productivity is strongly linked to flooding and regular floods are required to maintain a diverse age structure in the tree population (Roberts and Marston 2011). The productivity in woodland vegetation that follows flooding will contribute to the habitat requirements of terrestrial fauna, including a high abundance and diversity of bush birds (Carpenter 1990).

Lignum shrublands are associated with shallow floodplain depressions that are intermittently waterlogged or flooded by rainfall or high river levels (Roberts and Marston 2011). The dominant species are *Duma florulenta* and *Eragrostis australasica* and when flooded can support aquatic species such as *Marselia drummondii* and *Eleocharis acuta*. Flooded lignum shrublands will provide productive habitat for fish and provide nesting habitat for platform-building birds such as ibis and spoonbill (Ecological Assoc. 2013).

A range of flow-on benefits will be provided by improving the health of floodplain vegetation within the project area through weir pool manipulation and inundation. Floodplain vegetation will provide structural habitat for aquatic and floodplain fauna, particularly snags used for grazing and shelter by fish, fallen woody debris will provide shelter for small mammals, ground foraging birds, and many reptiles, and will provide tree hollows and nesting sites (Ecological Assoc. 2013). Flooding of woodland and lignum vegetation will provide nesting habitat for waterbirds and promote breeding by aquatic fauna including frogs and turtles. Insects that fall from the canopy will be consumed by frogs and small fish. Floodplain vegetation will contribute to the overall productivity of the floodplain by providing much of the organic matter, through leaves, woody debris, nectar and seeds, on which aquatic and floodplain food webs depend (Ecological Assoc. 2013).

Waterbirds

Wetlands and low-lying floodplain woodlands provide significant habitat for waterbird foraging. The project is expected to improve the poor bird foraging opportunities which result from the low productivity of permanently inundated riparian and wetland environments, the poor health and limited extent of littoral vegetation and the low frequency of events that inundate floodplain and wetland vegetation (Ecological Assoc. 2013).

Native fish

The project will inundate key habitat features and has potential to provide a cue for migration and spawning and maintain healthy populations of native fish species. Benefits will be provided for both small cod and large-bodied native fish as discussed below.

Small-bodied native fish tend to be wetland specialists and many have a close relationship to aquatic vegetation beds. Weir pool manipulations are expected to enhance habitat for small-bodied fish by providing more productive aquatic habitat, promoting the growth of aquatic macrophytes and providing access to flooded vegetation and woody debris. This will provide food and shelter required for small bodied native fish to complete their lifecycle stages (Ecological Assoc. 2013).

Many of the small-bodied fish live for only one or two years and annual breeding opportunities are required to sustain local populations. Many species will breed each year based on seasonal conditions and others are stimulated by rising flows and flooding; all species will benefit or exploit the favourable conditions that will be created by the newly inundated and productive aquatic habitats provided under the project. Most species require a specific substrate for laying eggs and a variety will be provided under the project. Dense aquatic vegetation will be used by a number of species to lay eggs, including rainbowfish, pygmy perch, hardyheads and smelt. The gudgeon species will use hard substrates such as woody debris to lay and raise their eggs (Ecological Assoc. 2013).

Large-bodied fish have, in general, a preference for larger, open water bodies and the main river channel. With the exception of bony herring, these species are predators and consume fish, frogs, yabbies and shrimps. Bony herring eat algae and micro-crustaceans and are a significant prey for the large Murray cod and golden perch (Ecological Assoc. 2013).

Weir pool manipulation can provide opportunities to promote fish recruitment by conditioning large bodied species and providing access to fish nursery habitat. The intermittently flooded wetlands will provide a valuable source of prey and are expected to be associated with the successful growth and development of juveniles of large fish species. Some large fish species spawn annually, but recruitment is significantly promoted by flooding or water level cues (Mallen-Cooper and Stuart 2003). Aquatic vegetation, reed beds and macroinvertebrate communities will provide juveniles with shelter from predators and abundant prey (Ecological Assoc. 2013).

The combination of inflows to the CCB Creeks system and fish passage within Frenchmans Creek and along the CCB Creeks will greatly improve the ability of native fish to access the habitat within the floodplain waterways.

The anabranch environments present within the Riverland-Chowilla Floodplain have been identified as supporting significant populations of native fish, including provision of valuable habitat for conservationally significant Murray cod (Zampatti et al. 2008; Newall et al. 2009; Zampatti et al. 2011). Key habitat features contributing to the viability of the Murray cod population in the Mullaroo Creek include the sustained moderate flows (e.g. >400 ML/d) and the hydraulic diversity, including sections of variable water velocity and high densities of submerged woody debris in the creek (Saddlier et al. 2008; Water Technology 2009).

The CCB Creeks system, particularly Capitts Creek, has been identified as having great potential for supporting large-bodied native fish such as Murray cod due to its considerable variation in structure (including availability of large woody debris) and geomorphology that provides hydrodynamic diversity – variation inflow velocity, turbulence, depth and width (NSW Public Works & FCS 2013; Ellis and Sharpe 2012). There is a high degree of confidence that the provision of flow, connectivity and hydrodynamic diversity within the CCB Creeks system will result in major improvements in the native fish population as fish respond rapidly to improvements and changes in habitats, especially if there is a source population nearby (such as the River Murray) (NSW Public Works & FCS 2013). It is expected that the diversity of large-bodied native fish will increase (to include both silver perch and freshwater catfish) and that the abundance of large-bodied species will increase so that species such as Murray cod and golden perch are common in the system (NSW Public Works & FCS 2013).

Other biota

There are numerous studies concerning the water requirements of flood-dependent vegetation communities and waterbirds and to a lesser degree the water requirements of native fish communities. The understanding of flow-ecology relationships of other faunal groups generally has more uncertainty owing to the more limited number of studies undertaken for these species (MDBA 2012a).

As per the Basin Plan assessment of environmental water requirements for this location (MDBA 2012a), there is confidence that the environmental water requirements identified to achieve the ecological objectives and targets under the project will also have valuable beneficial effects on the lifecycle and habitat requirements of amphibians, water-dependent reptiles and invertebrates. For example, the 2005 River Red Gum Rescue project recorded the presence of Southern Bell frog (Val et al (2007) and environmental watering sites downstream of the project area (for example at Nampoo and Cliffhouse stations) also have current populations of Southern Bell frog (NSW Environment, Climate Change and Water 2010).

5.4 Monitoring, evaluation and reporting plans

The effectiveness of the proposed supply measure and its operation will be monitored and reported on through NSW DPI Water's monitoring, evaluation and reporting (MER) strategies and protocols. These strategies and protocols aim to:

- Establish a robust program logic to define the correlation between works and other inputs and identified outputs and ecosystem outcomes. This provides the basis for a suite of KPIs that are relevant to the specific site.
- Monitor progress against those KPIs on a regular basis.
- Evaluate the implications of the results for the operational parameters of the scheme.
- Amend and adjust the operational arrangements to optimise performance and outcomes.

Monitoring data is required to plan weir pool raising and lowering regimes, to manage risks and to refine ecological objectives. The evaluation process involves analysing collected data and improving operations.

A suitable MER approach will be formalised once funding for the supply measure has been confirmed.

The final MER approach for this supply measure will be informed by broader intergovernmental arrangements for Basin-wide monitoring and evaluation under the Basin Plan. This measure is expected to contribute to the achievement of outcomes under two key Chapters of the Plan, namely: (i) under Chapter 8, the delivery of ecological outcomes and (ii) under Chapter 10, meeting the relevant sustainable diversion limit/s (SDLs), which must be complied with under the State's relevant water resource plan/s (WRPs) from 1 July 2019.

6 Potential adverse ecological impacts

6.1 Overview of risk assessment

This section provides an overview of identified risks related to ecological impacts associated with the works and operational measures proposed through this project for Locks 8 and 9, the CCB Creeks system and Frenchmans Creek. Where relevant, risks have been separated into two categories, *priority risks from construction* and *priority risks from operation*.

Four broad risk areas have been identified. These include:

- Increase in pest species
- Impacts on ecological function and connectivity
- Salinity and acid sulphate soils
- Temporary habitat disturbance

A full description of individual risks is provided in Appendix 3. Each individual risk has been rated and mitigation strategies developed to minimise impacts associated with the risk. Details of the risk methodology applied are provided below.

6.1.1 Risk assessment methodology

This risk assessment was completed in line with the requirements of AS/NZS ISO 31000:2009. This is a widely adopted and robust framework for these types of projects (Table 6-1 and Table 6-2) and has been applied to be consistent with earlier SDL offset business cases.

The assessment builds on the risk assessment undertaken by NOW during feasibility assessment stages for Locks 8 and 9 weir pool manipulation, which also applied the AS/NZS ISO 31000:2009 methodology.

A regional workshop involving the project steering committee and other experts in fish, floodplain ecology, and cultural heritage was conducted on 14 April 2015 to augment and confirm the risk assessment with key stakeholders.

Table 6-1: ISO Risk Matrix

Likelihood	Consequence			
	Minor	Moderate	Severe	Catastrophic
Remote	Very Low	Very Low	Low	Low
Unlikely	Very Low	Low	Moderate	Moderate
Possible	Low	Moderate	High	High
Likely	Low	Moderate	High	Very High
Almost certain	Moderate	High	Very High	Very High

Table 6-2: Definitions of the levels of risk

	Category	Definitions
Risk	Very Low	There is no reasonable prospect the project objectives will be affected by the event.
	Low	The event is a low priority for management but risk management measures should be considered.
	Moderate	The risk is a moderate priority for management. Risk management measures should be undertaken.
	High	The risk is a high priority for management. There is a reasonable likelihood it will occur and will have harmful consequences. Risk management is essential.
	Very High	The risk is a very high priority for management. It is likely to occur and will have very harmful consequences. Risk management is essential.

6.2 Locks 8 and 9, weir pool manipulation ecological risks

Overall the potential ecological impacts associated with proposed operational changes at Locks 8 and 9 are considered to be low.

Testing and trialling of weir pool manipulation at Locks 8 and 9 has been undertaken by the NSW DPI Water over the previous three years (2012 to 2015). As a result, ecological impacts have been considered through these trials and are used to inform this risk assessment.

Historically weir pools at Locks 8 and 9 have retained relatively stable water levels. The operational changes proposed under this project seek to increase hydrodynamic variability to return the weir pools, associated floodplains and wetlands to a more natural hydrodynamic regime. Increasing hydrodynamic variability can, however, result in some adverse ecological impacts. Potential relevant impacts are discussed further below.

The risks, ratings, mitigation measures and residual risks associated with weir pool manipulation at Locks 8 and 9 are provided in Table 6-3.

The priority ecological risks from operation after mitigation are:

- Enhanced carp recruitment (high)

These risks are a priority for management and will be subject to continual monitoring and mitigation by the operator of the assets. Ongoing monitoring and review of other risks with a residual risk rating of very low or low will be undertaken by the operator as part of regular operational practice to ensure these risks remain at this level.

NSW DPI Water has experience in managing ecological impacts of projects of this type and will also rely on proven collaboration in governance between the MDBA, SA Water and Victorian government agencies.

Table 6-3: Risk assessment and mitigation for potential adverse ecological impacts from operation of the Locks 8 and 9 weir pool manipulations

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Ecological risks from operation						
Increase in pest species						
Increased abundance of pest plant species	Possible	Moderate	Moderate	Where infestation extent and severity is high, implement appropriate control measures e.g. re-flooding vegetation to eradicate juvenile plants to prevent reseeding, modifying water level management to be less favorable for pest plant species.	Low	NOW (2014a) pg. 22; Ecological Assoc. (2013) pg. 72
Enhanced pest fish recruitment (other than carp)	Likely	Moderate	Moderate	During operation, promote conditions which favour native fish species (i.e. reduce scale of weir raising, alter seasonality of weir raising).	Low	Ecological Assoc. (2013) pg. 61, 72
Enhanced carp recruitment	Almost certain	Severe	Very High	During operation, promote conditions which favour native fish species (i.e. timing of weir heights, reduce scale of weir raising, alter seasonality of weir raising).	High	NOW (2014a) pg. 21, 22; Ecological Assoc. (2013) pg. 72
Impacts on ecological function and connectivity						
Mismatch between fish spawning cues and favorable recruitment conditions	Unlikely	Moderate	Low	Develop and implement an operational plan that is considerate of native fish spawning cues and adaptable to take advantage of optimal environmental conditions for native fish recruitment.	Very Low	NOW (2014a) pg. 22
Reduced functionality of existing fishways in Locks 8 and 9	Possible	Moderate	Moderate	Ensure fish passage requirements are built into operational regime. Monitoring and documentation of performance of fishways at different pool and tailwater levels. Adjust timing or maximum surcharge to accommodate fish passage needs.	Low	NOW (2014a) pg. 22
Food chain imbalance	Unlikely	Moderate	Low	Ensure operating reflects natural variability so that all aspects of the local ecology benefit from improved aquatic productivity.	Very Low	Ecological Assoc. (2013) pg. 19
Water quality and acid sulphate soils						
Black water events in areas with high organic loads (during weir pool surcharge)	Unlikely	Moderate	Low	Operating regime will be designed to minimise this risk e.g. increasing watering frequency can reduce build up of organic material	Very Low	Trials indicating low risk. Scott Jaensch Pers. Comm.
Accumulation of salt on floodplain soils	Unlikely	Moderate	Low	Strategic soil quality monitoring. Where salt accumulation threat is identified, reduce the scale of weir raising and increase the average annual weir level through longer drawdown events.	Very Low	Ecological Assoc. (2013) pg. 72 Scott Jaensch Pers. Comm.
Increased salt load in water discharged to the River Murray	Possible	Moderate	Moderate	Water quality monitoring. Where high salt load threat is identified reduce the scale of weir raising.	Low	Ecological Assoc. (2013) pg. 72
Exposure of acid sulphate sediments	Possible	Severe	High	Strategic soil and water quality monitoring. Develop and implement an appropriate operating regime which prevents the exposure of acid sulphate sediments as developed through 2013/14 trials e.g. use local structures to retain water where weir pools are lowered, use frequent short-term lowerings to neutralise acids and normalise soils.	Low	NOW (2014a) pg. 22, 23; Ecological Associates pg. 72

6.3 CCB Creeks connectivity ecological risks

Overall the potential ecological impacts associated with proposed works within the CCB Creeks system are considered to be low.

The existing infrastructure restricts flows within the CCB Creek system including two fixed crest weirs, three constructed block banks and six road crossings. This proposal seeks to upgrade the existing infrastructure to enhance environmental benefits and improve operational effectiveness. The proposed CCB Creek connectivity works all fall within the footprint of previous works.

The risks, ratings, mitigation measures and residual risks associated with CCB Creeks connectivity works are provided in Table 6-4. Potential ecological risks identified are separated into construction risks and operational risks.

No priority ecological risks from construction have been identified where the residual risk remains moderate to very high after mitigation measures have been taken.

Priority ecological risks from operation (i.e. where residual risk remains moderate to high) include:

- Enhanced carp recruitment (moderate)
- Enhanced pest fish recruitment – other than carp (moderate)

These risks are a priority for management and will be subject to ongoing rigorous monitoring and mitigation by the operator of these assets.

Table 6-4: Risk assessment and mitigation for potential adverse ecological impacts from construction works and operation of the CCB Creeks connectivity upgrades

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Priority ecological risks from construction						
Temporary habitat disturbance						
Terrestrial habitat disturbance to facilitate access to construction sites	Likely	Moderate	Moderate	Where tracks require widening or upgrade to provide access to construction sites, minimise native vegetation clearance and disturbance and attain appropriate permits and approvals.	Low	
Temporary habitat disturbance for aquatic fauna and flora (instream and bank)	Likely	Moderate	Moderate	Develop and implement construction plans that minimises the impact of habitat disturbance on aquatic flora and fauna (e.g. time construction to occur when most species are not breeding, select inert construction materials).	Low	
Priority ecological risks from operation						
Increase in pest species						
Enhanced pest fish recruitment (other than carp)	Likely	Severe	High	Adopt seasonal flow regimes that promote conditions which favour native fish species (i.e. hydrodynamic diversity for Murray cod)	Moderate	Ecological Assoc. (2013)
Enhanced carp recruitment	Almost certain	Severe	Very High	Adopt seasonal flow regimes that favour native fish species i.e. hydrodynamic diversity for Murray cod Risk may be reduced compared to current stagnant pools in the CCB	Moderate	NOW (2014a) Ecological Assoc. (2013)
Impacts on ecological function and connectivity						
Mismatch between fish spawning cues and favorable recruitment conditions	Unl kely	Moderate	Low	Develop and implement an operational plan that is considerate of native fish spawning cues and adaptable to take advantage of optimal environmental conditions for native fish recruitment	Low	NOW (2014a) pg. 22
Stream bank erosion after introducing regulated / higher flows	Likely	Moderate	Low	Variable flows will minimise risks. MER at key points as part of commissioning to confirm risk. Complementary actions such as stock management	Very Low	Risk workshop
Low flows at Lock 9 could see failure to maintain raised velocity inflows	Possible	Moderate	Moderate	Operating rules to be developed. Flows down CCB Creeks are a small % of total weir pool volume. Could target low flows down one creek to optimise outcomes	Very Low	Risk workshop
Poor reliability / operability of constructed vertical slot fishways at Carrs weirs	Possible	Moderate	Moderate	Through flows modelling and good design Observing and monitoring fish passage outcomes	Low	Risk workshop
Impacts on river below Lock 9 from flows diverted down CCB Creeks	Unl kely	Minor	Low	The majority of flows from CCB Creeks return to Lock 8 weir pool so there will be only limited impact at tail pool immediately below Lock 9	Very Low	Risk workshop

6.4 Frenchmans Creek fish passage ecological risks

Overall the potential ecological impacts associated with proposed works within Frenchmans Creek are considered to be minimal.

Currently the Frenchmans Creek Inlet Regulator is a significant barrier to fish movement along Frenchmans Creek. This project proposes undertaking works to install an appropriate fish passage that will allow for improved fish movement between Lake Victoria and the River Murray.

The risks, ratings, mitigation measures and residual risks associated with Frenchmans Creek fish passage works are provided in Table 6-5. Potential ecological risks identified are separated into construction risks and operational risks.

No priority ecological risks from construction have been identified where residual risk remains moderate to very high after mitigation measures have been taken.

Priority ecological risks from operation (where residual risk remains moderate to high) include:

- Enhanced pest fish recruitment – other than carp (moderate)
- Enhanced carp recruitment (moderate)
- Poor operability of fishway constructed at the inlet regulator leading to hampered fish passage (moderate)

These risks are a priority for management and will be subject to ongoing rigorous monitoring and mitigation by the operator of these assets.

Table 6-5: Risk assessment and mitigation for potential adverse ecological impacts from operation of the Frenchmans Creek fish passage works

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Ecological risks from construction						
Temporary habitat disturbance						
Temporary habitat disturbance for aquatic flora and fauna (instream and bank)	Likely	Moderate	Moderate	Develop and implement a construction plan that minimises the impact of habitat disturbance on aquatic fauna (e.g. time construction to occur when most species are not breeding, select inert construction materials)	Low	Risk workshop
Ecological risks from operation						
Increase in pest species						
Enhanced pest fish recruitment (other than carp)	Likely	Moderate	Moderate	Through fishway operation promotes conditions which favour native fish species	Moderate	Risk workshop
Enhanced carp recruitment	Likely	Moderate	Moderate	Limited controls effective	Moderate	Risk workshop
Impacts on ecological function and connectivity						
Poor reliability / operability of fishway constructed at the inlet regulator leading to hampered fish passage	Poss ble	Severe	High	Through flows modelling and good design Observing and monitoring fish passage outcomes Commissioning trialling and altering fishway operations Commitment by SA Water to ongoing maintenance	Moderate	Risk workshop

7 Current hydrology and proposed changes

7.1 Project area description

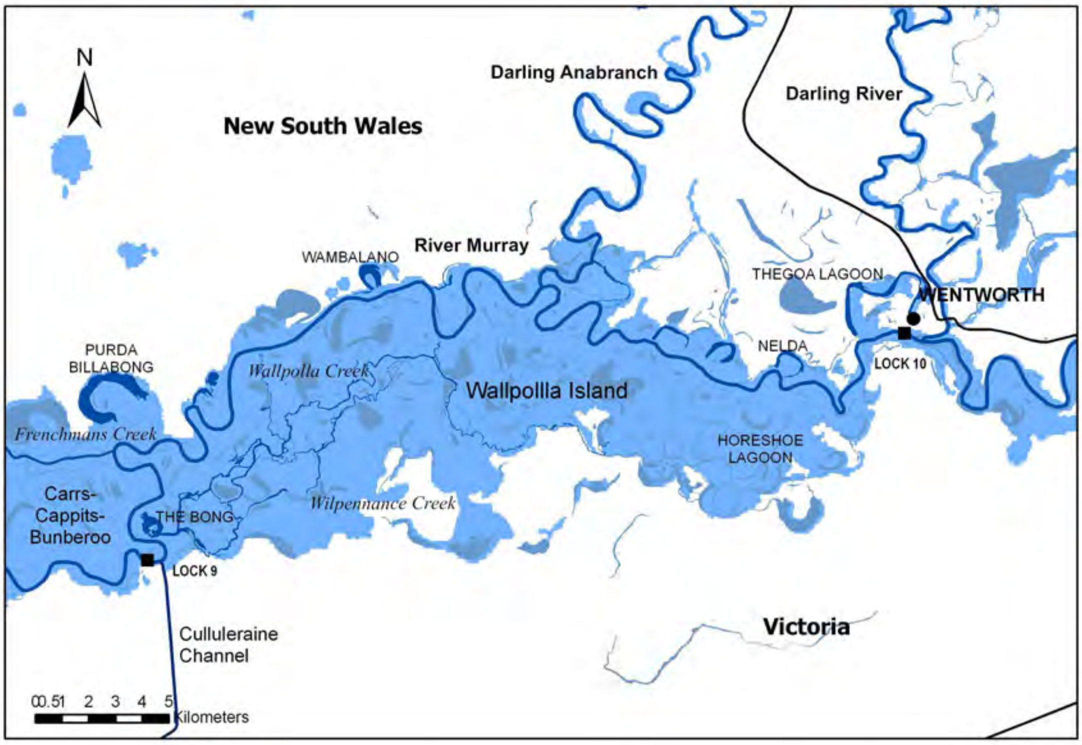
7.1.1 New South Wales floodplain from Lock 10 to Frenchmans Creek

The River Murray floodplain between the Darling River and Frenchmans Creek in New South Wales is generally less than 2 km wide (Figure 7-1). The floodplain features a series of billabongs with low-level sills at the downstream end through which water backs up when river levels first start to rise. At higher flows, water enters the upstream end of the billabong and through-flow commences.

When the River Murray is in flood, the floodplain corridor along the river is inundated, including the areas surrounding the billabongs. When the Darling River is in flood, water enters this reach via the Great Darling Anabranch and by overland flow from the Darling which inundates the area between Six Mile Creek, the Darling River and the Murray River (MDBA 2010). Darling River floods also follow the main stem of the Darling channel exiting at Wentworth just above Lock 10.

Thegoa Lagoon is a wetland located downstream of the Darling Junction, west of Wentworth, covering an area of 80 ha. The wetland is regulated and has been managed according to a wetland management plan since 1996. It can be filled from the Lock 10 weir pool and may be drained to the Lock 9 weir pool (Thegoa Lagoon Management Steering Group 2003). Nelda is a low-lying ephemeral wetland that is inundated by small increases in the river level upstream of Lock 9. Wambalano (351) is an oxbow wetland permanently inundated by the Lock 9 weir pool. Purda Billabong is connected to Frenchmans Creek on the northern (upstream) side. The wetland is permanently inundated by Lock 9. A second upstream connection diverts water to the wetland from the River Murray at high flows (Jensen 2004).

Figure 7-1: Floodplain features between Lock 9 and Lock 10 [Source: prepared by Ecological Associates 2015]



7.1.2 Darling Anabranch

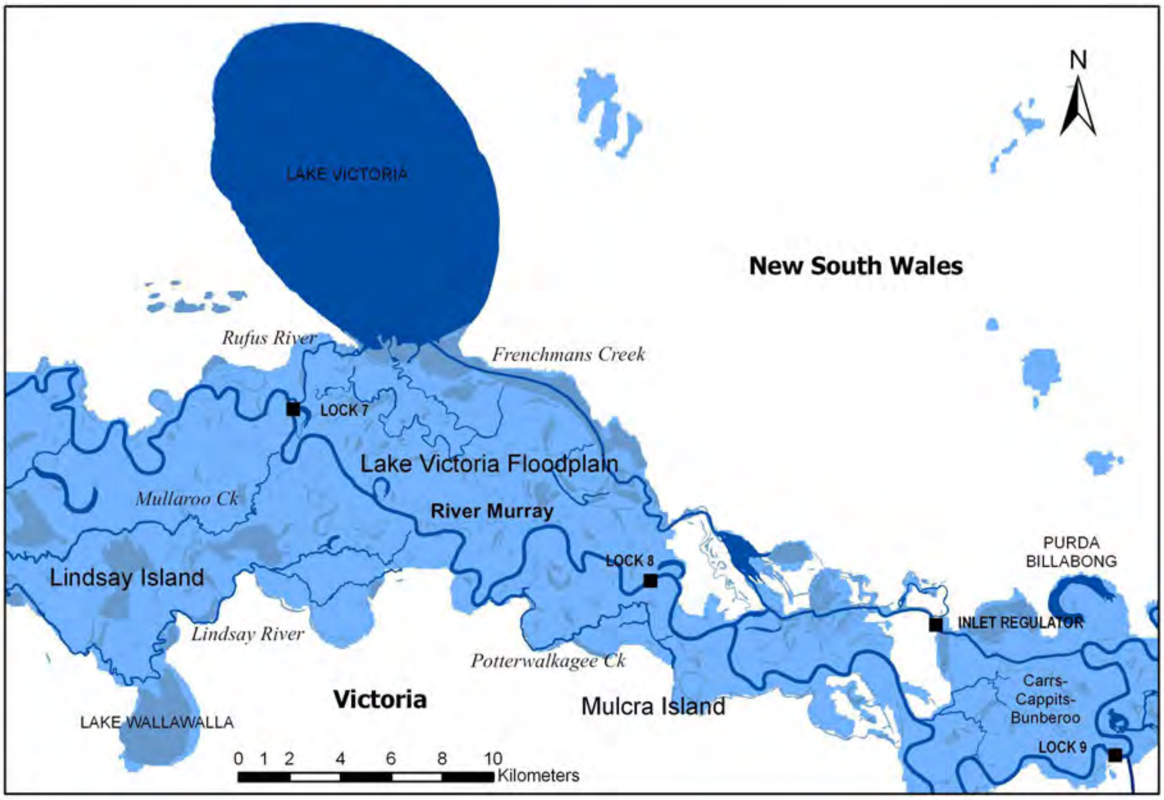
The Darling Anabranch is an ancestral channel of the Darling River. The anabranch is approximately 480 km long and diverges from the Darling River about 55 km south of Menindee. It joins the River Murray between Locks 9 and 10 at 807 river km. The anabranch receives water from the Darling River when flows upstream of the anabranch offtake exceed 9,000 ML/d at Weir 32 (Bogenhuber & Linklater, 2011) or via Tandou or Redbank Creeks when flows passing Menindee exceeds 20,000 ML/d (GHD 2008). Under low Murray flows, the Lock 9 weir pool backs up approximately 30 km into the anabranch (MDBA 2010). The weir pool has promoted the growth of *Typha* in the anabranch channel and maintains the health of red gum, black box and lignum on the banks (Bogenhuber et al. 2011).

7.1.3 Lake Victoria floodplain

Lake Victoria is a naturally occurring shallow freshwater lake that is managed as a water storage. The lake has an area of 12,200 ha and a maximum depth of about 5.5 m. The Lake Victoria floodplain comprises the area on the right bank of the River Murray between Frenchmans Creek (near Lock 9) in the east and the Chowilla Floodplain in the west.

River water is diverted to the lake from the Lock 9 weir pool, via Frenchmans Creek, and returned via Rufus River below Lock 7. Lock 8 is located near the mid-point of the system (Figure 7-2). The downstream extent of the NSW floodplain is defined by the Rufus River which joins the River Murray just below Lock 7. The northern boundary of the floodplain is broadly defined by the regulated channels that deliver water to and from Lake Victoria. Frenchmans Creek and associated floodplain comprises in the order of 1,000 hectares of high value, high productivity wetlands and floodplain area.

Figure 7-2: Lake Victoria Floodplain and upper Lindsay Island [Source: prepared by Ecological Associates 2015]



Frenchmans Creek diverges from the River Murray at 779 river km, approximately 14 km upstream of Lock 9. Lock 9 raises the river level to provide gravity feed to Lake Victoria, with flow controlled at the Inlet Regulator 7 km from the Murray. The creek flows approximately parallel to the river at a distance of 2 to 5 km in a channel that has been straightened and enclosed by levees to deliver water more efficiently. Regulated flow into Lake Victoria can often exceed the passing flow in the River Murray below Lock 9.

Substantial cut-off channels along Frenchmans Creek include Carrs Billabong to the north and Little Rigamy Creek to the south. Big Rigamy Creek is a broad backwater, approximately 100 m wide, that extends from the River Murray at 737 river km to the Frenchmans Creek levee bank. Levees on the south side of Frenchmans Creek limit the spread of water to the floodplain, but a number of wetlands are flooded by weir pools, including Latinas Flat and Purda Billabong to the north.

The CCB Creeks system is a network of floodplain anabranches within the upstream part of the Lake Victoria floodplain to the north of Lock 9. Banks prevent water spilling to the creeks from the Lock 9 weir pool in Frenchmans Creek: fixed crest weirs are located at the two major inlets at Carrs No. 1 and Carrs No. 2, while a block bank (B) is located on a higher level flood-runner that flows into Bunberoo Creek. The Lock 8 weir pool permanently inundates the lower reaches of the CCB system. Lock 8 Wetland is located adjacent to Lock 8. The entrance to the wetland is crossed by the access road to the lock where a regulator has been installed to allow water to be stored in or excluded from the wetland independently of Lock 8 levels.

With the exception of the Lake Victoria and the CCB Creek systems, the structure and hydraulics of the floodplain require further understanding. Further work is required to develop a comprehensive picture of flow paths and floodplain habitats.

7.1.4 Wallpolla Island

The River Murray floodplain upstream of Lock 9 on the Victorian side lies almost entirely within Wallpolla Island (Figure 7-1). Wallpolla Island is made up of watercourses, wetland basins and freely-draining floodplain areas. It extends for 29 km from east to west and covers an area of approximately 9,000 ha. Wallpolla Creek is 7 km from the river at the island's widest point.

The watercourses are deeply incised in the floodplain and, in the west of the island, are permanently inundated by the Lock 9 weir pool. The weir pool of Lock 9 extends 25 km upstream through Wallpolla Creek and a number of other channels (Ecological Assoc. 2007). The Bong is a permanent wetland within the island located 2 km upstream of the weir.

The upstream connections of watercourses in the east of the island start to become active at River Murray flows exceeding 3,000 ML/d, but significant anabranch flow requires higher levels. Finnigans Creek becomes active at flows exceeding 8,000 ML/d and Sandy Creek flows when river discharge exceeds 33,000 ML/d. The upstream connection of Wallpolla Creek becomes active when river discharge exceeds 70,000 ML/d.

There are few low-lying wetland areas at Wallpolla Island. Water backs into several scroll bar wetlands along the riverbank at flows exceeding 30,000 ML/d, including the Lilyponds. Horseshoe Lagoon also starts to fill at 30,000 ML/d. As river levels continue to rise, water spills into the surrounding river red gum forest and woodland. Several low-lying wetlands adjacent to the anabranches are filled as river levels increase. Most wetlands are filled at flows between 30,000 and 60,000 ML/d. Flood water is largely confined within the wetlands and deeply incised channels until river flows exceed 70,000 ML/d at which point water spills to black box woodlands and lignum shrublands. Widespread floodplain inundation, including to alluvial plain vegetation, occurs at flows exceeding 90,000 ML/d.

Table 7-1: Inundation thresholds for Wallpolla Island

Threshold flow (at Lock 10)	**Feature**
3,000 ML/d	Minor anabranch inflows
8,000 ML/d	Finnigans Creek inflow commences
30,000 ML/d	Inundation commences at Horseshoe Lagoon, the Lilyponds, other point-bar billabongs and surrounding floodplain
33,000 ML/d	Sandy Creek inflow commences
70,000 ML/d	Inflows to upstream connection of Wallpolla Creek Significant floodplain inundation commences
90,000 ML/d	Widespread floodplain inundation

7.1.5 Mulcra Island and Big Paddock

The floodplain upstream of Lock 8 on the left bank comprises Mulcra Island and Big Paddock (Figure 7-3). The Mulcra Island floodplain system comprises Mulcra Island and the adjacent floodplain areas, covering an area of 3,199 ha. The island is enclosed between the river and the Potterwalkagee Creek anabranch. The system is located on the left (Victorian) bank of the River Murray between 758 and 720 river km. Lock 8 is located on the River Murray at the mid-point of the island at 732 river km.

Potterwalkagee Creek diverges from the river at 746 river km. The first section of the creek flows intermittently and passes through the shallow wetland of Snake Lagoon. Near the central part of the island the creek receives inflows from the Stoney Crossing effluent which diverts water from the Lock 8 weir pool. The lower part of the creek, near the confluence with the River Murray, is permanently inundated by the Lock 7 weir pool.

The Mulcra Horseshoe is a deep billabong located between Potterwalkagee Creek and the River Murray below Lock 8. The billabong and its flood runners occupy 78 ha. The wetland starts to receive inflows from the river when discharge exceeds 26,000 ML/d and is filled when flow exceeds 40,000 ML/d.

Floodplain inundation commences with water spilling into low meander scrolls on the river bank and backing up into shallow woodland and lignum areas in the lower Potterwalkagee Creek area. Widespread inundation of woodland areas occurs at flows exceeding 60,000 ML/d with flooding of higher level black box woodland complete at flows over 120,000 ML/d.

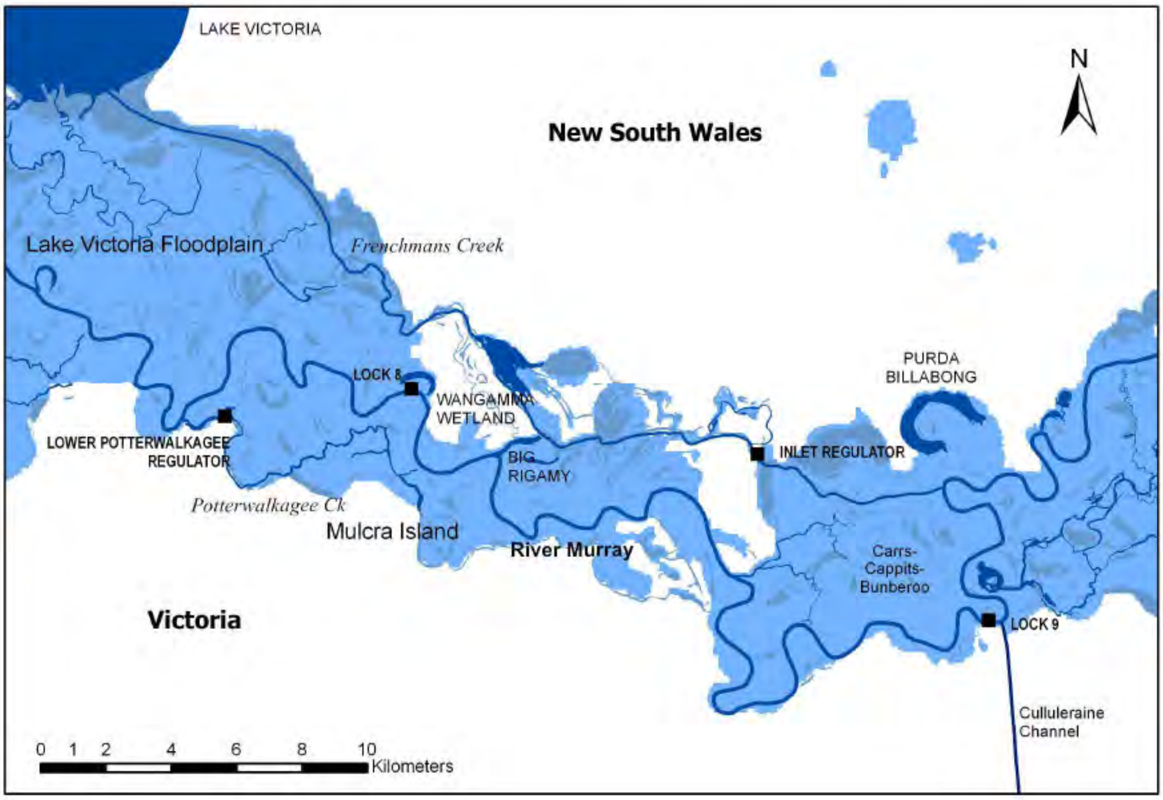
Under TLM Mulcra Island flood enhancement project, works were completed to promote flowing water habitat and more frequent floodplain inundation. The works involve:

- The Mulcra Weir on Lower Potterwalkagee Creek. This may be raised in conjunction with the Lock 8 weir pool to inundate a combined area of 822 ha in Victoria and NSW.
- A lower sill and regulator at Stoney Crossing and a regulator on Upper Potterwalkagee Creek. These works permit greater and more variable flow into Potterwalkagee Creek from Lock 8 and may be operated in conjunction with raising Lock 8.
- Regulators and stop banks on the Mulcra Horseshoe to detain flood water. Flood water may be introduced when the Mulcra Weir is raised, by natural flood events or by pumping.

Table 7-2: Key inundation for the River Murray floodplain at Mulcra Island

Threshold flow (at Lock 9)	**Feature**
Pool level	Stoney Crossing inflows to Lower Potterwalkagee Creek
40,000 ML/d	Mulcra Horseshoe filled
60,000 ML/d	Red gum woodlands largely inundated
120,000 ML/d	Black box woodlands largely inundated

Figure 7-3: Floodplain systems upstream of Lock 8 [Source: prepared by Ecological Associates 2015]



7.2 Hydrological context

River Murray flows originate in the largely temperate southern Murray-Darling basin, which includes the Murray, Murrumbidgee and Goulburn tributaries. These produce largely seasonal flows that are highest from late winter to early summer. The Darling River, which drains the northern basin, is often influenced by sub-tropical weather systems that typically generate large flows in the summer. The largest flow events downstream of Lock 10 occur when both the Darling and Murray systems are in flood.

River hydrology has been altered significantly by regulation and diversion upstream. Storages in Victoria and New South Wales are managed to capture water during winter and spring and to deliver this water at manageable flow rates to consumers (primarily irrigators) during the summer. The impact on river hydrology has been a reduction in large winter and spring flow peaks and enhancement of low summer flows. Locks and weirs have further altered floodplain water regimes by stabilising river levels for the purpose of navigation.

The ecologically significant adverse effects of the current infrastructure and operating rules compared to the natural hydrology have been to:

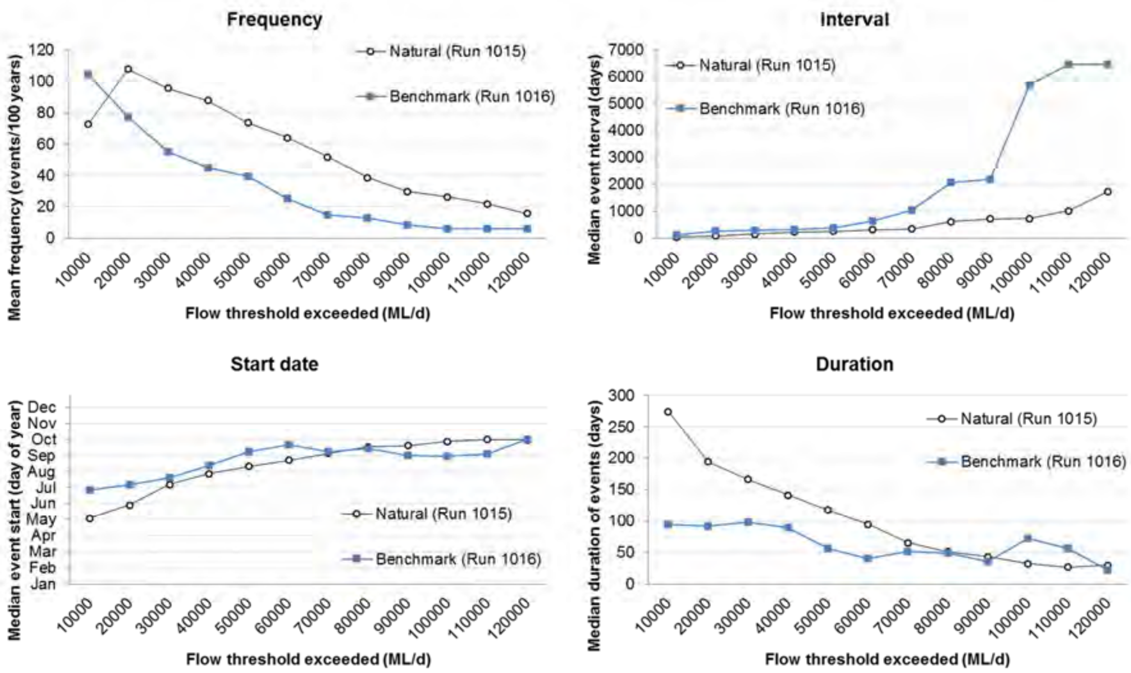
- largely eliminate flowing water habitat under normal regulated flows;
- permanently inundate wetlands, the river channel and low-lying floodplain areas in the vicinity of the weir pools; and
- reduce the frequency and duration of floods that reach higher-level wetlands and floodplain areas.

The hydrology of the river upstream of Lock 9 has been characterised by analysing the MSM_Bigmod daily flow series for Natural and Current (Benchmark) scenarios, using data from 1891 to 2009 (Figure 7-4).

The river now spends more time fluctuating at very low flows, less than 10,000 ML/d, than under natural conditions as indicated by higher than natural spell frequency but much shorter spell duration. Events that inundate low-lying wetlands, between 30,000 and 60,000 ML/d, now occur at less than half the frequency of natural conditions. The duration of these events, when they do occur, has also been reduced by approximately 50%. The impact on floodplain inundation is also significant. While the duration of spells exceeding 70,000 ML/d under current conditions is similar to natural, the frequency of these events has declined to as much as 25% of natural. This has resulted in a major increase in the interval between spells for very high flows.

The spell timing (represented by start day) was shifted forward by around one month for spells with threshold lower than 80,000 ML/d.

Figure 7-4: Spells analysis for River Murray flows upstream of Lock 9 for Natural and Benchmark scenarios over a 114 year modelled period (Source: Fluvial Systems 2014)



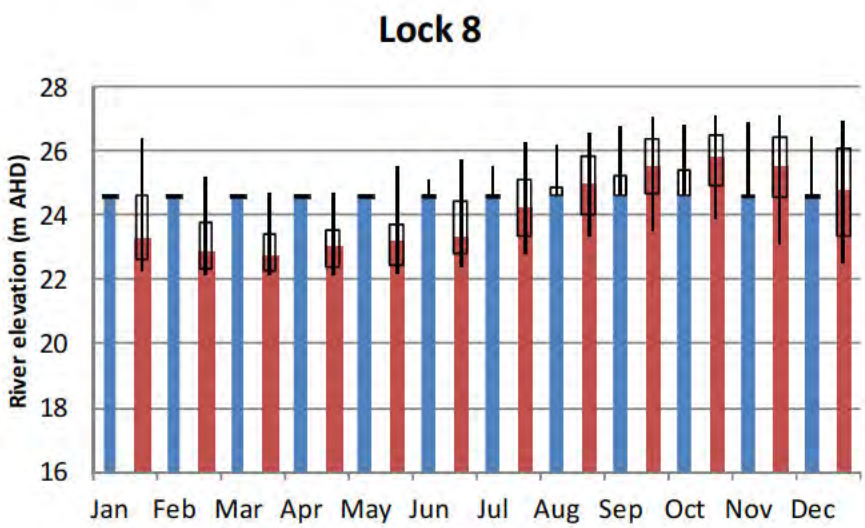
7.3 Hydraulic effects of the weirs

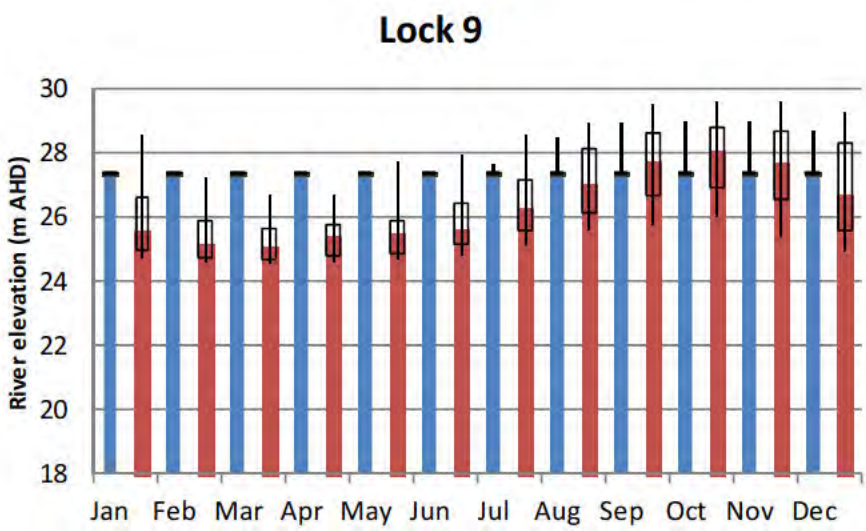
7.3.1 Water level variability

For navigation purposes, the weirs are currently managed to create a stable level upstream, close to the capacity of the river channel. The weirs are opened and closed as flow varies, so a stable river level can be maintained. The weirs are effective until discharge at the weir exceeds the capacity of the structure. At this point the river levels below and above the weir equalise. If the weir cannot be opened any further, it is removed and rising discharge results in rising river levels.

The influence of the weirs is strongest in the river immediately upstream. Water spilling over the next weir upstream creates a tailwater zone, where variation in river discharge results in variable river levels. The tailwater zone becomes longer as discharge increases, which corresponds to an expansion of the lower weir pool. Variation in river levels has been greatly reduced by the operation of the weirs and the depletion of flows through storage and diversion (Figure 7-5).

Figure 7-5: Monthly water levels at Locks 8 and 9 showing the median (bars), 25th and 75th percentiles (boxes) and 5th and 95th percentiles (whiskers) under natural (red) and current (blue) conditions [Source: Fluvial Systems 2014]





Notes:

(i) MSM_Bigmod hydrology 1895-2009 using run 23747 Benchmark for Current (includes TLM and a minimum Lock 9 downstream flow of 730 ML/d to supply Mullaroo Creek) and run 23743 for Natural

(ii) Current was applied to the rating upstream of weirs and Natural was applied to the rating downstream of weirs

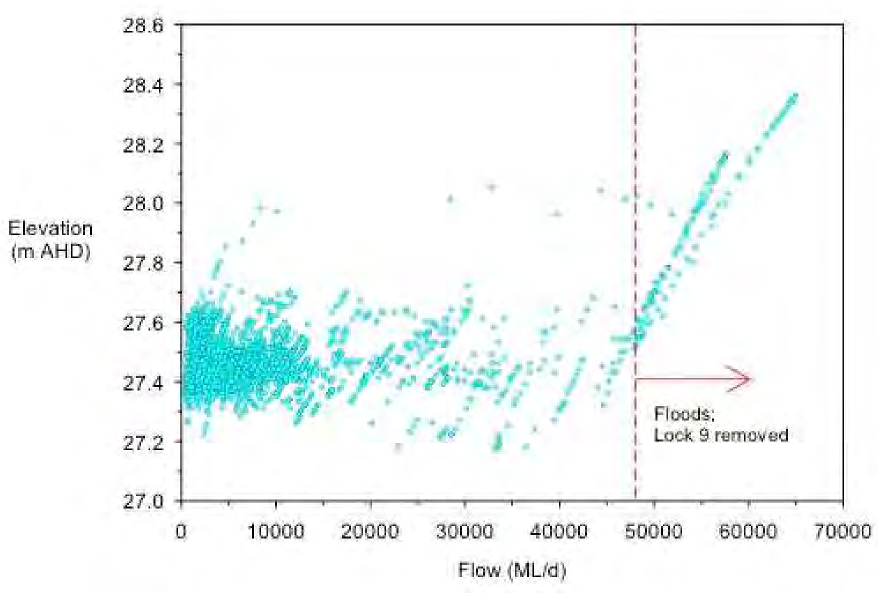
(iii) Ratings were derived from empirical data

(iv) Ratings downstream of weirs are influenced to some extent by the next weir downstream, so do not simulate the true natural situation. True natural levels would possibly be lower than indicated for the middle range of flows (i.e. low flows are free flowing and high flows are not impacted much by weirs).

Under natural conditions the river levels exhibited a strong seasonal cycle in water levels with the median autumn level two to three metres lower than the median level in spring. The river levels showed high inter-annual variability with range between the 5th and 95th percentile in spring ranging over 1.5 to 5 m, depending on the site. A smaller variability in flows is exhibited at sites where floodplains convey a substantial proportion of high flows (Lock 6, Lock 7, Lock 8). Variability is greater at Lock 9 and 10 where the floodplain is relatively narrow and high flows are conveyed in the main river channel.

Under current development and operating practices the weirs have raised the river to a level similar to the median annual peak, i.e. the spring seasonal level. Variation in river levels has been largely eliminated from the low-flow seasons of summer and autumn. In winter and spring, median river levels are maintained close to the target pool level, but rare, high flows continue to provide elevated water levels (Figure 7-6).

Figure 7-6: Lock 9 upstream gauge levels versus flow: 95% of the time the weir pool is within 27.3 and 27.6 m AHD when not in flood (Source Public Works NSW – FCS, 2013)



7.3.2 Velocity

Prior to the construction of the weirs, fast and slow-flowing habitat was present throughout the lower River Murray. Water velocity was elevated in areas where the channel bed was shallow or confined. Velocity was lower where the channel was deep and broad. The weirs have largely eliminated fast-flowing habitat and converted the lower River Murray into a series of lakes. Weirs confine head loss to the short step in river level immediately below the weir and create a relatively flat river surface elsewhere.

Weirs increase the cross-sectional area of the channel and reduced water velocities to ecologically insignificant levels. Anabranches provide moderately elevated velocities by spreading the weir head loss over a longer channel length; these conditions are provided around Lock 6 in the Chowilla floodplain, around Lock 7 in the Lindsay floodplain and around Lock 8 in the Mulcra floodplain. Significant velocities now only occur in the river channel at high river discharges.

Fast-flowing water is an important habitat requirement for native fish and is associated with the diversity, abundance and recruitment success of native fish populations in the Chowilla and Mullaroo Creeks. An analysis of the river channel between Lock 6 and 7 illustrates the effect of weir construction on velocity in the study reach (Mallen-Cooper, et al. 2011). This study classified channel velocities according to their ecological significance and modelled natural river hydraulics at a range of flows (Figure 7-3).

Table 7-3: Fish habitat velocity classification (Mallen-Cooper, et al. 2011)

Water Velocity m/s	Fish habitat
0 - 0.03	Backwaters
0.04 - 0.1	Weir pools in the main river channel
0.11 - 0.17	Slow-flowing
0.18 - 0.30	Moderate-flowing
0.31 - 0.50	Fast-flowing
>0.50	Very fast

A velocity greater than 0.17 m/s is the minimum required for species dependent on flowing habitat. Watercourses with velocities greater than 0.3 m/s provide the habitat for large-bodied fish but particularly for spawning Murray cod in spring. Murray cod and other large-bodied fish select these fast-flowing habitats (Mallen-Cooper et al. 2011).

7.4 Proposed hydrology

7.4.1 Locks 8 and 9 weir pools

The rise and fall of river levels is an important factor in the health of the River Murray and its floodplain. Intermittent flooding and exposure is associated with the growth, productivity and recruitment of floodplain vegetation, with the extent and complexity of riparian plant communities, with the formation of bacterial biofilms, with the mineralisation of organic matter and with the quality of habitat for birds, fish and other fauna (Ecological Assoc. 2013).

Water level variation has been reduced in the study area through a combination of lock operation and river regulation. Weirs raise and stabilise the river levels upstream while flow regulation has reduced the frequency and duration of peaks that inundate the floodplain. This project proposes to operate the weirs at Locks 8 and 9 to restore some water level variation to the riverbank and the nearby floodplain.

The primary targets are the water requirements of a small but important component of the ecosystem: the littoral and riparian zone of wetlands and watercourses, and flowing water habitat. The objectives are to promote a broader zone of macrophytes, to increase productivity and habitat quality, to promote habitat use by aquatic fauna and waterbirds and to promote fish growth and reproduction.

These objectives are met most effectively by a regime of inundation in late winter or spring and gradual drawdown over late spring and summer. Inundation provides aquatic fauna with access to flooded vegetation when it is most important to growth and reproduction. A gradual drawdown over spring will promote macrophyte growth over a broad zone, with shallow water and mudflats provided in summer. Inter-annual variability is an important component of natural water regimes. Variability would be imposed on this cycle by high river discharge or the operation of weirs to support floodplain inundation.

The scope for weir pool manipulation differs at each weir according to river hydraulics, structure design and local water uses. Ongoing investigations, monitoring and review is required to refine the limits of weir manipulation including the following questions:

- Effects of higher or lower pool levels on fishway function (to confirm that the proposed operating range is within the design range for the vertical-slot fishways)
- The tailwater levels required to maintain upstream passage to fishways
- The location, level and stability of banks, roads and other structures that are overtopped by weir raising
- Effects of raising weirs on upstream fast-flowing habitat
- Effects on flow velocity and fish habitat on drawing down pools at key times
- The potential to inundate private and public infrastructure e.g. isolating pumps by weir lowering

At present, weir pool manipulations represent a change from normal operations. For each event, planning and coordination is required between weir operators, environmental managers and the MDBA. In addition, significant communication is required with the community. It is planned that seasonal water level cycles will become a routine part of weir operations at Locks 7 to 9.

The first step to making seasonal weir variation routine is to establish management arrangements and to adjust community expectations. This began at Locks 8 and 9 in 2013 where there are low levels of development and there are few impacts on river users. Initially the objectives were not ecological, but administrative: to establish processes for administration and communicating forthcoming weir operating levels with the community. Once these arrangements are refined and in place, ecological objectives will become the primary focus, within the constraints of the overarching navigational objective.

Annual weir operating plans and areas of inundation

Illustrative weir height adjustment scenarios were developed during the Phase 1 feasibility assessment of the project (Ecological Assoc. 2013). Modelling of flood behaviour in the Lock 8 and 9 weir pools (and associated floodplain, creeks and wetlands) has been used to estimate the extent of inundation associated with raising the weir pools to their maximum extent and lowering the weirs to their minimum permissible levels. The modelling was conducted assuming either 10,000 or 20,000 ML/d flow in the River Murray (MIKEFLOOD model; MDBA 2012c). The illustrative modelled weir height scenarios are outlined in Table 7-4.

Table 7-4: Modelled weir height scenarios above normal operating level (m)

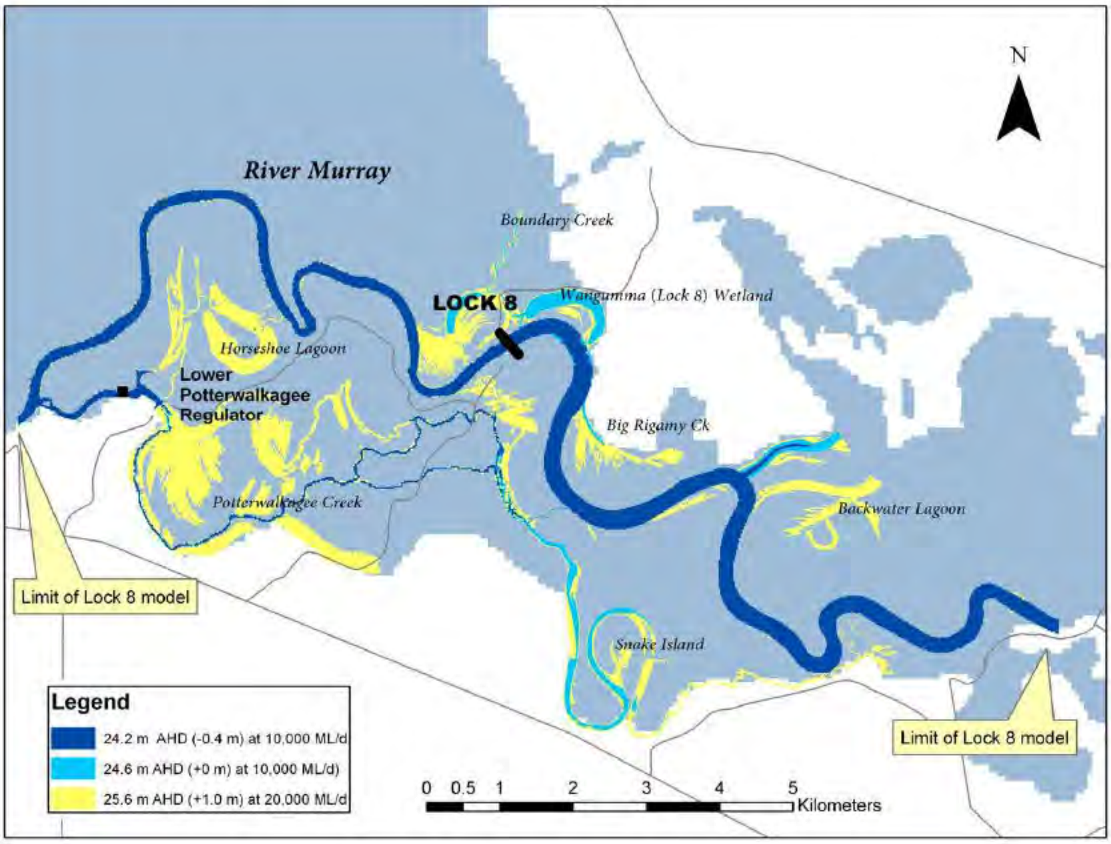
	Lock 8 24.6 m AHD	Lock 9 27.4 m AHD
Drawdown	-0.4	-0.4
	-0.2	-0.2
Surcharge	+0.2	+0.3
	+0.5	+0.5
	+1.0	

The extent of the Lock 8 weir pool is over 1200 ha when raised a maximum of 1.0 m. This is similar to the inundation achieved at high flows (50,000 ML/d) without the influence of the weir. This area of inundation can be achieved by simultaneously raising the Lower Potterwalkagee regulator. Overall an area of 700 ha can be exposed to seasonal inundation through manipulation of Lock 8 over a range of -0.4 and +1.0 m. Table 7-5 outlines the estimated change in area of inundation for Lock 8 for a range of illustrative weir height adjustments for three Murray River flow rates (noting that the actual regimes adopted will differ between seasons and years). The extent of inundation and exposure under this scenario is illustrated in Figure 7-7.

Table 7-5: Effect of weir level manipulation on the area (hectares) of the Lock 8 weir pool (Source: Ecological Assoc. 2013, MDBA 2012c)

Weir Adjustment (0 = 24.6 m AHD)	10,000 ML/d		20,000 ML/d		50,000 ML/d
	Area (ha)	Δ Area (ha)	Area (ha)	Δ Area (ha)	Area (ha)
-0.4	532	-106	575	-103	
-0.2	537	-101	582	-96	
0	**638**	**0**	**678**	**0**	**1,315**
+0.2	671	+33	701	+23	
+0.5*	931	+293	953	+275	
+1.0*	1,236	+598	1,270	+592	

Figure 7-7: : Extent of the Lock 8 weir pool under scenarios for raising (20,000 ML/d + 1.0 m) and lowering (10,000 ML/d – 0.4 m) [Source: spatial data provided by NSW DPI Water, Mallee CMA, MDBA, 2015; prepared by Ecological Assoc. 2015]



Raising Lock 9 by the maximum possible adjustment of +0.3 m results in only a modest increase in the extent of the weir pool of less than 200 ha at 10,000 ML/d. When the weir is lowered by 0.4 m between 480 and 580 ha is exposed for flows of 10,000 ML/d and 20,000 ML/d respectively. Table 7-6 outlines the estimated change in area of inundation for Lock 9 for a range of illustrative weir height adjustments for three Murray River flow rates (again noting that the actual regimes adopted will differ between seasons and years).

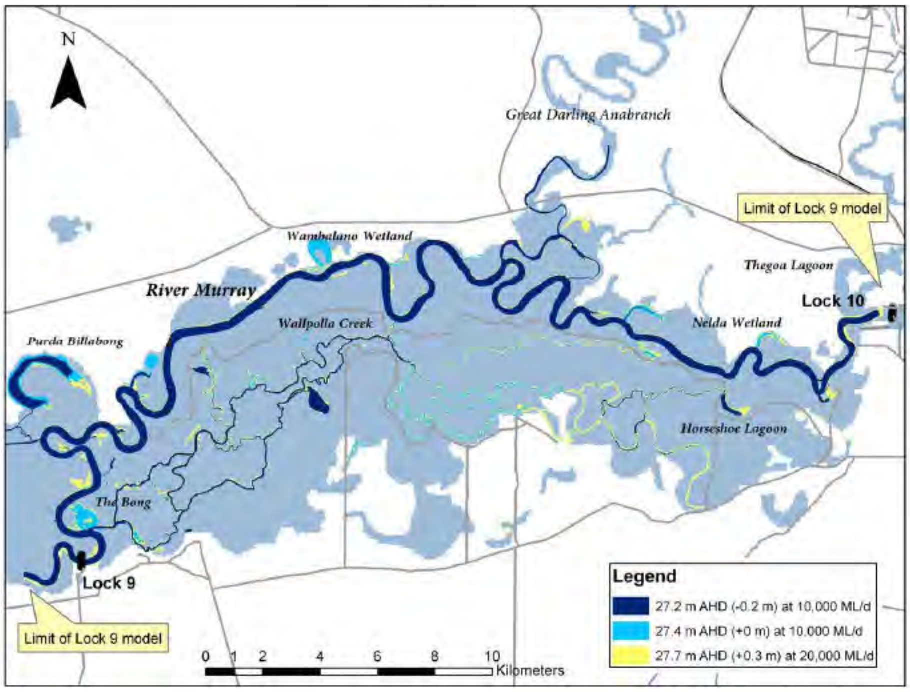
Table 7-6: Effect of weir level manipulation on the area (hectares) of the Lock 9 weir pool (Source: Ecol Assoc. 2013, MDBA 2012c)

Weir Adjustment	10,000 ML/d		20,000 ML/d		50,000 ML/d
(0 = 27.4 m AHD)	Area (ha)	Δ Area (ha)	Area (ha)	Δ Area (ha)	Area (ha)
-0.4	2,059	-478	2,335	-576	
-0.2	2,154	-383	2,375	-536	
0	**2,537**	**0**	**2,911**	**0**	**4,056**
+0.2	2,700	163	3,046	135	
+0.3	2,715	178	3,054	143	
+0.5	2,994	457	3,364	453	

Weir height variations affect floodplain inundation upstream as far as Lock 10. The water line can move more than 1 km between a lowered weir pool and a raised weir pool, for example using a scenario of drawing down 0.2 m at 10,000 ML/d and raising 0.5 m at 20,000 ML/d. The extent of inundation and exposure under this scenario is illustrated in Figure 7-8.

Trials continue to further test and expand limitations to weir pool manipulation and it is expected that further expansion in variation will be possible over time.

Figure 7-8: Extent of the Lock 9 weir pool under scenarios for raising (20,000 ML/d + 0.3 m) and lowering (10,000 ML/d – 0.2 m) [Source: spatial data provided by NSW DPI Water, Mallee CMA, MDBA, 2015; prepared by Ecological Assoc. 2015]



7.4.2 Carrs, Capitts and Bunberoo Creeks connectivity

Prior to the construction of weirs, fast-flowing water was a normal characteristic of the River Murray channel, even at low discharges. Fast-flowing habitat provides a diversity of hydraulic environments that support a wide range of macroinvertebrates, small fish and larvae that provide prey for large predatory fish like Murray cod and golden perch. It has been suggested that slower flowing habitats, adjacent to or downstream of these reaches, are the destination of eggs and spawn of these species, where food resources would be concentrated and aid in their survival (Mallen-Cooper et al. 2008).

The decline of fast-flowing habitat has contributed to the decline of native fish populations in the River Murray below Lock 10. The only two reaches of perennial fast-flowing habitat in the River Murray below Lock 10 are found in Mullaroo Creek and at Chowilla, where anabranches divert water around weirs. These sites support the only self-sustaining populations of Murray cod in the Lower Murray (Mallen-Cooper et al. 2008; Saddlier et al. 2008). These sites also contribute to healthy populations of golden perch, Australian smelt and freshwater catfish.

The hydraulics of natural channels are complex and involve spatial and temporal variation associated with channel form, debris, vegetation and variable discharge. As a general guide to managing flow for native fish mean, cross-sectional velocities between 0.3 and 0.5 m/s are targeted as fast-flowing habitat (previous Table 7-3).

A proposal has been developed to rehabilitate the CCB Creeks system to provide perennial, fast-flowing habitat over a total channel length of 12 km (NSW Public Works - FCS 2013). The proposal replicates elements of the perennial and hydraulically diverse environment of the river channel under natural conditions.

The proposal is to install regulators so that water can pass between the Lock 9 and Lock 8 weir pools to generate perennial flow through the network of narrow creek channels. The physical habitat in the creek includes deep holes, snags and backwaters that would contribute to significant hydraulic and habitat diversity for aquatic fauna. The system has the potential to support significant populations of Murray cod and golden perch and to support lesser populations of silver perch and freshwater catfish. Small-bodied fish would also benefit. Fish that live and reproduce in the CCB Creeks system are likely to contribute to regional populations as they disperse to other sites via the River Murray.

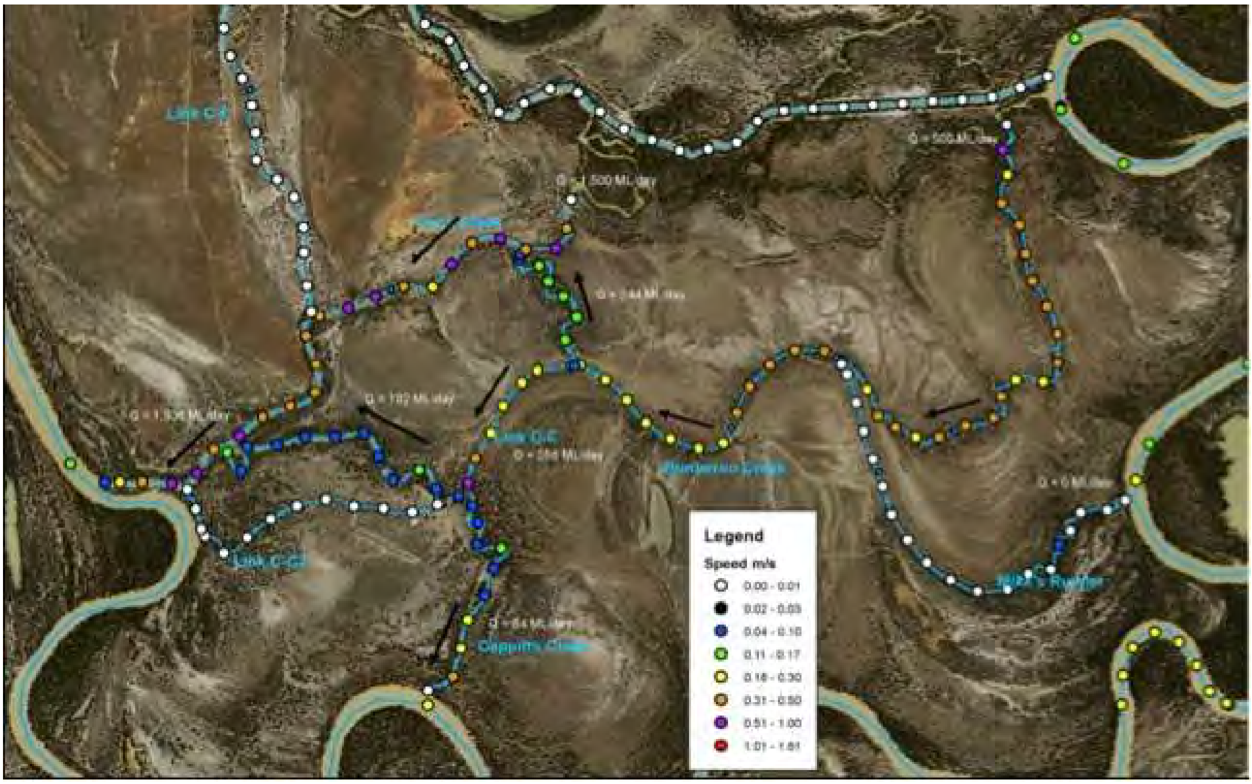
Hydraulic modelling indicates that suitable habitat is provided by discharges of 1,500 ML/d in Carrs Creek (via Carrs Weir No. 1) and 500 ML/d in Bunberoo Creek (via Carrs Weir No. 2). These flows generate significant hydrodynamic diversity including slow-flowing edge habitats, pools up to 2.5 m deep and fast-flowing reaches with channel velocities exceeding 0.3 m/s. The reaches where there is potential to achieve these velocities are identified in Figure 7-9. Noting that these velocities will only be able to be achieved in the lower parts of Carrs Creek when the Lock 8 weir pool is drawn down.

Further modelling is required to refine these flows and develop a program of seasonal flow variation.

The proposed works involve structures to control flow from Frenchmans Creek to Carrs Creek and Bunberoo Creek, two block banks and five road crossing structures. The works are designed to provide upstream fish passage with attractant flows and safe downstream passage for fish and their larvae. They will be designed to provide variable flows and would allow for the operation of Lock 9 at a raised level of +0.3 m. The works will reinstate connectivity of fish passage, flow and hydrodynamic variability into the CCB Creeks system.

The proposal to reinstate fish passage between Lake Victoria and the River Murray via the Frenchmans Creek Inlet Regulator will not significantly impact on the hydrology of the project area.

Figure 7-9: Hydrodynamic modelling of CCB Creeks system showing mean velocity within the channel with inflows of 1,500 ML/d at Carrs No. 1 and 500 ML/d at Carrs No. 2 [NSW Public Works - FCS 2013]



7.5 Water use

7.5.1 Locks 8 and 9 weir pools net water use

Raising weir pools will increase the area flooded and increase evaporation and seepage losses whereas lowering weir pools reduces these losses. Raising the weir height also increases the volume of water stored in the weir pool while lowering releases water downstream that must be supplied later when weir levels are restored (Ecological Assoc. 2013).

The MDBA's MIKEFLOOD model found that the initial water requirements to raise weir pools to their maximum levels are in the order of 15 GL in Lock 8 and 10 GL in Lock 9. This volume of water is expected to be reused downstream to satisfy water orders and other requirements and therefore would not be accountable against environmental water accounts (MDBA 2012c).

Incremental water use associated with illustrative weir pool scenarios has been estimated for 10,000 ML/d and 20,000 ML/d River Murray flows (Table 7-4). These estimates have been calculated on the basis of the increase in water surface area resulting from weir pool raising and applying probable evaporation and seepage factors (i.e. Lake Victoria pan evaporation with coefficient 0.8 and 5 mm/d respectively).

The Lock 9 weir pool manipulation cycles use less water than the current stable weir levels. The savings are derived from surcharging the weir and increasing the extent of the weir pool during winter and spring when evaporation is low and drawing down the weir pool in summer and autumn when evaporation is high. However, the Lock 8 weir pool manipulation cycles use more water that the current stable weir levels. The potential for evaporation and seepage savings is lower for Lock 8 because there is only a small area exposed at the minimum weir level compared with Lock 9 (100 ha compared with 500 ha).

Table 7-7: Estimated water use (GL) under illustrative operating scenarios: Locks 8 and 9 weir pools (source: adapted from MDBA 2012c)

Flow (ML/d)	Estimated water use (GL) Lock 8 0 = 24.6 m AHD	Estimated water use (GL) Lock 9 0 = 27.4 m AHD
10,000	1.8 (net water use)	-3.7 (net water saving)
20,000	1.7 (net water use)	-5.2 (net water saving)

In summary, additional net water use from weir pool manipulations (maximum raising and lowering at either weir) is not expected at 10,000 ML/d River Murray flow and a small water saving is expected to be generated at 20,000 ML/d (MDBA 2012c).

Reflecting arrangements in place during the weir pool manipulation trials, it is expected that net water use would be either debited or credited against an existing Commonwealth licence in accordance with an agreed watering strategy established at the beginning of each year.

7.5.2 Carrs, Capitts and Bunberoo Creeks connectivity net water use

Water from the Lock 9 weir pool will enter the CCB Creeks system through the proposed regulators on the Carrs weirs and be effectively delivered back as inflows and then reused downstream of Lock 9. A small volume of water is expected to be retained on the floodplain in wetlands systems and it is anticipated that there would also be small water losses through the creek itself (NSW Public Works and FCS 2013).

The water released back into the River Murray through the CCB Creeks system will be part of the water order that would normally have passed through Lock 9. During operation the flows through Lock 9 will be reduced to ensure that the net volume passed from weir pool 9 to weir pool 8 is the desired amount. It is expected that the only loss or use is the seepage and evaporation in the CCB creek network itself. Current conditions maintain a pool and for the most part provide a saturated stream bed throughout the CBB Creeks.

The MIKEFLOOD model of the CCB Creeks system was run using the flow characteristics:

- Carrs No. 1: 1,500 ML/day Carrs No. 2: 500 ML/day
- Carrs No. 1: 400 ML/day Carrs No. 2: 200 ML/day
- Murray River flow: 10,000 ML/day

The results of the model run are shown in Table 7-8 (NSW Public Works 2015).

Table 7-8: Inundation extents and system losses for CCB flows compared with base case (current conditions)

Option	CCB flow regime	Base case
Inundation area (hectares): i) Carrs No. 1: 1,500 ML/day & Carrs No. 2: 500 ML/day ii) Carrs No. 1: 400 ML/day & Carrs No. 2: 200 ML/day	 57 41	 28 28
Evaporation ML/year	535	327
Infiltration ML/year	855	518

The calculations of water requirements of the system used the following assumptions:

- 1D modelling results were mapped and overlayed onto the digital elevation model.
- For increased inundation area: Lake Victoria pan evaporation with pan evaporation coefficient 0.7; 5 mm/day infiltration losses
- Higher flow condition assumed during August to November

Under the proposal, the modelling estimated that the additional area inundated would result in increases in evaporation losses of 337 ML/year and infiltration of 208 ML/year giving a total additional water requirement in the order of 545 ML/year.

8 Environmental water requirements

8.1 Water requirements

Environmental water requirements have been identified for each of the hydrological environments (water regime classes and waterways), to enable achievement of the ecological objectives (Table 8-2 over page). These are based on evidence from the literature and expert ecological investigations at the sites (Ecological Assoc. 2013, Public Works NSW-FCS 2013) (see Supporting Documents in Appendix 1 for further evidence).

8.2 Hydrological gaps to be addressed

Within the project area, local hydrology is dominated by weir pool levels and is mostly independent of River Murray flows due to the extent of regulating structures. Therefore the modelled flows provided under the Basin Plan will not alter the requirements for weir pool manipulation or delivery of flows through the proposed CCB Creeks regulators.

Flows provided under the Basin Plan would have limited influence on inflows to the CCB Creeks system and therefore would not occur frequently enough under the Basin Plan 2,750 GL conditions to meet native fish objectives in the CCB Creeks system (under the existing stable weir pool level regime and fixed Carrs 1 and 2 weir structures).

Basin Plan flows would also have little influence on water level fluctuations at either Lock 8 or 9, as weir pool manipulation can counteract flow changes down the River Murray to ensure water levels remain stable. An analysis by Ecological Associates (2013) found only a minor increase in water level variation above current conditions in the high flow months of winter and spring through implementation of the Basin Plan.

Therefore, to achieve the ecological objectives of the project, weir pool manipulations to reinstate natural variability and regulators on the Carrs weirs in the CCB Creeks will still be required. The fixed weirs on Carrs 1 and 2 begin to spill into the CCB Creeks when Lock 9 is either removed or flooded, usually representing River Murray flows exceeding 52,000 ML/d. The construction of regulators will enable controlled flows into the creeks. Table 8-1 summarises the remaining hydrological deficit in the CCB Creeks under the Basin Plan.

Table 8-1: Hydrological gaps in achieving CCB component's ecological objectives under the Basin Plan

Equivalent River Murray flow threshold	Water regime parameter	Optimum	Basin Plan (2750 GL)	Deficit to be addressed by project
52,000 ML/d	Frequency (median)	10 in 10 years	4 in 10 years	6 in 10 years
	Duration (median)	365 days	65 days	300 days
	Timing (month of median event start date)	Winter, spring, early summer	August	-

Table 8-2: Indicative hydrological requirements to achieve the ecological objectives (based on Ecological Assoc. 2013)

Ecological objectives	Hydrological objectives						Watering mechanism
	Recommended number of events in 10 years	Tolerable interval between events once dry (months)	Duration of inundation (months)	Preferred timing of inflows/wetting	Depth (m)	Velocity (m/s)	
Aquatic macrophytes	5 to 10	Variable – depending on plant species	2 to 12	Late winter, spring, early summer	Variable – depending on location within littoral zone	N/A	Weir pool manipulation and CCB deliveries
Floodplain vegetation	2 to 10	36 - river red gums	1 to 4	Spring or summer	Variable – depending on plant species	N/A	Weir pool manipulation
Organic matter in wetlands	3 to 10	12 to 36	1 to 6	Spring or summer	N/A	N/A	Weir pool manipulation
Biofilms	10 to 30	3 to 11	>1.5	N/A	N/A	N/A	Weir pool manipulation
Waterbirds	3 to 10	12 to 24*	4 to 12	Late winter, spring, early summer	Fluctuate over time to promote productivity	N/A	Weir pool manipulation and CCB deliveries
Native fish (small and large-bodied)^	10	0	12	Winter, spring, early summer	>2m for adult large bodied fish. >1m for juvenile large bodied fish. Minimum to inundate substrate for egg laying.	>0.3 m/s for large bodied fish	Weir pool manipulation and CCB deliveries

*Outside inundation of aquatic macrophytes and floodplain vegetation, exposure of mudflats in summer for 2 to 4 months every year is beneficial for foraging.

^Large-bodied native fish such as Murray cod prefer hydrodynamic diversity e.g. slow flowing edge habitat, fast-flowing reaches (NSW Public Works & FCS 2013).

9 Operating regime

9.1 Overview

This section of the business case describes the impact the project will have on the operating regime of flows within the project area.

The project takes place within a sophisticated operating regime that has been developed over more than 100 years to control the flow of water for consumptive and navigational purposes. Lock 9 serves a critical role in the management of South Australia's consumptive share of the River Murray and is one of a number of locks that allow passage of vessels up and down the river. Lock 9 is also becoming increasingly important in the control of environmental water.

Implementation of the project will have limited impact on the operating regime of the river and locks. In summary:

- The water level in weir pools 8 and 9 will fluctuate more widely than the generally steady level at which they are now held. A typical monthly pattern for water levels is presented in this report but flexibility will be retained for river operators to vary pool levels within an overall range of heights to meet the various objectives of river operation.
- Variable flow rates and fish passage will be restored at two fixed crest weirs on Carrs and Bunberoo Creeks in the CCB Creeks system but the impact on weir and lock operation will be minimal.
- Fish passage will be installed at the Frenchmans Creek inlet regulator but this will be immaterial for system flows.

9.2 Operating scenarios

Operating scenarios have been designed to meet the ecological objectives of each of the three components of the project.

9.2.1 Locks 8 and 9 weir pool manipulation

There is a relatively high degree of flexibility with the adjustment of weir heights in Locks 8 and 9. The timing of adjusting weir height levels will be based on: floodplain requirements consistent with ecological objectives, ecological targets and preferred watering regime (comprising combinations of inundation and exposure). It will also take account of other river operations within the system, mainly the needs of navigation and provision of flow requirements to Lake Victoria.

There are several interacting and variable river operating factors that will be considered when determining the levels at which the weirs may be operated. Some represent structural limits while others are considerations of offsite impacts. Some of these are presented in Table 9-1 (Ecological Assoc. 2013).

Table 9-1: Operation considerations when raising and lowering weirs

Weir	Limit (m)	Rationale for consideration
Lock 9	+0.3	Top of piers with 0.33 m freeboard allowance
	+0.5	Fishway drowned
	+0.2	Lock 9 access track cut (only after prolonged surcharge)
	+0.27	Blockages in Carrs-Capitts-Bunberoo Creeks overtopped

	-0.1	Limit of Lake Cullulleraine offtake pump operation
Lock 8	+1.0	Top of piers with 0.11 m freeboard allowance
	+0.5	Fishway performance reduced
	+0.6	Potential for water to pond against left end of abutment
	+0.7	Fishway walls overtopped
	-0.3	Flow to Potterwalkagee Creek ceases

The weirs will need to be manipulated in a coordinated way, so that the passing flow at all weirs provides the required tailwater levels. Weir pool manipulation scenarios have already been trialled for Locks 8 and 9 (Table 9-2). These have been trialled with current manipulation limits in mind (+ 0.3 m/- 0.4 m for Lock 9; +0.8 m/-0.6 m at Lock 8) and the seasonality of peak surcharge will be matched to fish outcomes and balanced with requirements of other species (aquatic and vegetation).

Table 9-2: Past weir pool manipulation scenarios

Month	Lock 9 0 = 27.4 m AHD	Lock 8 0 = 24.6 m AHD
January	-0.2	-0.3
February	-0.4	-0.3
March	-0.4	-0.6
April	-0.2	-0.4
May	0	-0.2
June	0	0
July	+0.1	+0.3
August	+0.2	+0.5
September	+0.3	+0.8
October	+0.3	+0.5
November	0	+0.2
December	-0.2	-0.1

Trials have confirmed that these weir height adjustments are workable; however, there will be ongoing assessment of the ecological impacts (especially on the performance of existing fishways) during implementation of this measure. It is anticipated that annual weir pool manipulation scenarios will be reviewed and improved over time, knowledge gaps identified and ecological risk assessed and mitigated. For example, a trial is proposed for this coming watering year (2015-16) to adopt a surcharge during August followed by drawdown during September to October. A further surcharge is proposed for December 2015 with the objective of better identifying outcomes for fish.

Over time, weir pool manipulation scenarios will be trialled and developed that will balance the ecological requirements of:

- emergent aquatic macrophytes in the littoral zone of weir pools and connected wetlands
- floodplain vegetation communities (mainly red gum and black box woodland and lignum shrublands)
- biofilm communities of bacteria, algae and fungi through wetting and drying their substrates
- small-bodied fish by providing more productive aquatic habitat
- large-bodied fish by providing access to fish nursery habitat.

The operating plan will be flexible and respond to seasonal conditions, Murray River flows, and river operation and ecological requirements. A detailed account of how weir height manipulation can meet the ecological objectives of the project are provided in Section 4 on ecological objectives and targets. Illustrative floodplain areas that will be inundated and / or exposed are mapped and detailed in Section 7.4 (proposed hydrology).

9.2.2 CCB Creeks connectivity

Three scenarios have been developed to demonstrate how the CCB Creeks system will operate to meet the ecological objectives. The system will allow significant flexibility to vary flows outside the parameters of these scenarios, but they serve the important purpose of demonstrating the key aspects of hydraulic management.

Baseflows – the baseflow scenario is the default operating condition for CCB and provides the minimum flow for the system.

Baseflow is provided during autumn and winter or when other scenarios are not operating. Baseflow provides the minimum extent of fast-flowing habitat with reaches providing velocities between 0.3 and 0.5 m/s for Murray cod. Deep pools, more than 1.5 m and up to 5 m, are provided in the channels and in backwaters to provide habitat for freshwater catfish. In-channel benches and shallow backwater areas will be exposed to promote colonisation by aquatic macrophytes and desiccation of organic material.

Spring Fresh – will be provided over a period of 4 to 6 months starting in early August.

This scenario involves increasing inflows to inundate instream benches and shallow areas at the edge of backwaters. Decomposition of organic material will increase the availability of organic carbon and mineral nutrients, supporting increased zooplankton production. Inundation of the channel perimeter will initiate the seasonal growth of riparian plants, which contribute to the habitat requirements of macroinvertebrates, small fish and fish larvae. Inundation of benches may increase the extent of nesting habitat for Murray cod.

Flood Events – occur when river levels exceed the regulating capacity of Lock 9. Under these conditions, all structures will be fully opened.

These scenarios have been designed to redress the impacts of past management and rebuild the very low abundance and diversity of native fish in these creek systems. The project will restore velocity, turbulence and depth of flow in the creeks as well as improve connectivity and allow fish movement between the CCB Creeks system, Frenchmans Creek and Locks 8 and 9 weir pools. The relationship between the controlled flow scenarios and the ecological objectives for increasing the abundance and diversity of fish in the CCB Creeks system is outlined in Table 9-3.

Table 9-3: CCB Creeks system operating scenarios and ecological requirements for fish

Scenario	Flow rates	Duration	Example ecological requirements
Base flow	Estimated*: Carrs 1 - 400 ML/day Carrs 2 – 200 ML/day	Up to 6 months February to July	Maintain Murray cod habitat Create 1.5 - 2.0 m deep pools (catfish)
Spring fresh	1500 ML/d (maximum for Carrs 1 weir) 500 ML/d (maximum for Carrs 2 weir)	4 to 6 months starting August	Inundated benches as nesting habitat (Murray cod) Inundation channel perimeter initiating seasonal growth of riparian plants (macroinvertebrates, small fish, larvae)

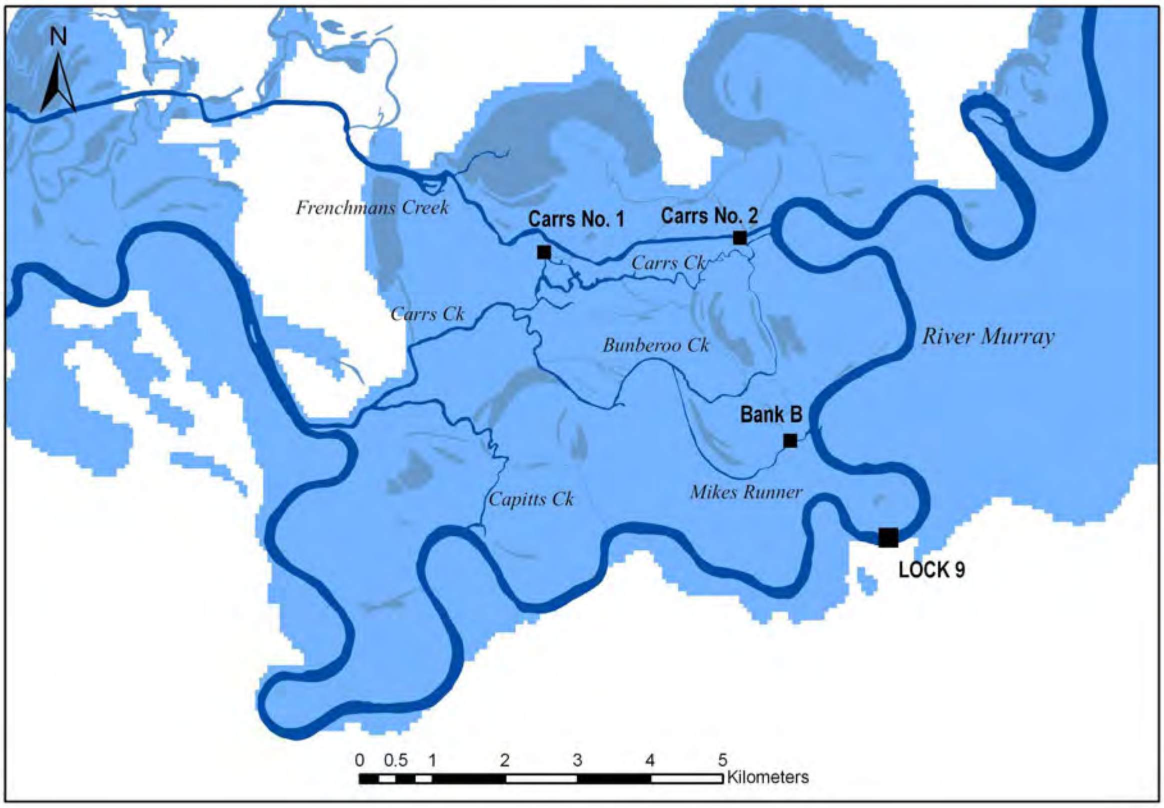
*Note: The minimum daily flow regime designed for fish in the Mullaroo Creek (a similar system) is in the order of 400 ML/d

A detailed account of how regulating flows and introducing fish passage into the CCB Creeks system will meet the ecological objectives of the project are provided in Section 4 on ecological objectives and targets.

Further work is required to establish inflow rates to target particular geomorphic features and hydraulic conditions. A more accurate hydraulic model needs to be developed based on detailed field survey of the creek, including bathymetry. This work will be undertaken during the detailed design and commissioning stage, providing funding is approved.

The location of the proposed flow regulators and fish passage structures in the CCB project area is shown in Figure 9-1**.**

Figure 9-1: Location of operational structures in the CCB project area [Source: prepared by Ecological Associates 2015]



9.3 Role of operating structures

The role of relevant structures (existing and proposed) required for the operating scenarios is outlined in Table 9-4. A map showing the location of each structure is shown in Figure 11-1 in Chapter 11 Technical feasibility and fit for purpose.

Table 9-4: Role of each structure in the operation of the project

Operating Structure	Present role in operations	Additional role in operations proposed in this business case
Component 1 – Locks 8 and 9 weir pool manipulation		
Existing and new structures		
Lock 9	Provide passage for vessels between pools 8 and 9.	Nil
Weir 9	Pass flow and maintain pool 9 level at a predetermined height.	Vary pool level up and down.
Fish Passage 9	Provide passage for fish between pools 8 and 9.	Nil
Lock 8	Provide passage for vessels between pools 7 and 8.	Nil
Weir 8	Pass flow and maintain pool 8 level at a predetermined height.	Vary pool level up and down.
Fish Passage 8	Provide passage for fish between pools 7 and 8.	Nil
Minor low level banks and crossings	New	To allow surcharge of the Lock 9 weir pool and maximise the extent of inundation
Millewa pump station (replacement)	Bulk irrigation water supply for horticultural developments and stock and domestic supply to properties at Lake Cullulleraine	Replacement and relocation of pumps will allow weir pool levels to be drawn down without disrupting water supply
Component 2 - CCB Creek system connectivity		
Existing, upgraded and new structures		
Carrs Weir No. 1	Block flow into Carrs Creek to maintain pool 9	Regulate set flow from pool 9 down Carrs Creek Provide fish passage between Carrs Creek and pool 9.
Carrs Weir No. 2	Block flow into Bunberoo Creek to maintain pool 9	Regulate set flow from pool 9 down Bunberoo Creek Provide fish passage between Bunberoo Creek and pool 9.
Block Bank 3 (James 1)	Block flow to an unnamed waterway to maintain pool 9	Release small flow to unnamed waterway and wetland.
Block Bank 6 (James 2)	Block flow to an unnamed waterway to maintain pool 9	Release small flow to unnamed waterway and wetland.
Block Bank B	Block flow to an unnamed waterway to maintain pool 9	Nil

Operating Structure	Present role in operations	Additional role in operations proposed in this business case
Road Crossing 1	Vehicular access across Carr Creek to Weir 9 and CCB creek area	To provide vehicular access across regulated flows and fish passage up and down Carrs Creek. (Note, these roles could be incorporated with proposed Carrs No 1 regulator and fish passage, in which case the structure will be abandoned)
Road Crossing 4	Vehicular access across an unnamed creek to Carrs Weir No 2.	To provide vehicular access across regulated flows.
Road Crossing 7	Vehicular access across Bunberoo Creek to Murray River	To provide vehicular access across regulated flows and fish passage up and down Bunberoo Creek. (Note, these roles could be incorporated with proposed Carrs No 1 regulator and fish passage, in which case the structure will be abandoned)
Road Crossing 9	Vehicular access across Bunberoo Creek to Weir 9	To provide vehicular access across regulated flows and fish passage up and down Bunberoo Creek. (Note, these roles could be incorporated into a new crossing upstream or downstream of the current crossing 9.)
Road Crossing A	Vehicular access across an unnamed creek to Weir 9	Nil (Works are already complete)
Component 3 – Frenchmans Creek fish passage		
Existing and new structures		
Frenchmans Creek Inlet Regulator	Regulate flows from pool 9 to Lake Victoria	No change, except accommodate variation in pool 9 level.
Vertical slot fishway	New	Provision of fish passage between Lake Victoria and the River Murray

9.4 Operational considerations

The works and measures proposed in this business case will be integrated within the existing operational framework for the River Murray. Day to day operations will continue to be undertaken by SA Water under the oversight of the MDBA.

Watering plans will be developed for the CCB Creeks system and for the weir pool levels and these plans will be reviewed to ensure their implementation is consistent with the other operational constraints within which the river operates.

This proposal therefore will not adversely impact on the operation of Lake Victoria or the navigation of the locks or the weirs.

10 Socio-economic impacts from operation

10.1 Overview

This section considers risks to socio-economic values that might arise from the operation of the proposed works and measures for Locks 8 and 9, the CCB Creeks system and Frenchmans Creek fish passage. Priority risks have been highlighted following a risk assessment process that rates the level of initial risk and residual risk after mitigation.

Socio-economic risks for each proposal have been separated into broad categories:

- Water supply
- Loss of access
- Cultural heritage
- Third party impacts
- Community backlash

Further detail on these risks and how they apply to the proposal is provided in Appendix 3.

Risks to socio-economic values have been identified and assessed throughout the early stages of this project. This experience, as well as experience from other environmental watering projects, has informed the selection of appropriate mitigation strategies.

The methodology for assessing the risks has been outlined in Section 6.

10.2 Locks 8 and 9 weir pool manipulation

Ongoing weir pool manipulation trials have alerted NSW DPI Water to the type and extent of potential impacts on socio-economic values that could occur from operation. The trials have also allowed DPI Water to plan for measures to mitigate against this risk. Locks 8 and 9 weir pool manipulation involves periodic wetting and drying that could impact freehold and leasehold land, access tracks and cultural heritage. However, trials have shown that the area of inundation is relatively small and that wetting and drying cycles will provide some benefit to neighbouring freehold owners and leaseholders through improved health of vegetation and wetland areas.

The exceptions where operation has the potential to impact on socio-economic values of the area include:

- Impacts to delivery of irrigation water where off-take pumps are isolated without warning
- Loss of access to Lock 9 for management and operation of the structure (NSW side of River Murray)
- Loss of access or impacts to stock management for landholders
- Potential for the project to conflict with the interests of the Tar-Ru Native Title Claimants

NOW will mitigate against these risks through effective coordination of weir pool manipulation with river operation and communication between stakeholders. The project has established strong governance and collaboration support from the MDBA, Victorian agencies, SA Water and other interstate agencies and has consulted with landholders and the Tar-Ru Native Title Claimants throughout the weir pool trials. This work, as well as NOWs extensive experience managing third party impacts for other similar projects, will be valuable when managing these risks.

Ongoing monitoring and review of other risks with a residual risk rating of Very low or Low will be undertaken by NOW as part of regular operational practice to ensure these risks remain low level.

Table 10-1 sets out the risk assessment for Locks 8 and 9 weir pool manipulation including proposed mitigation measures and residual risk.

Table 10-1: Risk assessment and mitigation for potential adverse socio-economic impacts from operation of Locks 8 and 9

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Loss of access						
Inundation of private tracks prevents or disrupts access	Unlikely	Moderate	Moderate	Provide advanced notice of weir level changes	Low	Ecol. Assoc. (2013)
Inundation of private land disrupts access and causes stranding of stock	Unlikely	Moderate	Moderate	Notify landholders of weir level changes – no evidence of stranding in three years of trials	Low	MDWWG (2013); Ecol. Assoc. (2013)
Access to structures (by SA Water) is restricted including road access to Lock 9	Possible	Moderate	Moderate	Notify stakeholders of weir level changes and coordinate operation with interstate organisations	Low	Risk workshop
Disruptions to navigation on the river and at locks	Unlikely	Moderate	Low	Weir height adjustments during low Murray River flows < 5,000 ML/d (no problems have been encountered during trials)	Very low	Scott J pers comm, NOW
Loss of access for recreation	Likely	Moderate	Moderate	Communicate project objectives and notify community of changes to access	Low	Risk workshop
Cultural Heritage						
Loss of engagement with Barkandji Traditional Owners and other indigenous stakeholders	Possible	Severe	High	Early and ongoing collaboration on cultural heritage approval processes	Low	Risk workshop
Third party impact						
Rise in river salinity and acid sulphate soils impacting landholders	Unlikely	Moderate	Low	Surface water salinity monitoring. Balancing weir pool regimes to reduce discharge of groundwater	Very Low	NOW (2014a)

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Disruption to surface water diverters through isolation of pumps (including Lake Cullulleraine customers and other private diverters)	Likely	Severe	High	The Millewa bulk water pump station at Lake Cullulleraine pump will be relocated and replaced as part of this project	Very Low	NOW (2014); Ecol. Assoc. (2013); GHD (2015)
Drawdown of weir pool allows stock to wander and become stranded or bogged	Possible	Moderate	Moderate	Notify landholders of weir level changes and lower weir levels slowly to reduce incidence of bogging	Low	Ecol. Assoc. (2013)
Community backlash						
Negative community perceptions of changes in weir pool levels	Unlikely	Moderate	Low	Communicate project objectives and notify community of changes to weir pool levels	Low	MDWWG (2013)
Backlash due to disruption to irrigation off-takes	Unlikely	Severe	Moderate	Notify Lower Murray Water and diverters of weir level changes	Low	Risk workshop

10.3 CCB Creeks connectivity and Frenchmans Creek fish passage

Most of the area of influence for the CCB Creeks connectivity proposal is located on Crown land that is currently vested in the Minister for National Parks and Wildlife NSW for transfer to the Barkandji Native Title Aboriginal Corporation. Following the transfer, the land will be managed by a Tar-Ru Lands Board of Management (to be established in the near future). This area was previously public land held by State Forests and then NSW National Parks and Wildlife Service with limited access or development. There is a small amount of leasehold land (long-term grazing licences, Western Lands Division) in the north of the CCB area around Purda Billabong and east of Carrs Creek. SA Water either owns or leases the land in close proximity of the weirs to undergo reconstruction and the Frenchmans Creek inlet regulator.

The Frenchmans Creek fish passage proposal involves construction of a fishway into an existing inlet regulator structure. The inlet regulator is an important component of river operation and the regulator is operated and maintained by SA Water. SA Water owns the land accommodating the structure and along the length of Frenchmans Creek. Reinstating fish passage will not affect flows in the Frenchmans Creek or inundate floodplain areas. There are very few risks to socio-economic values posed by the operation of the fishway and where identified, risks are rated low.

Because the CCB Creeks proposal involves restoring flows to existing stream channels in a relatively remote area, it is unlikely to have a significant impact on socio-economic values in the area. The maximum design flows are for bank full level only and it is intended that there be little overtopping of banks and inundation of floodplain areas. However, where this occurs there is the potential for a few key landholders and stakeholders to be impacted by the project:

- The Tar-Ru Native Title claimants (representing Barkandji Traditional Owners) will become title holders for the area and are yet to clearly specify their land and water management aspirations. However, early consultation suggests these objectives are consistent with the CCB proposal.
- There are opportunities to provide cultural flows and opportunities for Tar-Ru Lands representative to be involved in construction and ongoing monitoring activities should the project proceed.
- Moorna Station covers approximately 26,000 ha and comprises a mix of tenure including freehold, Western Lands lease, SA Water leased land along Frenchmans Creek and a freehold component (owned by the Walsh family of Limbra Pastoral Company). The proposal to restore flows to the creeks could impact access for cattle and stock management activities, however, the affected area is expected to be minimal because some of the works include an upgrade to existing road crossings. Effective communication with the landholders will help reduce the likelihood of impact.
- SA Water operates and maintains a number of tracks in the CCB Creeks system area used for access to Lock 9 and other structures including the Carrs weirs on behalf of the MDBA. A number of road crossings will be raised and reconstructed as part of this project to allow fish passage for this area. This will ensure all weather access is also provided and mitigate against the majority of the loss of access risk.

As such, priority risks (with a residual risk rating of moderate) for the CCB Creeks connectivity area include:

- Potential for damage to artefacts through stream bank erosion from excessive creek flows and/or during weir structures maintenance and operation
- Loss of engagement with Barkandji Traditional Owners and other Indigenous stakeholders
- Operating regime for CCB conflicts with water /l and management priorities of Tar-Ru representatives

- Conflict between managing desired flow regimes in CCB Creeks and meeting Lake Victoria water storage requirements

Work during the early stages of the project including ongoing consultation and engagement, contingency allowances in the design of the project and effective coordination between agencies, attractively positions NOW to mitigate against possible impact from these risks. SA Water will undertake ongoing monitoring and review of these risks as part of regular operational practice to ensure these risks remain low level. Table 10-2 summarises these risks and suitable mitigation options.

Table 10-2: Risk assessment and mitigation for potential adverse socio-economic impacts from operation of CCB Creeks connectivity

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Loss of access						
Inundation of private tracks and river crossings	Unlikely	Moderate	Low	Communicate with landholders if banks spill and access is affected.	Very low	NSW Public Works-FCS (2013)
Inundation of grazing land (Moorna Station)	Unlikely	Minor	Very low	Notify landholders of planned inundation	Very low	NSW Public Works-FCS (2013)
Cultural Heritage						
Artefacts are damaged or lost due to erosion from excessive flows and / or during weir structures maintenance and operation	Possible	Severe	High	Careful operation of regulator structures to manage creek flows Proactive engagement with Indigenous stakeholders	Moderate	Risk workshop
Loss of engagement with Barkandji Traditional Owners and other Indigenous stakeholders	Unlikely	Severe	Moderate	Early and ongoing consultation	Moderate	Risk workshop
Third party impact						
Rise in river salinity and acid sulphate soils impacting landholders	Unlikely	Moderate	Low	Surface water salinity monitoring. Balancing weir pool regimes to reduce discharge of groundwater	Very low	NOW (2014)
Operating regime for CCB conflicts with water/land management priorities of Tar-Ru representatives	Unlikely	Severe	Moderate	Early and ongoing consultation with Tar-Ru representatives	Moderate	Risk workshop
Conflict between managing desired flow regimes in CCB Creeks and meeting Lake Victoria water storage requirements	Possible	Severe	High	Appropriate scheduling of seasonal watering plan for CCB	Moderate	SA Water operations
Community backlash						
Negative community perceptions of increased creek flows Negative community perceptions about restoring fish passage at the Frenchmans Creek inlet regulator	Unlikely	Moderate	Low	Communicate project objectives and notify community of intention to reinstate constant flows into CCB Creeks system and fish passage at the inlet regulator	Very low	MDWWG (2013)

11 Technical feasibility and fitness for purpose

11.1 Overview

The types of works and measures proposed in this business case have been implemented along other parts of the Murray River system, although there are some unique aspects that will require special attention during the design and implementation phases. This section of the business case summarises and addresses the relevant technical issues:

- The proposal to vary the weir pool levels is within the height range of the existing lock structures and has been proven successful in operational trials over the past three years. There is little technical risk associated with this part of the proposal.
- The proposal includes relocation and replacement of the Millewa pump station to allow weir pool levels to be drawn down without disrupting bulk water supply to irrigators and stock and domestic users at Lake Cullulleraine (in Victoria).
- The technology for regulating structures like those proposed for the two Carrs Weirs is well developed although installing and operating such structures within the River Murrray floodplain presents challenges due to flooding and access. The ability to lower and control the Lock 9 weir pool helps mitigate these flooding risks.
- Fishways are technically complex structures and concerns about functionality and operational reliability are valid. As well as the normal engineering structural and hydraulic considerations, subtle matters such as the instinct and behaviour of the fish can be crucial to whether the fish actually use the structure as intended. There are examples of failed fish passages in other locations, so if the structures for this project are to function reliably, then the fitness of purpose will need to be addressed and confirmed through all phases of concept design, detailed design, installation and operation.
- Road culverts are standard engineering structures, but particular care will be needed in this design to account for the fact that the structures will sometimes be fully submerged under flood conditions, will pass continuous flow at all times and will have special design requirements for the purposes of enhancing fish passage.

Good design is paramount to the success of the works and measures proposed in this business case. The sections below explain two technical aspects for each of the project elements:

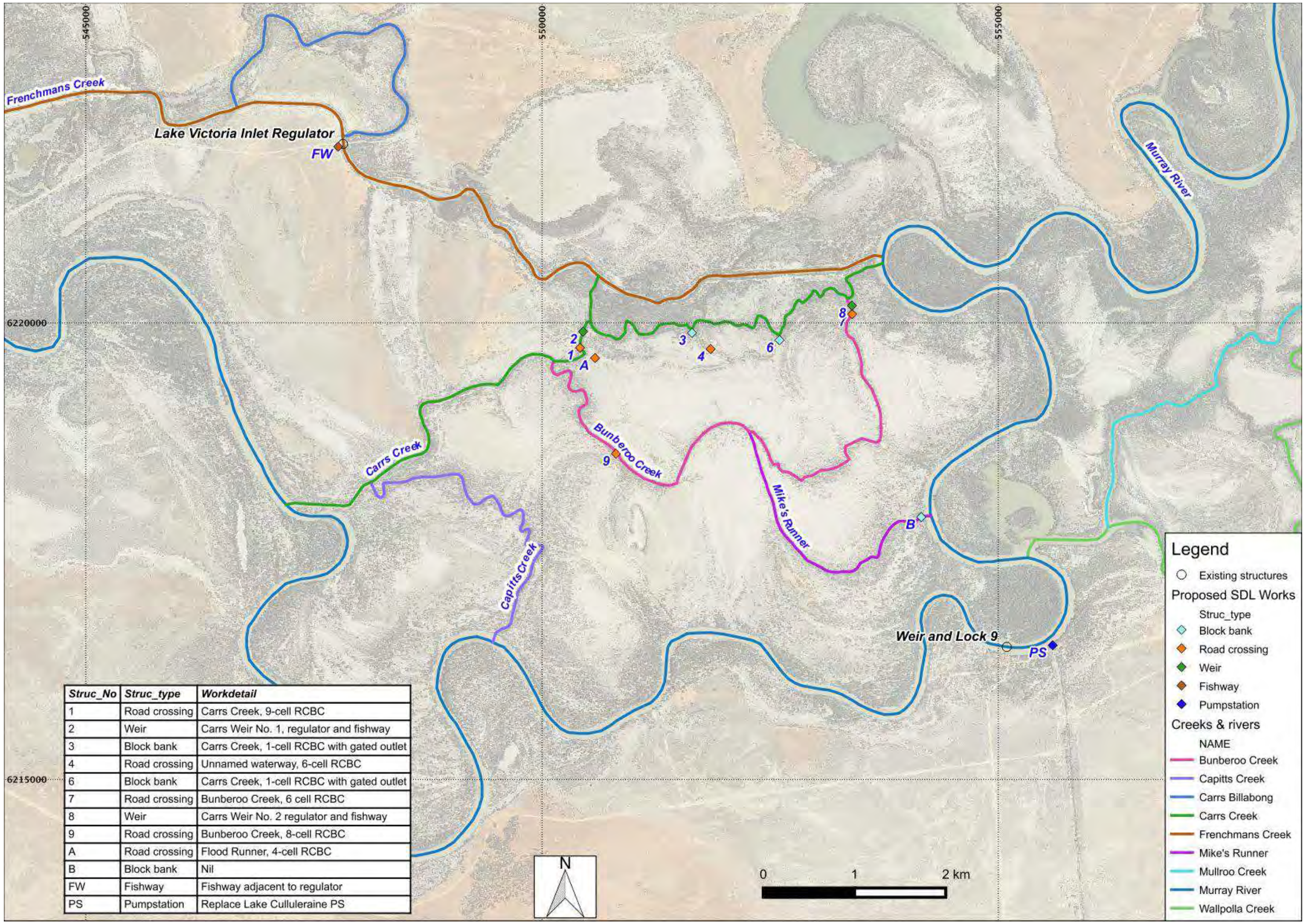
- Options analyses and planning: outlining the history of decision making to identify a preferred option
- Project design criteria: key design features to be aware of during implementation.

This section ends with short discussions on other design matters such as:

- Geotechnical studies;
- Reliance on other measures or actions; and
- Ongoing operation, maintenance and management of infrastructure.

The location of each element of the works package for the three components of the project is shown in Figure 11-1.

Figure 11-1: Location of the works package [Source: prepared by RMCG using imagery from the Victorian Government]



Struc_No	Struc_type	Workdetail
1	Road crossing	Carrs Creek, 9-cell RCBC
2	Weir	Carrs Weir No. 1, regulator and fishway
3	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
4	Road crossing	Unnamed waterway, 6-cell RCBC
6	Block bank	Carrs Creek, 1-cell RCBC with gated outlet
7	Road crossing	Bunberoo Creek, 6 cell RCBC
8	Weir	Carrs Weir No. 2 regulator and fishway
9	Road crossing	Bunberoo Creek, 8-cell RCBC
A	Road crossing	Flood Runner, 4-cell RCBC
B	Block bank	Nil
FW	Fishway	Fishway adjacent to regulator
PS	Pumpstation	Replace Lake Culluleraine PS

11.2 Locks 8 and 9 weir pool manipulation

11.2.1 Options analysis and planning

The technical feasibility of the proposal to manipulate the water levels in weir pools 8 and 9 has been demonstrated through experience from weir pool trials carried out over the past three seasons. These trials:

- Demonstrate the lock and weir structures' ability to accommodate the range of different levels.
- Prove the strength of inter-agency support and co-ordination for the project.
- Identify and largely resolve potential impacts on landowners, recreational users and access roads.

11.2.2 Project design criteria

The project includes relocation and replacement of the Millewa bulk water pump station at Lake Cullulleraine (in Victoria) and other minor works that will include construction of several low level banks and crossings to in order to maximise the extent of inundation.

A concept design with costing had been prepared by Lower Murray Water (GHD 2015) that outlines the required civil works (earthworks, concrete works, piling, pipelines, fittings and instruments) for relocation and replacement of the pump station. The design includes preliminary pump selection and assumes that the new station would require flow modulation, remote control and automation.

New operating regimes for the two weirs pools have been trialled and will be under continual assessment to ensure that peak times for fish movement are being accommodated. Operators and river managers will have the flexibility to adapt the temporal pattern of the weir pool levels to match the multi-objectives of river operations and ecological restoration; a process which is already being undertaken and has well-established protocols and responsibilities.

11.3 Carrs, Capitts, Bunberoo Creeks connectivity

11.3.1 Options analysis and planning

A study conducted by NSW Public Works and Fishway Consulting Services (*Engineering feasibility study – assessment & costings of structures & fishway(s) in the Carrs, Capitts & Bunberoo Creeks system 2013*) provides the foundation for the technical feasibility of proposed works and their operation in the CCB Creeks system. This study was project managed by the Murray Darling Wetlands Working Group and funded by the Murray Catchment Management Authority (now Western Local Land Services).

The technical concept underlying the proposal to restore hydrodynamic flows to the CCB Creeks system is straightforward; the creeks have been starved of water by the block banks and weirs on weir pool 9 and this proposal will restore the ability to regulate flows past Carrs Weirs 1 & 2 along the two major creeks.

A hydrodynamic study has shown that the desired velocities for fish habitat can be achieved in the creek systems and a temporal flow pattern has been developed for the two main creeks.

While the concept is technically sound, the works required to achieve this need to be subject to further flows modelling, refinement and optimisation. For example, it has been suggested that it may be possible to optimise the Carrs Creek design by combining a roadway with regulator/fish passage structure (noting that this will not be designed or costed in this business case).

Also, the initial planning and design (NSW Public Works – FCS 2013) concluded that it might be feasible to retrofit regulators into the Carrs 1 & 2 structures. Further consultation with SA Water infrastructure management personnel has resolved that it is more prudent to replace these structure completely given their age and their critical role in maintaining the Lock 9 weir pool. The cost estimate in this business case allows for this replacement.

11.3.2 Project design criteria

The key design considerations for CCB Creeks connectivity are:

- Operability – any works installed must either be remote-controlled or able to be controlled by SA Water operators. Access during floods is a consideration and power supply (given that there is no electricity at either fixed crest weir site) is a key issue, and some concern has been raised about the NSW Public Works' proposed method of portable power packs (Nigel Rutherford, SA Water pers. comm. April 2015)
- Fish passage – standard vertical slot fishways structures should be suited to these sites however ecological and hydrological analyses will need to be undertaken to confirm the suitability of this design.

Further work is required to establish inflow rates to target particular geomorphic features and hydraulic conditions. A more accurate hydraulic model needs to be developed based on detailed field survey of the creeks, including bathymetry.

11.4 Frenchmans Creek fish passage

11.4.1 Options analysis and planning

The Frenchmans Creek regulator impedes upstream fish passage completely and the undershot gates cause significant turbulence and sheer stresses so that downstream passage for small fish and larvae is severely compromised. The need for a fish passage was identified and given a high priority in the Sea to Hume study (MDBC 2008).

In recent years, interested authorities have explored a range of alternative designs for the site including Denil, vertical slot, fish lock and bypass channel options. The MDBC engaged Connell Wagner and Fishway Consulting Services to undertake concept design of options for a fish passage at the inlet regulator in 2007. This was a collaboration between the former MDBC, SA Water and NSW Department of Primary Industries. A Denil fishway was identified as the preferred concept and concept designs for four fishway routes were investigated (Connell Wagner 2007).

A range of fishway options were considered for this project. These are described in Table 11-1 together with a general description of the advantages and disadvantages of each option

Table 11-1: Fishway options for the Frenchmans Creek inlet regulator

Type	Location / function	Advantages	Disadvantages
Denil	A Denil fishway was designed by Connell Wagner in 2007	Design well advanced Caters well for larger fish Good for downstream passage Low cost	Poor passage of small fish Medium to large footprint Entrance conditions and location will be problematic
Vertical	Will require approx. 40 cells /	Good for a range of fish species including the target	Large footprint (40 cells ea 3 m x 2 m)

Type	Location / function	Advantages	Disadvantages
Slot	slots (@ 0.11 m drop). Proposed for west bank	species Good precedence examples of effective fishways. Can provide downstream passage.	Will require multiple exits to cater for range of HW-TW differences. May require multiple entrances to cater for suitable entrance conditions at different weir discharge rates. Will require physical modelling.
Fish Lock	Requires lead-in channel, lock chamber, and lead out channel. Gate operation for inlet and outlet. Proposed as top-fill lock. Proposed for west bank.	Can readily provide passage for full range of fish sizes (20 – 1000 mm long). Small footprint. Operation cycle can be varied to optimise effectiveness, or to target specific species or sizes. Relatively lower capital cost.	Few examples of successfully operating fish locks in Australia. Design and maintenance are seen to be the key issues affecting existing locks. Requires commitment to regular maintenance to ensure operational reliability. Entrance location will be critical to cater for different weir discharge flows / conditions. Requires physical modelling. Can be difficult to maintain attraction of large-bodied fish between cycles.
Bypass	A bypass channel could be constructed on the east side, linking with Carrs Lagoon - approx.. 300 m long and would pass under the existing road. There would be a regulator at the upstream end to control the discharge rate into the bypass channel. A connection would be constructed from Carrs Lagoon to Frenchmans Creek on the downstream side of the weir.	Suitable conditions for fish passage can be built into the channel. The entrance (downstream) becomes less critical because the downstream flow can be manipulated by adjusting the flow split – bypass/weir, to ensure that attraction flow is achieved. A natural habitat/environment is created.	Minimum flow for fish passage may be relatively large and could be an issue in low flow periods. The construction footprint is very large with potential for cultural heritage / environmental issues. May lead to drawdown / draining of Carrs Lagoon. Likely to be the most expensive option.

11.4.2 Fishway design criteria

The project is at an early design stage with limited readily available information. Based on available information and considered assumptions the following criteria have been adopted for the concept design (Table 11-2).

Table 11-2: Fishway design criteria (source: Alluvium 2015)

Criteria	Value(s)	Basis
Max HW – TW Range	4.5 m	Laura McCann, MDBA, Hydraulic Analysis (2015)
Min operating TW (AHD)	RL 23.9 m	Connell Wagner (2007)
Normal U/S Pool level (AHD)	RL 27.4 m	Connell Wagner Drg TS01 (2007)
Raised U/S Pool Level (AHD)	RL 27.9 m	Connell Wagner Drg TS01 (2007)
Top of bank (AHD)	RL 31.0 m	LiDAR (2007)
Low flow rate (Weir)	200 ML/d	Discussions with SA Water (Nigel Rutherford, March 2015) 90 % exceedance
Target fish sizes	20 – 1,000 mm	Discussions with local fish ecologist (Clayton Sharpe)

Other key design considerations for the Frenchmans Creek fish passage include:

- Operability – any works will need to be reliable and operable by SA Water, especially given its remote location.
- Remote operation by Supervisory Control and Data Acquisition (SCADA) is likely to be adopted
- Existing undershot gates are not being considered for upgrade or replacement
- A physical model will need to be built to inform the detailed design so that the entrance conditions to any fish passage can be evaluated.
- Potential for cultural heritage issues on floodplain adjacent to Frenchmans Creek

One of the critical components in making the fishway work effectively is ensuring that the entrance location and flow conditions will enable migrating fish to locate the entrance easily and move into it. This is generally achieved by placing the fishway entrance at the upstream limit of fish migration (often in close proximity to the weir) to manage attraction flows through the fishway in association with flow conditions over the weir. Physical modelling will be required to determine an optimal location for the fishway entrance. It is also anticipated that there may be a need for some ancillary structures to guide fish to the entrance, especially during low flows.

11.4.3 Options assessment

The four fish passage design options have been compared in an options assessment matrix, provided below as Table 11-3.

It is clear from this assessment that the Vertical Slot Fishway (VSF) and the Fish Lock both score very well. The fish lock scores better on functionality, while the VSF scores better on the operational aspects. The indication is that either one of these two options would be suitable for implementation at the site however there are relevant concerns about the operational effectiveness of a fish lock due to current experience with fish locks in NSW.

After consideration of the advantages and disadvantages of each it was concluded that a Vertical Slot Fishway is the preferred design for this site, given currently available information. The concept arrangement for the VSF option is described in the following section.

Table 11-3: Fishway options assessment matrix

		Vertical Slot Fishway	Denil Fishway	Bypass Fishway	Fish Lock
CRITERIA : All scores rated from 1 (Poor) to 5 (Very Good)					
	Weighting	Score	Score	Score	Score
FUNCTIONALITY					
Effective in passing target species					
Small fish (20 - 90 mm)	5	3	1	5	5
Large fish (90 mm - 800 mm)	5	5	4	4	5
Suitable for HW Range	4	5	4	5	5
Suitable for TW Range	4	4	4	3	5
Entrance conditions (attraction)	4	3	4	4	3
Exit conditions	3	5	5	3	5
Downstream passage	3	3	3	5	3
Ability to monitor performance	1	5	5	1	3

		Vertical Slot Fishway	Denil Fishway	Bypass Fishway	Fish Lock
Sub-total for Functionality		117	102	118	129
OPERATION					
Mechanical / electrical maintenance	4	4	4	4	1
Ease of maintenance	3	4	4	3	3
Sediment accumulation	3	5	5	3	3
Debris	4	4	2	3	4
Sub-total for Operation		59	51	46	38
ENVIRONMENT					
Footprint	3	3	4	1	4
Heritage / Environment impacts	2	4	4	1	4
Sub-total for Environment		17	20	5	20
RISK					
Public access / Safety	3	4	4	3	3
Vandalism	3	3	3	4	3
Constructability	4	4	5	4	4
Sub-total for Risk		37	41	37	34
Total Overall Score		**230**	**214**	**206**	**221**

11.4.4 Vertical slot fishway

The vertical slot fishway option for Frenchmans Creek Inlet Regulator is located on the western bank, as shown in Figure 11-2. The optimal arrangement is subject to detailed design considerations and matching the function with the range of hydraulic conditions at the site.

The factors that make a VSF an attractive option for the Frenchmans site are:

- It has a limited footprint and is able to be located mostly in areas previously disturbed.
- It is able to cater for a large and variable headwater / tailwater (HW/TW) ranges through use of multiple gates. The multiple gates allow different parts of the fishway to be engaged to correspond with specific HW – TW ranges.
- It is able to cater for a large variety of fish species size.

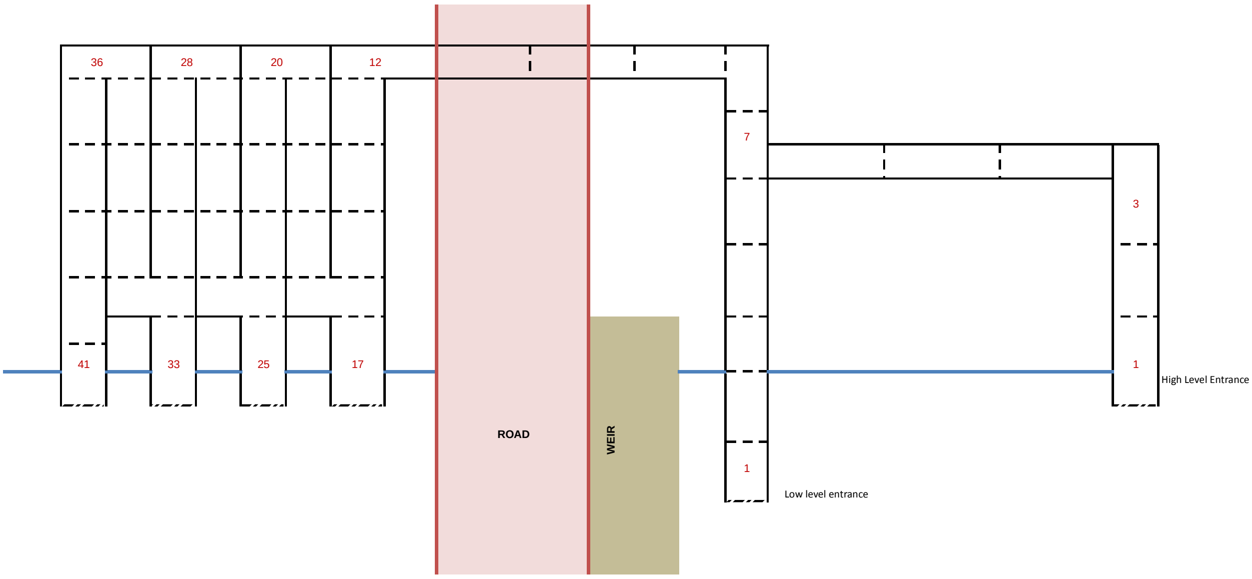
An indicative configuration of the VSF is shown in a schematic diagram over page (Figure 11-3). The design comprises the following configuration:

- Multiple entry gates to cater for the attraction point being different at high and low regulator discharge rates.
- Multiple exit gates to provide the greatest adaptability to HW – TW range.
- Pool cell size = 3 m x 2 m. Resting pools = 5 m x 2 m
- Max water level drop between pools of 0.11 m.

Some recent yet preliminary analysis (MDBA 2015, Mallen-Cooper and Stuart 2015) indicates that there is potential, with further investigation, to optimise the design of the fishway by tailoring it to a limited range of species and seasons. This could result in a smaller head height difference, for example, and refinement of costs. This should be considered further during the detailed design phase.

Figure 11-2: Alternative conceptual layouts of VSF at Frenchmans Creek Inlet Regulator

Figure 11-3: An indicative schematic of Vertical Slot Fishway configuration



11.4.5 Downstream migration

For downstream migrating fish, safe passage over the Frenchman's Creek Inlet Regulator is currently not feasible because of the undershot weir arrangement. Both a fish lock and VSF design can function to provide downstream passage of fish, larvae and eggs. To do this successfully will require the installation of floating booms, or similar, as guides into the upstream fishway channel.

Further hydraulic and ecological modelling is planned as part of more detailed project feasibility through to implementation, focussing on the concept of a Vertical Slot Fishway or a fish lock. Options will remain under review until a detailed concept design has been prepared. A concept arrangement for a fish lock option (including indicative costing) is described in Appendix 4.

11.5 Other design matters

11.5.1 Geotechnical investigations

Detailed assessments of the potential impact that weir pool manipulation could have on the stability of the weirs have been previously undertaken and this aspect has been resolved. No works, apart from the Lake Cullilleraine pump station, are proposed at Locks 8 and 9 so no further geotechnical investigations are planned.

Geotechnical investigations are yet to be undertaken for the CCB Creeks system or Frenchmans Creek works proposed in this business case. Geotechnical survey work will begin during 2015.

11.5.2 Reliance on other measures or actions

The ecological benefits of these works and measures will be optimised if they are implemented in concert with watering plans for other sites, such as Mulcra and Wallpolla. This business case is not, however, reliant on any other measures or actions.

11.5.3 Ongoing operation, maintenance and management of infrastructure

Responsibility for operation of all of the works and measures proposed in this business case will fall on SA Water. While most of the structures are on the MDBA assets register, operations will be integrated into the existing operating role fulfilled by SA Water.

Information on the technical specifications of Locks 8 and 9 (including their limitations) is provided in Appendix 5.

12 Complementary actions and interdependencies

12.1 Synergies

The integration of all the elements of this proposal generates significant synergies.

- Adjusting the weir pool heights within and between seasons provides richer more diverse ecosystems for both aquatic and riparian ecosystems.
- Restoring flows within the CCB Creeks system provides connectivity, flow and hydrodynamic diversity within a 12 km creek system that will restore a key part of the aquatic environment including fish nursery and spawning grounds to generate benefits at a regional scale, including the wider Murray system.
- Linking Lake Victoria with Frenchmans Creek and the CCB Creeks system through a fishway on the Inlet Regulator will re-connect the aquatic population of Lake Victoria with the CCB Creeks and the wider lower and mid Murray.
- The new works and measures will be more easily integrated into the existing MDBA asset base and operational and management regimes if the whole package is developed and implemented together.
- Complementing and extending reach wide benefits for the Lower Darling, Darling Anabranch, Lower Murray and associated works and measures.

Each investment generates its own benefits but taken together the combined elements promote connectivity both at a local and a regional scale with a particular focus on aquatic ecology.

12.2 Interdependencies

The proposed project will also support and enhance the effectiveness of other regional initiatives:

- The Living Murray works e.g. Mulcra Island has five environmental regulators that operate to mimic natural flooding patterns – delivering more frequent flows down Potterwalkagee Creek, filling wetlands and inundating floodplain areas during early winter through to late spring, and allowing them to dry through summer and early autumn.
- Mallee CMA SDL offset business cases: the Mallee CMA has proposed a set of SDL offset business cases to promote major environmental assets in the Lower Murray at Lindsay Island, Hattah North, Belsar Yungera and Wallpolla Island.
- The Murray Darling Wetlands Working Group (MWWG) has submitted a proposal for 2015/16 to the CEWO for a pilot environmental watering of floodplain wetlands to the west of the CCB Creeks system, south of Frenchmans Creek and within the influence of the Lock 8 weir pool. It is planned for siphons to be placed over the Frenchmans Creek levee to water wetlands on the NSW side of the River Murray. The site has been included in the NSW Annual Environmental Watering Plans for the Murray Lower Darling as a priority watering site and will be incorporated into the long term Environmental Watering Plans; as per Basin Plans requirements.
- Lower Darling environmental flows.
- The Great Darling Anabranch Environmental watering and flows to the Murray.
- A proposal for a parallel initiative in the management of the weir pool at Lock 7 which is at an earlier stage than the more developed experience at Locks 8 and 9.
- Lock 7 Weir pools trials

- Lock 5 weir pool manipulation trials
- Pike and Kataraptco creek proposals

The combined projects will generate valuable interactions e.g. the manipulation of levels at Lock 9 will facilitate controlled inundation at Wallpolla Island and variable flows down the CCB Creeks system.

A more detailed outline of interdependencies with other environmental watering activities (ongoing and proposed) is outlined in Section 4.4. The assessment of benefits and outcomes from this project does not involve double counting with the outcomes of these other initiatives. However, all linkages and inter-dependencies for this measure and its associated SDL resource unit, particularly with any constraints measures, will become better understood as the full adjustment package is modelled by the MDBA and a final package is agreed to by Basin governments.

12.3 Complementary actions

There is a range of complementary actions that relevant agencies will endeavour to implement to enhance the value of the proposed investment. These are described below. However, the proposals do not require any significant change to the way the river is operated or any sizeable volumes of held water to deliver the desired outcomes.

12.3.1 Small scale works to improve the hydrology of wetland areas on the NSW floodplain

Small scale works (e.g. executing earthworks and siphoning) on the CCB Creeks system and Frenchmans floodplain would enable watering of high value wetland areas that would complement reintroducing flows into the CCB Creeks system (Howard Jones pers. comm. 2015, MDWWG).

12.3.2 Pest plant and animal control

Similar to native flora, some pest plants also benefit from an improved water regime. Ongoing monitoring and management of pest plant species will be necessary to ensure that native flora benefit where possible at the expense of pest species.

Pest animals (particularly feral pigs) have the potential to degrade the aquatic environments watered under the project. In the Mallee region, pigs are more prevalent in the riverine environments adjacent to the River Murray where even just a few pigs can cause serious damage to riparian and aquatic environments (Mallee CMA 2011). Control programs will be needed to contain the impact of feral animals so that ecological outcomes are maximised.

12.3.3 Grazing management

Overgrazing by domestic stock contributes to a loss of flora diversity and abundance, weed dispersal, decreased water quality, erosion and degradation of soil structure (MDBA 2011). The floodplain within the project area has been historically and continues to be used for stock grazing.

The impacts of grazing on ecological values has not been comprehensively documented throughout the project area, however, monitoring of grazing exclusion areas along parts of the Frenchmans Creek has shown improvement in vegetation condition (Sluiter and Robertson 2000).

To ensure that the ecological outcomes of the project are realised, grazing management will be an important complementary activity. NSW and Victorian Government agencies will work with landholders to ensure that the benefits of the project are retained, and that stock are not directly impacted by watering e.g. through becoming stranded in waterlogged soils.

12.3.4 Cultural heritage protection and enhancement

Aboriginal cultural heritage sites are known throughout the project area. Complementary actions include works to isolate and protect areas of cultural heritage value and minimise incidental damage from users of the area (e.g. recreational users) and other potential sources of disturbance.

There are also opportunities to provide cultural flows and potential opportunities for Tar-Ru Lands representatives to be involved in construction and ongoing monitoring activities should the project proceed.

13 Costs, impacts and funding arrangements

13.1 Overview

This section reports on the costs that will be incurred in implementing the proposed project and the socio-economic impacts of the proposed suite of actions. It also confirms the governance and administrative responsibility for the ongoing costs of maintaining the effective delivery of the project outcomes.

The project involves three core components:

- Weir pool manipulation for Locks 8 and 9
- Restoration of flows in the CCB Creeks system
- Provision of fish passage between Lake Victoria and Frenchmans Creek

These elements have different implications for costs and impacts. The location of the works is shown in Figure 11-1 in earlier section 11. Technical feasibility and fit for purpose.

13.1.1 Weir pool manipulation – an operating rule change

The weir pool manipulation proposal is an "*Operating rule change*". It involves confirming an amended protocol for weir pool management that assumes increased variability in weir pool height within and between seasons. The amended rules would establish agreed triggers and scenarios that would specify when weir pools are raised or lowered to meet environmental outcomes, within river operation constraints and risk mitigation measures. The initiative involves few costs as the rule change can be implemented largely as an administrative decision. However the project includes the relocation and replacement of the Lower Murray Water Millewa pump station at Lake Cullulleraine (in Victoria) used for bulk water supply and other minor works that will include construction of several low level banks and crossings in order to maximise the extent of inundation from weir pool manipulation.

There will be little socio-economic impact to the few users of the weir pools who will be impacted. The proposed changes have been proof tested through a series of pilot trials over a series of years (Ecological Assoc. 2013; MDBA 2014; NSW Office of Water 2014a and 2014b). This has allowed the practical feasibility of the proposals to be explored, the potential impacts to be confirmed and interested parties to adjust their activities.

13.1.2 CCB Creeks system

The CCB Creeks system investment represents an "*Environmental works and measure at a point location*". This involves the provision of infrastructure measures to deliver enhanced environmental outcomes that will allow the same outcomes to be achieved with a lower volume of held environmental water. Those works include:

- Replacement of existing weirs with regulators that will restore flows, connectivity and diversity
- Culverts on block banks to provide flows and connectivity
- Fish passages on weirs and regulators to promote connectivity
- Culverts on road crossings for operational access.

The project will increase the diversity and quality of aquatic habitat, promote fish populations by providing regionally important spawning and nursery areas, and support bird breeding events.

Almost all projected flows will remain within the existing creek channels through an area deep within the main floodplain where land use is limited to grazing, reserves and recreation, so there will be few impacts on neighbouring properties in terms of access or use.

13.1.3 Frenchmans Creek fish passage

Frenchmans Creek is the flow path from the River Murray to Lake Victoria. The lake is one of the major storages on the River Murray and is used, in particular, to ensure minimum passing flows to South Australia during the height of summer when there are constraints on supply from the River Murray itself.

The inlet regulator on Frenchmans Creek is one of the last major barriers to fish passage along the River Murray. This project involves the concept design and costing for the provision of an appropriate, fit-for-purpose fish passage facility. Once again this is an "*Environmental works and measure at a point location".* The Lake Victoria site and related creeks are important locations for local Indigenous groups, however, if the construction is contained within the existing footprint of the inlet regulator and related roadway (and Indigenous representatives employed to monitor activity) there should be few impacts.

13.2 Weir pool manipulation costs and impacts

13.2.1 Construction costs

The weir pool manipulation proposal involves an operating rule change. Historically, the two weir pools for Locks 8 and 9 have been maintained at a relatively stable level both within and between seasons. This facilitated transport and maintained a steady head for off-take to Lake Victoria.

The proposal involves implementing a more variable weir pool height to generate water savings and promote enhanced environmental outcomes. However, trials over the past few years have demonstrated that the increased variability is within the capacity of the existing design specification of the weir pool and lock infrastructure.

The only capital works required will be the relocation and replacement of the Millewa pump station at Lake Cullulleraine (in Victoria) and other minor works that will include construction of several low level banks and crossings in order to maximise the extent of inundation. The works proposed for the weir pool manipulation component are presented in Table 13-1. The construction costs involve a total investment of [redacted]).

Some additional minor ancillary works may also be required if the operating limits are extended to the extreme, in order to minimise risks of leakage around the infrastructure. The full extent of the need for this will be dealt with as part of the ongoing project planning, design, construction and operation.

Table 13-1: Weir pool manipulation construction cost estimate [Source: GHD 2015]

[redacted]

13.2.2 Operating costs

Operating and maintaining the weirs and locks is a costly exercise irrespective of whether the weir pool is held level or varied. Changing the pool height more frequently will add only a little additional workload to the day-to-day operational and management responsibilities.

Some costs have been incurred to-date in undertaking trials of the proposed manipulation regime. That has included the provision of media-releases and newsletters to regional stakeholders. The aim has been to accustom the community to the expectation that the weir pools will be varied in height within seasons, and it is hoped that this becomes the community norm.

Some ongoing operating costs will be involved in identifying and documenting the optimal manipulation regime and in the MER protocols to validate outcomes. This will include information to third parties. These costs will be small and included as part of the existing lock operation budgets.

13.3 CCB Creeks costs and impacts

13.3.1 Introduction

The CCB Creeks system were part of a complex mosaic of waterways and billabongs prior to the construction of Lock 9 and the Frenchmans Creek as a channel to Lake Victoria. Physical barriers were constructed at several points along the CCB Creeks system to maintain water within the Lock 9 weir pool. This meant that there were then minimal flows in the CCB Creeks system, except during flood events, which in turn has resulted in a highly depauperate ecology within the creeks.

This project seeks to restore flows, connectivity and a diverse hydrodynamic regime within the CCB Creeks system. This involves undertaking works to replace and modify the various assets originally installed to constrain those flows. The works proposed for the CCB are presented in **Table 13-2** and described in more detail in the following sections. Taken together, the proposed CCB Creek system construction costs involve a total investment of [redacted]. This costing comprises [redacted]

Table 13-2: CCB construction cost estimate [Source: NSW Public Works-FCS 2013]

[redacted]

[redacted]

13.3.2 Overview of CCB works

There are three asset types, which require different interventions to deliver the outcomes sought:

- Weirs: the two fixed crest weirs are the major assets restricting flows. The works required include:
  - Decommissioning the old structures and rebuilding new weir structures including gated outlets to provide controlled flows
  - Constructing fish passages around the structures
- Block banks: these are simple embankments that block access across side effluent channels, which will require installation of gated reinforced concrete box culverts (RCBC)
- Road crossings: there are five road crossing that will require RCBCs to provide flow continuity and maintain vehicle access.

The assets and the proposed works are summarised in Table 13-3.

Table 13-3: CCB Creeks - proposed works by type

Asset type	Proposed works
Weirs	New Carrs Weir No. 1, gated outlets & fish passage (Structure No. 2) New Carrs Weir No. 2, gated outlets & fish passage (Structure No. 8)
Block Banks	Structure No. 3 - Carrs Creek, 1-cell RCBC with gated outlet. Structure No. 6 - Carrs Creek, 1-cell RCBC with gated outlet.
Road Crossings	Structure No. 1 - Carrs Creek, 9-cell RCBC Structure No. 4 - Unnamed waterway, 6-cell RCBC Structure No. 7 - Bunberoo Creek, 6-cell RCBC Structure No. 9 - Bunberoo Creek, 8-cell RCBC Structure "A" - Flood Runner, 4-cell RCBC

The following proposals, designs and costing are sourced from a study conducted in 2013 by Public Works NSW and Fishway Consulting Services (FCS). The costs in this business case have been inflated from a 2013 to a 2015 price base to be consistent with all other costs in the business case.

13.3.3 Carrs Weirs No 1 & 2

Carrs Weirs Nos. 1 & 2 are fixed crest weirs used to prevent water from the Lock 9 weir pool flowing down Carrs Creek (Figure 13-1) and Bunberoo Creek (Figure 13-2) respectively. The weir structures are almost identical and comprise:

- Reinforced concrete (RC) buttressed crest walls (height 4.52 m - Carrs 1 and 2.62 m - Carrs 2) sitting on an unreinforced concrete foundation slab
- RC apron extending downstream and upstream
- Clay blanket over the creek bed on the upstream side to act as seepage cutoff provision
- Rock erosion protection

Figure 13-1: Carrs Weir No. 1 on Carrs Creek [Source: March 2015 project steering committee site inspection]

The existing weirs were constructed in 1926 and have operated for around 90 years. The NSW Public Works study found that *numerous aged cracks are evident in reinforced concrete batter slab areas that are visible above the water line* (Section 6-2).

Although NSW Public Works concluded that the majority of the existing weir structures could be retained, after discussions on site with Nigel Rutherford SA Water, Scott Jaensch, NSW DPI Water and Michael Bain, Alluvium it became clear and was agreed that replacement, rather than retrofit, would be the preferred option for Carrs 1 and Carrs 2 weirs. NSW Public Works included estimates in their 2013 report for the additional cost of full replacement and these costs have been added to the total cost, as shown in **Table 13-2**.

The preferred alternative option involves the removal of the existing weirs and the construction of new steel sheetpile weirs with raised crests and gates installed into cut-outs in the exposed sheetpiling. Access provisions would be fixed to the sheetpiling and supported at a height similar to that currently proposed for the retrofit options.

The concept design for Carrs 1 and Carrs 2 replacements are almost identical and include:

- Three single-leaf vertical slide overshot gates
- A vertical slot fishway with adjustment to the existing right side batter slabs
- An access walkway over the structure from which the gates would be operated.

The estimated capital construction costs would be [redacted] for Carrs 1 and [redacted] for Carrs 2.

Figure 13-2: Carrs Weir No. 2 on Bunberoo Creek [Source: March 2015 project steering committee site inspection]

13.3.4 Block banks

There are three block banks, constructed as earth and rock embankments, to prevent flows within the CCB Creeks system. The works required are the installation of reinforced concrete box culverts (RCBC) through the banks with gated outlets to restore and control flows to provide connectivity within the creek system. However, these are simpler installations than the larger scale interventions at the two weirs.

Works are required at two such block banks, referred to as structures #3 and #6, at around [redacted] per block bank. A third block bank, structure #B, is on an effluent channel direct from the weir pool and will be retained without modification.

13.3.5 Road crossings

There are several known road crossings, within the creek system, that are used by SA Water to access Lock 9 and the fixed weirs. The proposed upgraded road crossings involve the provision of multi-cell, precast RCBCs through the current roadway embankments. However no gates are required.

The culverts are sized to provide about 1.2 times the natural creek waterway area to ensure velocities within the culverts are passable to fish and other aquatic biota. This design also avoids the need for the provision of any additional fish passage. Because of the large waterway area the capacity is the same as the creek and so velocities are low at high flows and the erosion risk downstream is minimised. The height of the culverts has been based on providing free water surface flow through the culverts at the simultaneous design discharges for Carrs Weirs 1 and 2. The culvert cells would be founded on a RC slab cast in-situ to promote a tight concrete-soil joint interface to minimise seepage. RC wingwalls would be provided to retain embankment bank materials at each end of the structure and to provide a stable transition. The same design criteria for the culvert sizing apply as for the block banks with unit costs of between [redacted] depending on their length and number of culvert cells.

A detailed ground assessment will be undertaken to identify any other structures that are impeding flows.

13.3.6 Commissioning

Commissioning will require testing of the fishways on Carrs weirs 1 and 2 over a range of weir discharge flows. This is likely to require several site visits over a period of 3 to 6 months.

13.3.7 Contingency

The costing was for a preliminary feasibility study with concept designs. The study was based on professional judgment from other similar projects constructed elsewhere. However, no geo-technical investigations were completed. The study confirmed that *The proposed structures have been developed to an initial feasibility level and accordingly all aspects will need to be confirmed at a later design stage.*

It is therefore appropriate at this stage in the project planning to include a raised value for contingencies, to reflect likely price escalation risks. A 40% contingency is a standard approach for such studies. Applying a 40% contingency mark-up raises the total construction cost to [redacted]

A priority for the project is to commission a more detailed design and cost study to narrow down the uncertainty and enable a suitable contingency to be allocated to the final projected budget.

Supporting investigations that require commissioning during 2015 include: collection of more detailed hydraulic information for the CCB project component (including an on-ground survey of the creeks including bathymetry) and geotechnical and cultural heritage surveys in proximity to the proposed worksites.

13.3.8 CCB operating costs

There will also be ongoing annual costs for the operation and maintenance of the new assets. Operating costs would be relatively low and comprise mostly labour and transport to access the site. There would also be routine maintenance and replacement costs.

In the NSW Public Works costing study, these annual costs are estimated at [redacted] of the capital construction costs at [redacted]. Once again these costs will need to be confirmed as part of the detailed design costing.

13.4 Frenchmans Creek fish passage costs and impacts

13.4.1 Introduction

This project seeks to restore fish passage between Lake Victoria and the River Murray by constructing a Vertical Slot Fishway (VSF) adjacent to the inlet regulator on Frenchmans Creek.

The works proposed at the inlet regulator are presented in Table 13-4 and are described in more detail in the following sections. The proposed Frenchmans Creek VSF structure involves a total investment of [redacted]. This costing comprises [redacted] construction costs and a further [redacted] in project management costs, including commissioning.

Table 13-4: Cost estimate for construction of a Vertical Slot Fishway at Frenchmans Creek Inlet Regulator

[redacted]

13.4.2 Contingency

Similar to the CCB works, the costing provided is a preliminary feasibility study that includes a concept design for a VSF. The study was based on professional judgment from other similar projects constructed elsewhere and no geotechnical investigations were completed. A 40% contingency is a standard approach for such studies where limited data is available and the time frame precludes collecting new data. Applying a 40% contingency mark-up raises the total construction cost to [redacted]

A priority for the project is to commission a more detailed design and cost study to narrow down the uncertainty and enable a suitable contingency to be allocated to the final projected budget.

Supporting investigations that require commissioning during 2015 include: physical modelling of flows at the Frenchmans Creek inlet regulator to confirm the most suitable fish passage design, and geotechnical and cultural heritage surveys in proximity to the worksite.

13.4.3 Commissioning

Commissioning will require testing of the fishway over a range of weir discharge flows, and possibly using different lock attraction flow values. This is likely to require many site visits over a period of 3 to 6 months.

Figure 13-3: Downstream of the Frenchmans Creek inlet regulator [Source: D. Wallis, April 2015]

13.4.4 Frenchmans Creek fishway operating costs

The time and costs associated with operation of the fishway depend on the operational tasks required and the facilities provided for remote operation. For the purposes of the business case the following is presumed:

- all mechanical components do not require manual operation
- the operation of fishway components can be connected to the SCADA system at the site, allowing remote operation.

Initial 12 Months

Following commissioning the fishway operation will be closely monitored for approximately 12 months. This will be at least twice weekly, and may be up to daily visits. These visits will identify any issues that may be associated with entrance and exit conditions, with debris and/or sediment, with gate operation, water quality, and any observable fish behaviour. It will also involve inspection of the fish monitoring system (Pit Tag readers) and any observable defects or damage with the structure.

Note that some of the site inspections can be undertaken coincidentally with weir inspections, although they will extend the time spent at the site.

Subsequent period

Subsequent inspections / operational visits can be co-ordinated to coincide with the weir inspections. They will add approximately 2 hours to each weir visit.

There may be a need for site visits specifically for the fishway where operational issues or alarms are triggered.

Maintenance activities

These may include clearing debris from the entrance or exit, removing accumulated sediment or debris in the fishway, etc. The business case costing has assumed debris clearing at exit / entrance will occur approximately 4 times per year and the fishway will be cleaned out on an annual basis.

The annual operation and maintenance costs of the VSF are estimated to be in the order of 3% of the capital cost at [redacted] in the first year and 1% of the capital construction costs at [redacted] per year, for subsequent years.

Monitoring

The fish tag reader will monitor the performance of the fishway for at least two years. However it will itself require regular inspection and performance assessment. In the absence of intermittent failures or problems, an annual assessment would be satisfactory.

13.5 Proposed financial responsibility for ongoing costs

It is proposed that the assets would be owned by the MDBA and operated and maintained by the State Constructing Authority, SA Water River Murray Operations (RMO) Group, who are contracted by the MDBA to operate and maintain Locks 1 to 9, Lake Victoria works and the five Murray Mouth barrages. Costs would be recovered through the existing arrangements from the member jurisdictions.

13.6 Social and economic costs and benefits

The Phase 2 Guidelines ask for:

> *a description of the expected environmental, social and economic costs and benefits, quantitative where possible, otherwise described qualitatively [Clause 4.10.1]*

The environmental benefits are described fully above. This section assesses the projected social and economic costs and benefits of the projects. Some of these are explored more fully in the risk assessment.

In this section it is necessary to make a judgment about causation, that is, which outcomes should be attributed to this project and which are assumed to be the result of wider policy decisions? The Basin Plan represents a major strategic framework to implement policy decisions regarding the restoration of sustainable flows to the river systems in the Basin. At a formal level it can be seen as implementation of legal obligations under the Commonwealth *Water Act 2007.*

On this basis Third Party Impacts are defined as effects that occur as a result of initiatives beyond existing policy and legislative agreements. These are described below.

13.6.1 Locks 8 and 9 weir pool manipulation

The operation of the weir pools (to result in greater variability in height and extent) represents the implementation of well-established prior policy decisions and operating practice. On this basis no additional social or economic costs or benefits can be attributed to the SDL adjustment supply measure.

There are also limited third party effects in practice, as the major purpose of Lock 9 is to provide hydrostatic head for the Frenchmans Creek transfer to Lake Victoria and facilitate navigation; Lock 8 was constructed primarily for transport purposes to create a weir pool up to Lock 9.

As described previously, the project includes relocation and replacement of the Millewa pump station (just upstream of Lock 9) at Lake Cullulleraine (in Victoria) to mitigate against impacts on irrigators and stock and domestic water users. Replacement of this pump is consistent with Victorian government policy for bulk water supply reliability (DELWP advice April 2015).

Few other parties are affected by the changed weir pool operation:

- Raised levels in the weir pools over the winter months will result in limited floodplain inundation, with the majority of the additional flows occurring in wetlands or billabongs along the length of the river. There is therefore limited impact on commercial activities on floodplain sites, such as grazing, apiary or timber harvesting
- Land-based recreation and tourism are limited as the location is isolated and surrounded by State Forest. Any potential restriction to access will be limited to the winter months, which is outside the main tourist season. Any potential impact will be more than offset by the enhanced ecosystem values of the river
- Lowered weir pool levels in the summer months may impact existing diversion rights if the water levels drop below existing pump intakes, particularly at the extreme of the variability. This could impact on private diverters in NSW. The trial periods over the last three years have helped inform these diverters of likely impacts and NSW DPI Water has held meetings to brief these parties about the future planning context. The provision of advanced notice of proposed weir pool levels provides these parties with the opportunity to adjust their pump locations.

13.6.2 CCB Creeks connectivity

The proposed works will restore flows to the CCB Creek system which is located within the main floodplain of the River Murray.

The design of the new outlet flow regulation gates at the Carrs No. 1 and 2 weirs will generate a maximum flow of 1,500 ML/d down Carrs Creek (via Carrs Weir No. 1) and 500 ML/d down Bunberoo Creek (via Carrs Weir No. 2). Modelling results confirm that at these rates, the flows will be contained almost entirely within the existing creek channels without causing overbank flow (NSW Office Water 2014, NSW Public Works – FCS 2013). Therefore, the initiative will not impact on neighbouring properties. There will be enhanced access through properties because of restored and upgraded road crossings and potential access to the creeks for stock watering.

The work sites and area of influence for the CCB proposal is located mostly on one land Tar-Ru, currently held by the *Tar-Ru Lands Native Title* claimants. SA Water (either owns or) leases the land in close proximity of the weirs. Consultation with the landholder is ongoing. The Coordinator of the group currently sits on the Project Steering Group for the Carrs Capitts Bunberoo project and at this stage the works appear to be consistent with the management aspirations the Tar-Ru Lands claimants have for the property and for the reinstatement of 'cultural flows'.

Impacts on other landholders, diverters and river users will be temporary or minor.

13.6.3 Frenchmans Creek fish passage

There will be limited socio-economic impacts from the proposed initiative at a local scale as the works will be entirely within the existing disturbed footprint of the inlet regulator and access roadway.

At a wider regional scale the initiative will benefit recreational angling as it will promote a richer and more diverse fish population along the River Murray both upstream and downstream of Lock 9.

13.7 Funding sought and co-contributions

The New South Wales State Government will be seeking 100 per cent of project funding for this supply measure proposal from the Commonwealth. The funding requested will ensure the proposed supply measure is construction ready, built in accordance with all regulatory approval requirements and conditions, and fully commissioned once construction is completed.

14 Stakeholder management

An overview of the key components of stakeholder management during project implementation and the outcomes from the business case development phase is provided in the following sections.

14.1 Project phases

Four project phases have been identified for the project's engagement with stakeholders. These are:

- Phase 1: Business case development including weir pool manipulation trials
- Phase 2: Approvals and detailed design
- Phase 3: Construction
- Phase 4: Operation (

The various phases of the project will require different approaches to engagement with various stakeholder groups. There will be some overlap as the project moves into different phases and adaptive management will need to be adopted in order to respond to stakeholders needs.

14.2 Key stakeholders

This project is multifaceted as it spans two states (Victoria and New South Wales) with another state responsible for operations (SA Water) under the coordination of a Commonwealth Authority (MDBA). Moreover, much of the affected land title on the right bank (NSW) is held by the Tar-Ru Native Title Land Claimants in addition to there being several additional landholders and graziers likely to be marginally impacted by the proposed works and operation changes.

Extensive consultation and engagement activities have been underway since the early stages of this project, for parallel TLM and other environmental watering projects in the area. Existing channels of communication have been established between key agencies, groups and individuals and as a result, cooperation and coordination between parties has been excellent.

Phase 1 of this project involved early consultation with Tar-Ru Lands Aboriginal Traditional Owners who are currently engaged by the NSW OEH to provide advice on the Tar-Ru Lands Transfer. Further consultation will occur when the Tar-Ru Lands Board of Management has been fully established under the Barkandji Native Title Group Aboriginal Corporation who have been nominated to take ownership of the Tar-Ru Lands.

Three stakeholder groups have been identified for this project (Table 14-1). Within these groups, agencies are mainly involved through two main steering groups:

- An MDBA Operational Advisory Group (OAG) for Locks 8 and 9 who meet by telephone and comply with the MDBA Operating Advisory Group Terms of Reference.
- A project steering group for the CCB component consisting of agency and landholder representatives.

These groups and other important stakeholders are described in Table 14-1 and Table 14-2.

Table 14-1: Local and regional stakeholder groups

Stakeholder group	Details
Group 1: Agencies	▪ Department of the Environment (Commonwealth) ▪ Commonwealth Environmental Water Office ▪ MDBA ▪ SA Water ▪ Lower Murray Water ▪ Mallee CMA ▪ Western Local Lands Services (previously the Murray CMA) ▪ NSW Office of Environment and Heritage and NSW National Parks and Wildlife Service ▪ Parks Victoria ▪ Murray Darling Wetlands Working Group Ltd. ▪ Department of Environment, Land, Water and Planning (Victoria)
Group 2: Landholders and directly impacted stakeholders	▪ Tar-Ru Native Title Claimants ▪ Landholders directly impacted by the project (see Appendix 3 for more details) ▪ NSW and Vic diverters
Group 3: Other community members and groups	▪ Broader community ▪ Boating, fishing and general river use community ▪ Broader NSW and Vic Aboriginal community ▪ Other NSW and Vic landholders

Table 14-2: Agencies involved in existing and past steering groups for Locks 8 and 9 and CCB

Stakeholder group	Details
L8 and L9 OAG (existing)	▪ MDBA River Operations (Chair) ▪ NSW DPI Water ▪ SA Water River Murray Operations ▪ SA Water Lock 8 and 9 staff ▪ NSW State Water Lock 10 staff ▪ Mallee CMA ▪ Commonwealth Environmental Water Office ▪ Victorian Department of Environment, Land, Water and Planning ▪ MDBA TLM (Works and Measures and Delivery) ▪ NSW State Water ▪ Lower Murray Water ▪ NSW Office of Environment and Heritage
CCB project steering group (existing)	▪ Western Local Land Services ▪ Murray Darling Wetlands Working Group Ltd. ▪ NSW National Parks and Wildlife Service [Office of Environment and Heritage] representing the Native Title Land Claimants during transition ▪ NSW DPI Water [Department of Primary Industries] ▪ SA Water River Murray Operations ▪ Murray-Darling Basin Authority (Works and Measures and Delivery) ▪ NSW Office of Environment and Heritage ▪ Community representative

The aims and approaches for engaging with each of the key stakeholders will differ depending on their expectations and needs. Section 14.5 describes the proposed consultation approaches for these groups during the project implementation phase.

14.3 Phase 1 stakeholder group engagement

The following stakeholder groups have been consulted as part of phase 1 of the project.

Agency groups: The MDBA Operational Advisory Group (L8 and L9 OAG previously the Lindsay Mulcra Operations Group) was established to coordinate watering events across agencies and the project area. The group meet via teleconference on an as needs basis (usually fortnightly to monthly). Project partners in this group include; MDBA, NOW, SA Water, Mallee CMA, Commonwealth Environmental Water Office, OEH, Victorian DEWLP (formerly DSE) and Lower Murray Water.

CCB Project Steering Group (implemented by the MWWG): This steering group includes both community and agency membership. Representatives include, Western Local Land Services, Murray Darling Wetlands Working Group, NSW National Parks and Wildlife Services (representing Native Tittle claimants), MDBA, NOW, SA Water, NSW Office of Environment and Heritage and community representatives.

Landholders and community members: Broader engagement with landholders and community groups has occurred as part of the 2013/14 weir pool trials. Engagement methods include, one-on-one conversations with those potentially impacted, notifications on "flow advice" emailed directly to landholders and community groups, posting information sheets on the MDBA website, media releases, and reporting weir levels in the newspaper.

Stakeholder engagement and communication to date is summarised in Table 14-3.

Table 14-3: Stakeholder engagement and activity log

Event	Target audience
Provision of advice about weir manipulation progress	Water Liaison Working Group
Reporting of weir levels in River Murray weekly report	Broader Community
Provide information page on website	Broader Community, Recreational users of the River
Forecast expected downstream salinity loading, notification of anticipated salinity issues	Broader Community
Press release prior to manipulation	Recreational users of the River
Distribute information sheet	Recreational users of the River
Provide one-on-one advice	Recreational users of the River
Referral of enquiries to MDBA for further advice	Recreational users of the River
Advise of weir manipulation program prior to implementation	NSW Landholders, Vic Landholders
Mail out information sheet	NSW Landholders, Vic Landholders
Advise of weir manipulation program prior to and during implementation	NSW Aboriginal Communities, Vic Aboriginal Communities
Advise through normal customer channels of weir manipulation program prior to and during implementation	NSW Diverters, Vic Diverters
Distribute information sheet on request	NSW Diverters, Vic Diverters

14.4 Outcomes of Phase 1 stakeholder engagement

There have been a variety of different approaches used to engage the diverse group of stakeholders who have an interest in or may potentially be impacted by weir pool manipulation or increased CCB flows within the project area. The weir pool trials have been successful in highlighting any expected and unforseen community impacts and in getting the community used to changing river levels and therefore more accepting of future changing weir heights without constant notification. The trials have initiated a cultural change at both the river operations and community level.

The main findings from the phase 1 engagement include:

- There is recognition of the environmental importance of the creek and floodplain systems targeted in this project amongst the community.
- There is broad support for the proposed environmental works as the most effective way to restore the systems of interest.
- The community is becoming more accepting of surcharges and drawdowns in weir pools.

Some concerns and interests have been raised by the community and these issues have been evaluated through the risk assessment process. Issues raised include:

- Property access.
- Stock bogging, stock wandering off property and possible isolation of stock.
- Isolation of irrigation and house pumps.
- Access for campers and fishers.

14.5 Proposed consultation approaches for the implementation phase

Further engagement activities will continue into the next phase of the project. An overview of the proposed approach is provided in Table 14-4.

Table 14-4: Consultation approach for the implementation phase

Stakeholder group	Consultation approach
Group 1: **Agencies**	▪ Intensive engagement with technical experts through Steering Committees ▪ Construction and operation progress meetings
Group 2: **Landholders and directly impacted stakeholders**	▪ Irrigator/adjacent landholder meetings (face-to-face) ▪ Special events – site tours (e.g. commencement of construction) ▪ Meetings with the Tar-Ru Native Title Claimants ▪ Notifications via email, mail or phone as necessary
Group 3: **Other community members and groups**	▪ Information packages via website (e.g. fact sheets, photos, contact information) ▪ Media communication (e.g. media releases, newspaper articles, radio and television interviews) ▪ Emails or mail outs if necessary

15 Legal and statutory requirements

15.1 Regulatory approvals

No regulatory approvals or statutory requirements apply to the Operating Rule change for the Locks 8 and 9 weir pool manipulation, although the change will require amendment to the Objectives and Outcomes (O&O) for river operations in the River Murray System document (see Section 15.2 below).

Implementation of the supply measures for the CCB Creeks and Frenchmans Creek fish passage will be subject to approvals at Federal, State and Local government levels. Approvals refer to environmental and planning consents, endorsements and agreements required from government agencies arising from legislative of other statutory obligations. The following legislation is potentially relevant to the project:

- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth);
- *Native Title Act 1995* (Commonwealth);
- *NSW Environmental Planning and Assessment Act 1979* (EP&A Act);
- *NSW Crown Lands Act 1989*
- *NSW Water Management Act 2000*
- *NSW National Parks and Wildlife Act 1974* (cultural heritage), and
- *NSW Fisheries Management Act 1994*

The main considerations for approvals and the relevant determining authority are presented in Table 15-1.

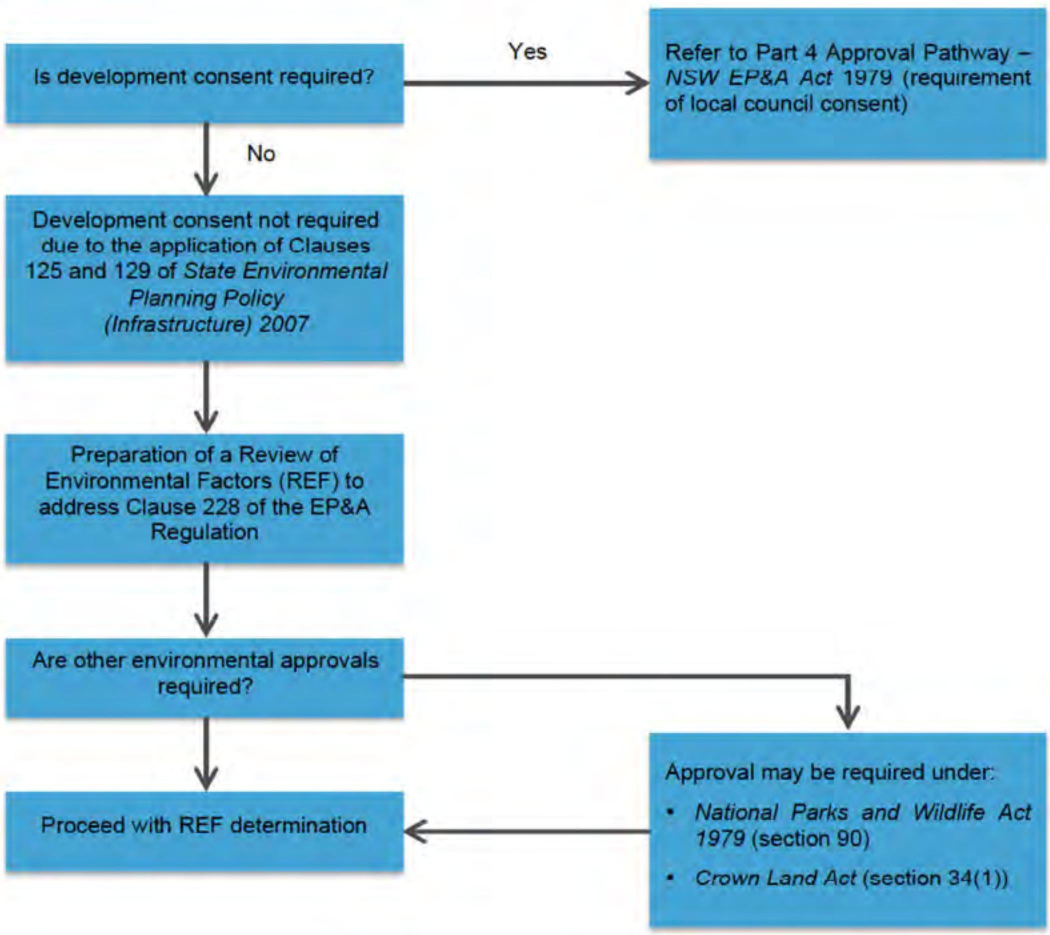
Table 15-1: Summary of possible Commonwealth and State approvals (NSW DPI Water 2014a)

Works requiring approval	Approval required	Legislation	Determining Authority
Potential impacts to Matters of National Environmental Significance	Determination under the *EPBC Act 1999* if the action constitutes a significant impact to MNES.	*Commonwealth Environment Protection and Biodiversity Conservation Act 1999*	Commonwealth Department of the Environment
All works	Decision on whether or not the project needs to be assessed under an Environment Effects Statement.	*NSW Threatened Species Conservation Act 1995* *NSW Fisheries Management Act 1994*	NSW Office of Environment and Heritage NSW Department of Trade and Investment NSW Fisheries
All works	Planning Permit assessment and consent process for the entire project	*Environmental Planning and Assessment Act 1979*	NSW Planning and Infrastructure
Any listed threatened or protected flora or fauna potentially impacted upon by project footprint	Permit to harm or remove protected flora or fauna	*NSW Threatened Species Conservation Act 1995* *NSW Fisheries Management Act 1994*	NSW Office of Environment and Heritage NSW Department of Trade and Investment (NSW Fisheries)
Damage to or clearing of native vegetation	Authority to clear or harm native vegetation	*NSW Native Vegetation Conservation Act 2003*	NSW Trade and Investment

Works requiring approval	Approval required	Legislation	Determining Authority
			(NSW Local Land Services)
Work and access approvals in relation to water diversions and use	Works associated with control structures, banks regulators	*NSW Water Management Act 2000*	NSW DPI Water
All works	Public Land Managers Consent	*Crown Lands Act 1989*	NSW Lands
River Operations, Weir Pool Manipulation	Consent from MDBA for weir pool manipulation	*Water Act 2007*	MDBA
Creation of easements, licences or leases	Creation of easements, licences or leases across crown land that also relates to any permits or authorities under legislation that relates to the management or regulation of water	*Native Title Act 1995*	

The proponent for the project will be the NSW DPI Water. As a public authority the proposal would be permissible without development consent and would be assessed under Part 5 of the EP&A Act (see Figure 15-1).

Figure 15-1: Approvals pathway under Part 5 of the *EP&A Act 1979* (GHD 2014b)



The statutory approvals for the project are considered straight forward for environmental works projects. Construction would be undertaken by the constructing Authority, SA Water and each component will will require assessments, consents and approvals – which can take time. It is anticipated that the proposed works are consistent with legislation outcomes and so should pass without undue delays.

This would include a study to assess the potential impacts of the proposal on threatened species and endangered ecological communities listed under the *Threatened Species Conservation Act 1995*, *Fisheries Management Act 1994* and *EPBC Act 1999*.

15.2 Legislative and policy amendments and inter-jurisdictional agreements

The weir pool manipulation project requires significant cross jurisdictional coordination as it spans two states (Victoria and New South Wales), with another state responsible for operations (SA Water) under the coordination of a Commonwealth Authority (the MDBA).

To date, the cooperation and coordination demonstrated between these agencies and authorities in relation to weir pool manipulation trial has been excellent (NSW Office of Water 2014a).

The current weir pool management terms are included within the Objectives and Outcomes (O&O) for river operations in the River Murray System document. The revised operating rules would require amendments to the O&O, which would need approval from the Basin Officials Committee.

Detailed procedures and manuals will then need to be updated to reflect the approved rule change. It is expected that these changes will fall within the delegated authority of MDBA senior officers.

It is not anticipated that there will be any significant legal or regulatory approval barriers to implementation of this rule change, once the change has been adopted as an SDL adjustment measure. Much of the necessary implementation planning has been done as part to the MDBA/NOW trial of the proposed rule change.

15.3 Cultural heritage assessment

The weir pools component will not impact on cultural heritage values as there is no construction footprint. Within the CCB component, cultural heritage values are regarded as high. Much of the proposed activities will occur within the disturbed footprint of previous works. However, it is recognised that the cultural heritage values in the area will require careful planning and assessment and monitoring. This will take account of the proposed transfer of the lands to the Native Title Land Claimants.

Given the cultural sensitivity of the CCB area the NSW DPI Water will be commissioning a due diligence assessment to identify possible impacts on sensitive locations. A more detailed Aboriginal cultural heritage assessment would be required to obtain a permit under Section 90 of the *National Parks and Wildlife Act 1974* if Aboriginal items would be impacted.

These assessments will be undertaken in consultation with representatives of the Tar-Ru Lands Native Title Claimants.

16 Governance and project management

16.1 Governance arrangements during business case development

Responsibility for the business case development lies with the NSW DPI Water on behalf of the Sustainable Diversion Limit Adjustment Assessment Committee (SDLAAC). Development of the business case has involved close liaison with interested parties including:

- NSW DPI Water, as the project proponent
- SA Water, as the State Constructing Authority and manager of the relevant assets
- MDBA as the owner of the relevant assets
- Mallee CMA: as the interested party in Victoria for the Locks 8 and 9 weir pool initiative
- Other NSW agencies as appropriate, including NSW Fisheries, NSW National Parks and Wildlife Service

16.2 Governance arrangements during project implementation

16.2.1 Locks 8 and 9 Weir pool manipulation

The initiative is co-ordinated through an MDBA Operational Advisory Group (L8 and L9 OAG). This OAG complies with the MDBA OAG Terms of Reference. Membership comprises:

- MDBA River Operations (Chair)
- NSW DPI Water
- SA Water River Murray Operations
- SA Water Lock 8 and 9 staff
- NSW State Water Lock 10 staff
- Lower Murray Water
- Mallee CMA
- Commonwealth Environmental Water Office
- Victorian Department of Environment, Land, Water and Planning (DELWP).
- MDBA TLM (Works and Measures and Delivery)
- NSW State Water

This group meets on an as-needs-basis under the auspices of the *Lindsay Mulcra Wallpolla Operations Group*, currently chaired by the Mallee CMA.

16.2.2 CCB Creeks system and Frenchmans Creek works

The four primary players are NSW DPI Water as the project proponent, the MDBA as the owner of the assets, SA Water River Murray Operations as the manager of the assets and the Tar-Ru Lands Aboriginal Traditional Owners. These partners have a proven track-record of effective project development and implementation.

17 Risk assessment of project development and construction

17.1 Overview of risk assessment

This section considers project development and construction risks that could impact on project delivery and values of the area for Locks 8 and 9, the CCB Creeks system and Frenchmans Creek. Priority risks are highlighted through a risk assessment process that rates the level of initial risk and residual risk after mitigation.

Risks for each proposal have been separated into broad categories:

- Governance and project management
- Cultural heritage and other approvals
- Design, commissioning and delivery

Further detail on these risks and how they apply to the proposal is provided in Appendix 3.

Project development and construction risks have been identified and assessed throughout the early stages of this project. This experience, as well as experience from other environmental watering projects, has informed the risk assessment and proposal of mitigation efforts.

The methodology for assessing the risks has been previously outlined in Section 6.

17.1.1 Locks 8 and 9 weir pool manipulation

Project development and construction risks for the Locks 8 and 9 weir pool manipulation proposal are negligible (initial risks are low or very low and residual risk are very low) because:

- The proposal involves the relocation and replacement of the Millewa pump station which will be executed by Lower Murray Water and does not pose any substantive risks that are relevant to this business case.
- Governance, coordination and stakeholder risks that could affect project delivery have been shown to be very low through ongoing weir pool manipulation trials.

Weir pool manipulation trials have allowed governance and project management mechanisms to be put in place and tested and will provide a sound basis for project delivery, including:

- Tri-state cooperation and coordination for the weir pool manipulation trials has been found to be excellent.
- Consultation and engagement activities have involved key stakeholders including the Barkandji Traditional Owners through the Tar-Ru Native Title Claimants who have expressed their broad support for the project.

Accordingly, no further project development and construction phase risk assessment has been undertaken for the Locks 8 and 9 weir pool manipulation proposal.

17.1.2 CCB Creeks system connectivity

Of the three proposals, the CCB Creeks system connectivity has the potential for the most significant impact on project delivery and socio-economic values as a result of construction activities. Sources of risk for this proposal include:

- Works for the CCB proposal could be impacted by adverse weather and inundation due to the environmental conditions of the site.
- Cultural heritage values could be impacted by construction works and access due to the proximity of the site to known cultural heritage sites and values.
- Detailed geotechnical studies and further modelling and design will be required to progress the project to build-ready and could uncover additional costs unforseen by the original proposal.

However, with proper governance, project management arrangements and approvals processes in place the majority of these risks are readily mitigated and the residual rating is reduced to low to very low.

There are, however, two priority risks (where residual risk is moderate) for this proposal that should be given additional consideration. These are:

- Risk of impact on cultural heritage values because of the high incidence of cultural sites in the area.
- Geotechnical investigations are yet to be undertaken which represents some risk of impacting the project design and therefore costs.

Table 17-1 highlights the key construction and project development risks for the CCB Creeks system connectivity proposal and suitable mitigation options.

17.1.3 Frenchmans Creek fish passage

Proposed construction works at Frenchmans Creek are limited to a small area mostly contained within the existing footprint of the regulator. The operating authority, SA Water, holds the tenure of this land. As such, most construction risks are negligible for this project.

However, one risk that cannot be fully eliminated and should be considered for this proposal:

- Unforseen design issues or geotechnical risks that could impact on construction ease and project delivery.

Table 17-2 highlights the key construction and project development risk for the Frenchmans Creek fish passage proposal and suitable mitigation options.

Table 17-1: Risk assessment and mitigation for project development and construction risks for CCB Creeks system connectivity

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Governance and project management						
Costs exceed approved funds due to errors or emissions or because of costly mitigation requirements	Possible	Severe	High	40% contingencies factored into cost estimates. Provision for additional modelling is factored into estimates.	Low	MDWWG (2013)
Tri-state institutional arrangements are too complex or insufficient leading to a lack of cooperation and collaboration during project delivery	Unlikely	Severe	Moderate	Arrangements will draw on established relationships between agencies and experience from Locks 8 and 9 weir pool manipulation trials.	Low	MDWWG (2013)
Unforseen delays in project delivery due to flooding	Possible	Severe	High	Contingencies for flooding are factored in.	Low	MDWWG (2013)
Unforseen delays in project delivery due to adverse weather, approval processes or conflict with stakeholders	Likely	Moderate	Moderate	Contingencies for adverse weather are factored in. Communication plans and approvals processes will be put in place.	Low	MDWWG (2013)
Cultural Heritage and other approvals						
Artefacts are damaged or lost due to construction activities	Possible	Severe	High	Cultural heritage approval processes and proactive engagement with Indigenous stakeholders. Small construction footprint at weirs.	Moderate	Risk workshop
Loss of engagement with Barkandji Traditional Owners and other Indigenous stakeholders	Possible	Moderate	Moderate	Early and ongoing consultation and cultural heritage approval processes	Moderate	Risk workshop
Approvals for creation of easements, licences or leases cannot be obtained	Unlikely	Severe	Moderate	Sound approvals processes are in place. Early consultation with landholder	Low	Risk workshop
Design and delivery						
Additional detailed design work is required	Likely	Moderate	Moderate	Provision is made for additional flows modelling and design assessments	Low	MDWWG (2013)
Geotechnical risks compromise the project	Possible	Moderate	Moderate	Provision is made for geotechnical testing, laboratory analysis and reporting	Low	NOW (2014a)

Table 17-2: Risk assessment and mitigation for project development and construction risks for Frenchmans Creek fish passage

Description of threat	Likelihood	Consequence	Initial risk	Mitigation	Residual risk	Source
Governance and project management						
Costs exceed approved funds due to errors or emissions or because of costly mitigation requirements	Possible	Moderate	Moderate	40% contingencies factored into cost estimates. Provision for additional modelling is factored into estimates.	Low	Risk workshop
Unforseen delays in project delivery due to adverse weather, approval processes or conflict with stakeholders	Possible	Moderate	Moderate	Contingencies for adverse weather are factored in. Communication plans and approvals processes will be put in place.	Very Low	Risk workshop
Cultural Heritage and other approvals						
Artefacts are damaged or lost due to construction activities	Unlikely	Moderate	Low	Cultural heritage approval processes and proactive engagement with indigenous stakeholders. Fishway to be constructed within existing construction footprint alongside inlet regulator.	Low	Risk workshop
Loss of engagement with Barkandji Traditional Owners and other Indigenous stakeholders	Unlikely	Moderate	Moderate	Early and ongoing consultation and cultural heritage approval processes.	Low	Risk workshop
Design and delivery						
Additional detailed design work is required	Likely	Moderate	Moderate	Provision is made for additional flows modelling and design assessments.	Low	Risk workshop
Geotechnical related construction risks compromise the project e.g. groundwater infiltration into works area, it will be a deep excavation due to bank height relative to the depth to invert of the lock (around 8 m)	Possible	Severe	High	Provision made for geotechnical testing, laboratory analysis and reporting. A suitable construction approach be adopted to manage these issues.	Moderate	Risk workshop

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Appendix 1: Supporting documents

- Alluvium (2015). Concept design report: Lower Murray SDL Offsets - Frenchmans Creek Fishway. Report prepared by Alluvium Consulting Australia prepared for NSW Office of Water, April 2015.
  - preliminary feasibility concept design for restoring fish passage at the inlet regulator on Frenchmans Creek

- NSW Office of Water (2014a) SDL adjustment feasibility proposal: Locks 8 and 9 weir pool manipulation optimisation – incorporating Carrs, Capitts and Bunberoo Creek systems. NSW Department of Primary Industries, Office of Water, Buronga NSW.
  - the foundational feasibility proposal for the project

- Ecological Associates (2013) Locks 8 and 9 Weir Pool Manipulation Optimisation Plan – Analysis Report. ES001-2-C. Prepared for NSW Office of Water.
  – for rationale behind choice of values and processes for setting ecological objectives and targets.

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  – for design and costing of CCB works

- Mallen-Cooper, M and Stuart, I. (2015) Lake Victoria inlet fish passage design considerations. Memorandum to NSW Fisheries and NSW Office of Water prepared by Martin Mallen-Cooper and Ivor Stuart.

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- MDWWG (2014) Project and planning approvals for the Carrs, Capitts and Bunberoo Creeks system 2013/14 project delivery. Report prepared by the Murray Darling Wetland Working Group for NSW Local Land Services Western.
  - for evidence on a suitable statutory framework and expected approval processes

- MDWWG (2013) Locks 8&9 Weir Pool Manipulation Optimisation Plan: Incorporation the Carrs, Capitts and Bunberoo Creeks system – Business Case. Murray Darling Wetland Working Group for NSW Department of Primary Industries- Office of Water.
  - background information describing the overall project concept and case for investment

- NSW Public Works (2015) Results of MIKEFLOOD model run for Carrs, Capitts and Bunberoo Creeks system. Correspondence to NSW Office of Water from Bob Clark, NSW Public Works, Sydney.

Appendix 2: Species of conservation significance

1. Fauna

The Frenchmans and CCB Creeks environments are predicted to contain threatened aquatic species listed as part of the Lowland Murray aquatic ecological community (determined by the Fisheries Scientific Committee, NSW Department of Primary Industries). The listing of this aquatic ecological community provides all native fish and other aquatic animal life the status of endangered species. The community includes 23 native fish species and over 400 recorded native invertebrate species (NSW DPI 2007).

Table A2- 1: Native fish and conservation status surveyed in the project area (Ellis and Meredith 2005; Reid et al. 2009; Gilligan 2008; Ellis and Sharpe 2012; Henderson et al. 2013, Lloyd 2012)

Scientific name	Common name	Commonwealth	Victoria		NSW
		EPBC	FFG	VROTS	FMA
Small-bodied native fish (<100mm)					
Retropinna semoni	Australian smelt				
Galaxias rostratus	Flat-headed galaxias			DD	
Ambassis agassizii	Olive perchlet		L		
Nannoperca australis	Southern pygmy perch				ES
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead			DD	
Nannoperca obscura	Yarra pygmy perch		L		
Craterocephalus stercusmuscarum fulvus	Freshwater hardyhead		L		
Craterocephalus fluviatlis	Murray hardyhead	E	L		CES
Melanotaenia fluviatilis	Murray-darling rainbowfish		L		
Philypnodon grandiceps	Flathead gudgeon				
Philypnodon macrostomus	Dwarf flathead gudgeon				
Hypseleotris spp.	Carp gudgeon				
Mogurnda adspersa	Purple spotted gudgeon		L		ES
Craterocephalus stercusmuscarum fulvus	Un-specked hardyhead			DD	
Large-bodied native fish (>100mm)					
Biyanus bidyanus	Silver perch			CR	V
Nematalosa erebi	Bony herring				
Leiopotherapon unicolor	Spangled perch				
Maccullochella peelii	Murray cod	V		V	
Macquaria ambigua	Golden perch			V	
Tandanus tandanus	Freshwater catfish		L	V	

Table notes: Australian government: Environment Protection and Biodiversity Conservation Act 1999 (EPBC) listed – E Endangered; V Vulnerable. Accessed 3 June 2015 http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna#fishes_critically_endangered

Victoria: *Flora and Fauna Guarantee Act 1988* (FFG) listed - L Listed as threatened; Vulnerable, rare and threatened species listing (VROTS) – CR Critically endangered, V Vulnerable; DD Data deficient Accessed 3 June 2015 http://www.depi.vic.gov.au/environment-and-wildlife/threatened-species-and-communities/threatened-species-advisory-lists

New South Wales: *NSW Fisheries Management Act 1994* (FMA) - CCE – Critically endangered species; ES – Endangered species; V - Vulnerable Accessed 3 June 2015 http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/identifying

Twelve native fish species are encountered regularly in the study area indicated in Table A2-1 By an asterix.

Small fish species that inhabit localised riparian and wetland habitats include flat-headed galaxias, southern pygmy perch and hardyhead species. Large-bodied fish that specialise in deeper channel habitat include Murray cod, golden perch and silver perch. Freshwater catfish spend time in deep channel habitat but use wetlands to breed. Fast-flowing habitat in Mullaroo Creek and Chowilla Creek support the only two self-sustaining populations of Murray cod in the lower River Murray (Mallen-Cooper, Koehn, King, Stuart, & Zampatti 2008) (Saddlier, O'Mahony, & Ramsey 2008). The high quality of fish habitat in these creeks also contributes to healthy populations of golden perch, Australian smelt and freshwater catfish.

The study area has a highly diverse bird fauna with 196 bird species reported, of which 35 have conservation significance at the state and national level and four are protected under international migratory bird agreements (Table xx). A recent bird survey in 2013 observed 93 species (GHD 2014a).

Wetlands provide habitat for dabbling, diving and filter feeding ducks while small fish will provide prey for piscivorous waterbirds such as white-bellied sea-eagle. Large wading birds such as egrets, herons and spoonbill will prey on macroinvertebrates, frogs and small fish and will make use of large woody debris and emergent macrophytes for cover.

Flooded woodland and lignum shrubland provide nesting sites for waterbirds including waterfowl and colonial nesting species. Broad areas of shallow flooding in alluvial plains and wetlands provide feeding areas for waterbirds, including migratory species which visit Lindsay Island in summer and early autumn. Flooding promotes plant productivity and will increase the food resources for bush birds that depend on fruit, seeds, nectar and insects. Understorey complexity will increase the availability of vertebrate prey species such as lizards and will provide sheltering and nesting sites for bush birds.

Table A2- 2: Rare or endangered birds of conservation significance expected to occur in the study area (GHD 2014a)

Scientific Name	Common Name	Conservation Status			Migratory Bird Agreements	
		EPBC	FFG	VROTS	Bonn	CAMBA JAMBA ROKAMBA
Anas rhynchotis	Australasian Shoveler			V		
Ardea intermedia	Intermediate Egret		L	E		
Ardea modesta	Eastern Great Egret		L	V		C J

Aythya australis	Hardhead			V		
Biziura lobata	Musk Duck			V		
Burhinus grallarius	Bush Stone-curlew		L	E		
Charadrius australis	Inland Dotterel			V		
Egretta garzetta nigripes	Little Egret		L	E		
Falco subniger	Black Falcon			V		
Gelochelidon nilotica macrotarsa	Gull-billed Tern		L	E		
Geopelia cuneata	Diamond Dove		L	NT		
Haliaeetus leucogaster	White-bellied Sea-Eagle		L	V		C
Hydroprogne caspia	Caspian Tern		L	NT		C J
Lophocroa leadbeateri	Major Mitchell's Cockatoo		L	V		
Lophoictinia isura	Square-tailed Kite		L	V		
Melanodryas cucullata cucullata	Hooded Robin		L	NT		
Ninox connivens connivens	Barking Owl		L	E		
Oreoica gutturalis gutturalis	Crested Bellbird		L	NT		
Oxyura australis	Blue-billed Duck		L	E		
Polytelis anthopeplus monarchoides	Regent Parrot	V	L	V		
Pomatostomus temporalis temporalis	Grey-crowned Babbler		L	E		
Ptilonorhynchus maculatus	Spotted Bowerbird		L	CE		
Pyrrholaemus brunneus	Redthroat		L	E		
Stictonetta naevosa	Freckled Duck		L	E		
Struthidea cinerea	Apostlebird		L			
Tringa nebularia	Common Greenshank			V	A2H	C J R
Turnix pyrrhothorax	Red-chested Button-quail		L	V		

The bat fauna of Lindsay Island is diverse with nine species observed at the site (Table xx). Bats are almost entirely insectivorous. Flooding maintains the high levels of canopy and understorey productivity required to provide insect prey while trees provide roosting habitat in bark, crevices and hollows.

Table A2- 3: Native mammal species reported from Lindsay Island (GHD 2014a)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Chalinolobus gouldii	gould's wattled bat				x	x
Chalinolobus morio	chocolate wattled bat				x	
Hydromys chrysogaster	water rat				x	x
Macropus fuliginosus	western grey kangaroo				x	x
Macropus giganteus	eastern grey kangaroo				x	x

Macropus rufus	red kangaroo				x	x
Mormopterus sp. 3	inland freetail bat					x
Mormopterus sp. 4	southern freetail bat					x
Nyctophilus geoffroyi	lesser long-eared bat					x
Ornithorhynchus anatinus	platypus					x
Planigale gilesi	Giles planigale		L	NT	x	x
Scotorepens balstoni	inland broad-nosed bat				x	
Sminthopsis crassicaudata	fat-tailed dunnart			NT	x	x
Tachyglossus aculeatus	short-beaked echidna				x	x
Tadarida australis	white-striped freetail bat					x
Vespadelus regulus	southern forest bat					x
Vespadelus vulturnus	little forest bat					x

The open plains and grassland provide habitat for kangaroo species while watercourses and wetlands provide habitat for water rat and platypus. Understorey vegetation, including lignum shrublands, is an important habitat component for Giles planigale.

Wetland, forest and woodlands provide habitat for a range of reptiles and frogs. Twenty eight reptiles have been reported from Lindsay Island including five species of conservation significance (Table xx). Six frog species occur at Lindsay Island, of which one, the growling grass frog is vulnerable nationally and endangered in Victoria (GHD 2014a).

Table A2- 4: Reptiles and amphibians of conservation significance reported from Lindsay Island (GHD 2014a)

Species	Scientific Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Reptiles						
Furina diadema	red-naped snake		L	V		x
Chelodina expansa	broad-shelled turtle		L	E		x
Morelia spilota metcalfei	carpet python		L	E		x
Pseudonaja aspidorhyncha	patch-nosed brown snake			NT		x
Varanus varius	lace monitor			E	x	x
Amphibians						
Litoria raniformis	growling grass frog	V	L	E		x

2. Flora

The study area has a diverse flora and supports numerous plant species of conservation significance. A recent vegetation survey (Australian Ecosystems 2013) reported 228 indigenous plant species of which 44 are floodplain species that are rare or threatened under the Victorian Advisory List of Threatened Plants. One species, *Eleocharis abicis*, is vulnerable in Victoria and listed vulnerable under the Commonwealth EPBC Act.

The survey confirmed the presence of most species that had been reported from databases and previous surveys (Table A2-2).

Table A2- 5: Plant species of conservation significance reported from Lindsay Island (Australian Ecosystems 2013)

Scientific Name	Common Name	Conservation Status			2013 Survey	Data-bases
		EPBC	FFG	VROTS		
Asperula gemella	Twin-leaf Bedstraw			R	x	x
Atriplex holocarpa	Pop Saltbush		L	V	x	x
Atriplex limbata	Spreading Saltbush		L	V	x	x
Atriplex lindleyi subsp. *conduplicata*	Baldoo			R	x	x
Atriplex nummularia subsp. omissa	Dwarf Old-man Saltbush			R	x	x
Atriplex pseudocampanulata	Mealy Saltbush			R	x	x
Atriplex rhagodioides	Silver Saltbush		L	V	x	x
Bergia trimera	Small Water-fire			V	x	x
Calotis cuneifolia	Blue Burr-daisy			R	x	x
Centipeda crateriformis subsp. compacta	Compact Sneezeweed			R	x	x
Centipeda thespidioides s.l.	Desert Sneezeweed			R	x	x
Craspedia haplorrhiza	Plains Billy-buttons			K	x	x
Crinum flaccidum	Darling Lily		L	V	x	x
Cynodon dactylon var. *pulchellus*	Native Couch			K	x	x
Eleocharis obicis	Striate Spike-sedge	V		V	x	x
Eragrostis lacunaria	Purple Love-grass			V	x	x
Eremophila bignoniiflora	Bignonia Emu-bush		L	V	x	x
Eremophila divaricata subsp. divaricata	Spreading Emu-bush			R	x	x
Frankenia serpyllifolia	Bristly Sea-heath			R	x	x
Glossostigma drummondii	Desert Mud-mat			K	x	x
Haloragis glauca f. *glauca*	Bluish Raspwort			K	x	x
Lawrencia spicata	Salt Lawrencia			R	x	x
Lepidium fasciculatum	Bundled Peppercress			K	x	x
Lepidium papillosum	Warty Peppercress			K	x	x
Lepidium pseudohyssopifolium	Native Peppercress			K	x	x
Malacocera tricornis	Goat Head			R	x	x
Mimulus prostratus	Small Monkey-flower			R	x	x
Picris squarrosa	Squat Picris			R	x	x
Rumex crystallinus s.s.	Glistening Dock			V	x	x
Sclerolaena decurrens	Green Copperburr			V	x	x
Sclerolaena divaricata	Tangled Copperburr			K	x	x
Sclerolaena muricata var. *muricata*	Black Roly-poly			K	x	x
Senecio cunninghamii var. cunninghamii	Branching Groundsel			R	x	x
Solanum lacunarium	Lagoon Nightshade			V	x	x
Stellaria sp. 2	Rangeland Starwort			K	x	x
Swainsona greyana	Hairy Darling-pea		L	E	x	x

Swainsona microphylla	Small-leaf Swainson-pea			R	x	
Swainsona phacoides	Dwarf Swainson-pea		L	E	x	x
Tecticornia triandra	Desert Glasswort			R	x	x
Tetragonia moorei	Annual Spinach			K	x	
Wahlenbergia tumidifructa	Mallee Annual-bluebell			R	x	
Tecticornia tenuis	Slender Glasswort			R		x
Tetragonia eremaea s.l.	Desert Spinach			K		x
Zygophyllum ammophilum	Sand Twin-leaf			R		x

Appendix 3: Detailed risk descriptions

3. Ecological risks

3.1. Increased abundance of pest plant species

Key pest plant species present across the works area that have the potential to increase in abundance following even minor inundation events include: Noogoora burr, golden dodder and thistles. These species germinate following flood events and are prolific seeders, their seeds can remain dormant in the soil for several years (Cunningham et al*.* 1992).

3.2. Enhanced carp recruitment

Common carp are highly invasive fish that can significantly degrade aquatic ecosystems. Carp disturb soil and vegetation and can increase turbidity and reduce aquatic plant growth.

Floodplain inundation promotes breeding in common carp. Carp predominantly spawn during spring in shallow water among newly flooded vegetation. Carp spawn under a wide range of temperatures and may successfully breed any time from winter to summer. Carp are capable of multiple spawning events in a year if conditions are favourable.

There is little scope to effectively manage pest fish threats associated with the project. The breeding season for carp and other pest fish overlaps with that of native fish, so it is not possible to time weir pool manipulations or flows down the CCB to differentiate the benefits.

It is expected that by promoting conditions that favour native fish, the impacts of pest fish will be mitigated.

3.3. Enhancement of other pest fish recruitment

Key pest fish species include: goldfish, tench, gambusia, oriental weatherloach and redfin perch. Weatherloach are highly invasive fish that can significantly degrade aquatic ecosystems. They prey on the eggs of native fish and compete with native fish for food and spawning sites. Their burrowing habits increase turbidity and uproot aquatic plants.

Goldfish, tench, gambusia and redfin perch are primarily of concern for their impacts to native fish species through predation and competition. Breeding by these pest fish species is increased by flooding, but not to the same extent as carp.

3.4. Barriers to fish movement

Raising of weir pools can create a barrier to fish movement where there is no provision for appropriately designed fishways. The fishways on Locks 8 and 9 use a vertical-slot design constructed on the weir abutment. The design incorporates a series of stepped pool separated by walls that incorporate vertical openings. The fishways are designed for maximum functionality at normal operating levels. Surcharging the weir pool for example increases the velocity of water in the fishway and will prevent some fish swimming upstream (Ecological Assoc. 2013). The limits and effectiveness of adjustments to accommodate raising weir levels have not been properly trialled and/or evaluated. This will form part of an ongoing assessment of impacts of weir manipulations.

3.5. Mismatch between fish spawning cues and favorable recruitment conditions

There are several species of native fish that use the proposed project area as habitat and that the proposed works seek to benefit.

Although there will be similarities in recruitment cues amongst the key native fish such as light and temperature, there is also likely to be some recruitment requirements that are unique to particular fish species. Of most concern are native catfish, a species listed under the *EPBC Act 1999* as vulnerable. Catfish are known to abandon their nest under fluctuating water levels and therefore there may be potential to impact spawning and in particular nesting for catfish under the proposed water manipulations.

3.6. Stranding and isolation of native fish on the floodplain

In the event that the rate of fall in water levels for flow events is increased too high there is the potential for fish stranding and isolation on the floodplain and in downstream creeks.

3.7. Food chain imbalance

The diversity of wetland water regimes and connection regimes is important to the diversity of aquatic fauna communities. Predation by large fish can reduce the abundance of small fish, macroinvertebrates and frogs and can thereby impact on the food available to waterbirds. Diversity is promoted when wetlands are connected to permanent aquatic habitat at different times and the access of large predators is varied.

It is therefore important that the operating regime reflects the natural variability of the system so that different aspects of the local ecology (fish, birds) all benefit from the improved aquatic productivity.

3.8. Accumulation of salt on floodplain soils

Raising weir pools will promote recharge from the river to the Channel Sands aquifer and raise groundwater levels near the river. Recharge will also increase as a result of floodplain inundation, particularly where the overlying Coonambidgal Formation is sandy or absent. Groundwater recharge will raise groundwater levels and may accelerate evapotranspiration and the accumulation of salts in floodplain soils.

3.9. Increased salt load in water discharged to the River Murray

When weir pools are restored or lowered, groundwater will flow from the floodplain aquifer to the River Murray. Discharging groundwater will carry salts which may impact on river water quality.

A weir level regime that involves raising and lowering but does not affect average annual weir levels may have a very low or no net impact on groundwater discharge or salt loads to the river.

Monitoring the risk of salt loads to the river would be achieved by surface water salinity monitoring of wetlands and anabranches and at the weirs.

Extensive investigations have been undertaken of the interactions between weir pool levels and groundwater and provide further detail on evaluation and monitoring of these risks (REM 2006; REM 2008). Results from the 2013/14 manipulation trial suggests impacts are minimal and should be manageable (NSW Office of Water 2014b).

3.10. Exposure of acid sulphate sediments

Permanent inundation of many wetlands along the River Murray since the construction of the weirs has enhanced accumulation of sulfidic materials in flooded soils. Sulfide minerals such as pyrite (FeS_2) and monosulfides (FeS) accumulate under saturated conditions that are sufficiently reducing due to the presence of labile organic matter and anaerobic bacteria where there is a source of sulphate (SO_4) and iron (Fe) (Shand et al. 2008).

When these anoxic, sulfidic, reduced soils are drained and exposed to air, they are oxidised and can form sulfuric acid. When reflooded, acidic soils potentially release toxic quantities of iron, aluminium and heavy metals from the soil. Reflooded acid sulphate soils can have severe impacts on aquatic flora and fauna as conditions may be toxic to fish and aquatic invertebrates and macrophytes may be unable to grow in affected soils (Shand et al. 2008).

Overall, studies undertaken to date suggest some of the wetlands of interest in the project area may potentially form acid sulphate soils and the severity of risk varies (Ecological Associates 2013).

3.11. Temporary habitat disturbance for aquatic fauna and fauna (instream and bank)

Construction activities including completion of infrastructure upgrades for CCB Creeks system connectivity and installation of a fishway within Frenchmans Creek may result in localised and temporary habitat disturbance for aquatic fauna and flora e.g. increased turbidity, changes to hydrodynamics, increased noise and vibrations and physical disturbance.

4. Socio-economic impacts of operation

4.1. Water storage

Lowering weir pool levels may isolate pumps from water and interrupt water supply to irrigators and stock and domestic water users.

The New South Wales government does not guarantee water supply. There is no obligation to provide river level heights for diversion, water quality nor water quantity. The supply of water is maintained with the best reasonable efforts of the water resource managers. The governments cannot be held liable for water supply quantity, river level height nor water quantity. However, community expectations is a significant consideration when planning environmental weir level adjustments.

The Lock 9 weir pool is accessed by water supply pumps to Lake Cullulleraine. The pumps operate at levels as low as -0.3 m (27.1 m AHD) from the normal operating level (Peter Ebner Lower Murray Water August 2013). There are no significant diversions from the Lock 8 weir pool (Ecological Assoc. 2013).

Achievement of desired flow regimes through the proposed Carrs weirs regulators into the CCB Creeks system will need to be balanced with meeting Lake Victoria water storage requirements (Pers. Comm. Nigel Rutherford SA Water).

4.2. Loss of access

Loss of access can occur through inundation of private or public land or tracks as a result of raising the height of the weir pool. This could impact grazing activities and other properties, public land management activities or the operation or management of structures by SA Waer. Ongoing trials have shown that loss of access due to weir pool manipulation at Locks 8 and 9 is not significant and where it does occur, there are likely to be alternative tracks available for use or opportunities to avoid impact through notification.

Table A3-1 below lists the landholder and stock management impacts (due to drawdown and weir surcharge) that were identified during the weir pool manipulation trials (Ecological Associates 2013).

In some cases, creek crossings in the CCB area will be reconstructed to allow fish passage. This work will involve raising creek crossings and installing culverts to provide all weather access. This will benefit both project outcomes and stakeholders and has been included in the costs of the project. With appropriate and timely notice, impacts to the community and other stakeholders will be minimal.

4.3. Cultural heritage

The Murray River is rich with cultural artefacts, sites and values that could be impacted by the project. There has been a recent change in land tenure in the CCB area (part of the Tar-Ru Lands) with land being handed back to the Barkandji Traditional Owners. There is a risk that the Barkandji Traditional Owners have conflicting priorities for the land and oppose the project. However, early consultation suggests this is not the case. Proper cultural heritage surveys and ongoing consultation with Traditional Owners will ensure these risks are managed and kept low.

4.4. Third party impacts

Impacts on third parties from changing water levels could include loss of access from floodplain inundation, increased river salinity, isolation of pumps and assets during drawdown, and interrupting river navigation. Risks identified for the Locks 8 and 9 and CCB projects include:

- Restoring or lowering weir pools will cause groundwater to discharge into the river, possibly carrying significant salt loads that could impact on the river. A weir pool regime that involves raising and lowering but does not affect average annual weir levels is unlikely to have a net impact on salt levels to the river. Extensive investigations of the interactions between groundwater and river water suggest impacts are minimal and should be manageable with monitoring (NSW Office of Water 2014a).
- There could be conflict between managing desired flow regimes in the CCB Creeks system and meeting Lake Victoria water storage requirements. Seasonal watering will need to be scheduled such that the delivery of CCB flow requirements are balanced with required flows into Lake Victoria flows via Frenchmans Creek (Pers. Comm. Nigel Rutherford SA Water).
- Lowering pool levels has the potential to isolate pumps that provide water to dwellings, for stock or for irrigation. There are few pumps in the Lock 8 and 9 weir pools and, in general, landholders will be able to accommodate lowered weir levels if sufficient notice is given. Lowering pool levels below the Lake Cullulleraine off take would impose significant inconvenience and disruption to Lower Murray Water, who operates the offtake, and Lake Cullulleraine water users. The off take requires the weir to be operated at levels greater than -0.15 m. Lower Murray Water is currently investigating options for upgrading the pump and offtake due to increasing demands on the system through expansion of irrigation developments (NSW Office of Water 2014a; Ecological Assoc. 2013).
- Navigation issues could arise during raising and lowering of weir heights. For example, lowering weir pools may increase the exposure of river traffic to reefs and other navigation hazards. Furthermore, while the weir is in place, the lock chamber allows boats to pass from one weir pool to the next. Locks are usually operated so that the depth of water immediately downstream of the lock makes navigation though the locks possible, except when closed for maintenance or in an emergency. There are limitations on weir lowering to meet the navigation requirements during low flows less than 5000 ML/d (Ecological Assoc. 2013).
- Risks associated with exposing land through lowering the weir pool after inundation. This could allow stock to wander between properties and potentially become stranded when weir levels are restored. If drawdown occurs too quickly, large muddy areas are exposed and cattle can become bogged. These

problems can be avoided by notifying landholders in advance and ensuring weir pools are lowered slowly (Ecological Associates, 2013).

Table A3- 1 lists the third parties that could be impacted by lowering of the weir pool.

Table A3- 1: Potential impacts to landholders identified during the weir pool manipulation trials (Ecological Associates, 2013).

Landholder	Potential Effects	
Lock 9	**Drawdown**	**Surcharge**
Moorna Station	Possibly stock bogging Possibly stock wandering off property	Access around property disrupted Stranding of stock
Lake Cullulleraine Offtake Pump	Isolation of pump at levels below -0.1 m	No known issues
Fort Courage Caravan Park	Access issues for campers and fishers Possibly isolation of pumps	No known issues
Warrananga Station	Possibly isolation of stock and domestic pumps Possibly isolation of irrigation pumps Stock bogging Stock wandering off property	No known issues
Grand Junction Station	Stock bogging Loss of access to water in Lock 9 weir pool in Great Darling Anabranch	No known issues
Oakbank Station	Stock wandering off property	No known issues
House landholder	Isolation of house pump	Possibly access around property disrupted
Robertson Road, Wallpolla Island		Road cut when weir raised more than 0.5 m. Road could be built up with rock to improve access.
Cowra Station	Possible isolation of stock pump on Wallpolla Creek	
Kulnine Station	Possible isolation of stock water	
Keera Station and Subdivision	Possible isolation of stock water	
New Kulnine Subdivision	Possible isolation of stock water	Access to Ranka Creek property cut. Notification is required.
Lock 8		
Moorna Station	Bogging of stock Stock wandering off property	Access around property disrupted Stranding of stock
Holiday Shack landholder	Pump for holiday shack is isolated by weir levels lower than -0.5 m Stock wandering on to property	No known issues
Wangumma Station	Stock wandering on to property	No known issues

4.5. Community backlash

The community may perceive the change in weir pool levels to be negative due to poor communication or misunderstanding of the projects objectives and ongoing operations. Community backlash has the potential to generate pressure that could prevent the site from being operated as required. There is also a risk that there is backlash from diverters due to disruptions to water supply as a result of weir pool lowering. The 2013/14 weir pool manipulation trial has already involved extensive consultation with landholders and community groups. Ongoing consultation and engagement that clearly explains the objectives of the project will help satisfy the concerns of community members.

5. Risk assessment of project development and construction

5.1. Governance and project management

There may be impacts to project delivery or to NOW's institutional relationships and reputation if governance and project management risks are not well managed. As with any works projects of this type, there are risks that project costs could escalate or project delivery could be delayed due to unforeseen events. This includes costly mitigation requirements, complex approvals processes, conflict with stakeholders, adverse weather and costing errors and omissions. Chapters 14, 15 & 16 of this report describe the proper processes and contingencies that will be in place to mitigate against cost and delay risks.

The Locks 8 and 9 weir pool manipulation proposal does not involve the delivery of a works program and program development is well underway as a result of the weir pool manipulation trials. Therefore cost and delay risks for this proposal are negligible.

Poor institutional arrangements for tri-state coordination could also impact project delivery. However, it is thought that this is unlikely and in some cases remote given that there are strong existing relationships between agencies established through collaboration on the Locks 8 and 9 weir pool manipulation trial and other similar projects.

5.2. Cultural heritage and other approvals

The CCB area is known to be rich in cultural heritage values (MDWWG, 2014). Furthermore, the CCB area has recently been returned to the Barkandji Traditional Owners who may oppose the proposed works. However, the Locks 8 and 9 proposal does not involve construction works and construction works for Frenchmans Creek are within the footprint of the existing structures and are unlikely to impact on cultural values.

Early cultural heritage work for the CCB area (MDWWG, 2014) suggests that impact to cultural heritage values during construction can be avoided with proper processes

Phase 1 of this project involved early consultation with Tar-Ru Lands Aboriginal Traditional Owners who are currently engaged by the NSW OEH to provide advice on the Tar-Ru Lands Transfer. Further consultation will occur when the Tar-Ru Lands Board of Management has been fully established under the Barkandji Native Title Group Aboriginal Corporation who have been nominated to take ownership of the Tar-Ru Lands.

The need to create an easement on private land has been identified in the CCB area for reconstruction works. This easement will require approval and there is a risk that there will be a delay obtaining a permit or that a permit cannot be obtained. Consultation with the relevant landholder is already underway and will help flag any major issues early in the process. This will increase the likelihood that the approvals process goes smoothly.

5.3. Design and delivery

There is a potential for risks arising from design and delivery to impact project delivery through impact to project timelines, costs or structural integrity. Feasibility concept scale design and modelling has been undertaken to help identify any major risks or limitations of the project. This is sufficient for early project phases however, more detailed modelling and design and a geotechnical assessment will be required to bring the projects to a shovel-ready phase. Provision has been made for these assessments, including costings for the reconstruction of weirs should the integrity of these existing structures be compromised.

Providing alternative access and plans to stage works according to weather conditions will help to reduce the risk of access to construction camps being blocked by inundation.

The Locks 8 and 9 weir pool manipulation proposal does not involve the delivery of a works program and therefore design and delivery risks for this proposal are not relevant.

Appendix 4: Fish lock design considerations and costing

A vertical slot fishway has been selected as the pefered design for a fishway at the Frenchman's creek weir, however, options to overcome operational reliability concerns associated with existing fishlocks in NSW will continue to be explored during the detailed design phase.

Fishlock design details are included in this document for completeness.

1. Overview

The fish lock option for Frenchman's Creek weir is located on the western bank, as shown in the figure below:

Frenchmans Creek weir with fishlock arrangement shown

The factors that make a fish lock an attractive option for the Frenchmans site are:

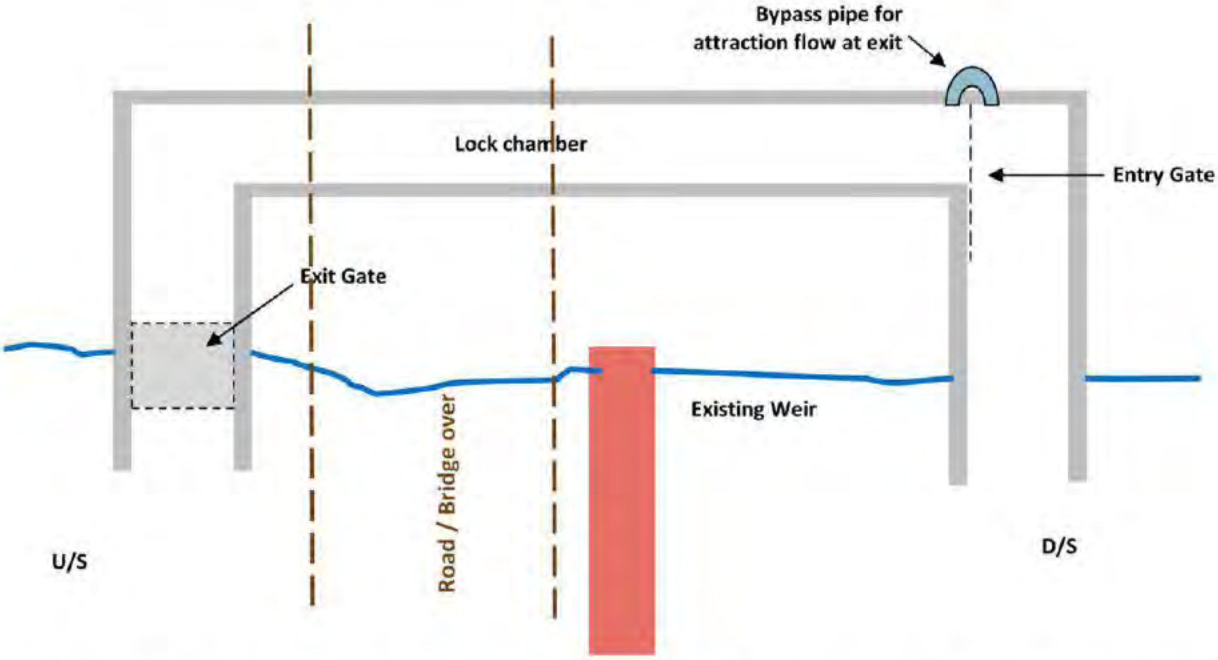
- It has the smallest footprint and is able to be located in areas previously disturbed. It will have minimal potential for environmental and cultural heritage impact.
- It is able to cater for large and variable headwater / tailwater (HW/TW) range with a maximum range of approximately 4.5 metres.
- It is able to cater for a large variety of species size.
- It is expected to be the lowest capital cost.

The proposed configuration of the fish lock is shown in a schematic diagram over page. The design comprises the following configuration:

- Top fill lock chamber

- Entrance gate is a sidewinder gate
- Exit gate is a layflat gate

Schematic of fish lock configuration (upstream pool on left hand side)



Whilst cycle time is an aspect of detail design indicative timing is shown in Table A4-1 which also describes the operation of the fish lock. This cycle timing would result in 8 cycles per day.

Table A4-1: Fish Lock operation

	Step in cycle	Period (mins)
1	**Entry Phase** Entry gate is open. Exit gate is set to pass a pre-determined attraction flow. Fish are attracted into the lock chamber.	30
2	**Filling Phase** After a period of time the entrance gate is closed. The exit gate is adjusted to allow the infill flow into the chamber, gradually raising the water level. As the chamber fills fish are attracted towards the exit gate by the flow.	30
3	**Egress Phase** When the chamber is nearly full the bypass pipe is operated and begins to discharge past the entry gate. The exit gate is now fully opened and is passing flow, maintaining the lock chamber water level. This creates a current through the lock chamber, attracting fish into the upstream pool.	90

4	**Emptying Phase** After a period of time the upstream (exit) gate closes and the water level in the lock chamber begins to drop via flow through the bypass pipe system. At a pre-determined water level (e.g. existing tailwater level) the entry gate is opened.	30
5	Cycle is repeated from Step 1	180

2. Fish lock construction costs

The proposed Frenchmans Creek fish lock construction costs involve a total investment of [redacted]. This costing comprises [redacted] construction costs and a further [redacted] in project management costs.

There are few examples of successfully operating fish locks in Australia and good design will be paramount to ensure good functionality. It is therefore appropriate at this stage in the project planning to include a raised value for contingencies, to reflect likely price escalation risks. A 40% contingency is a standard approach for such studies where limited data is available and the time frame precludes collecting new data.

Table A4-2: Cost estimate for construction of a fish lock at Frenchmans Creek inlet regulator

[redacted]

3. Fish lock operation and maintenance costs

There will be ongoing annual costs for the operation and maintenance of the fish lock. These costs can be higher for a fish lock than other types of fishways due to the need for frequent gate operation. The proposed design, however, is intended to minimise these costs by reducing the number of gate movements required. Fish locks require a commitment to regular maintenance that would include some replacement costs.

A flood episode also has potential to deposit a high sediment load in the fish lock on recession of the floodwater and in the event of gate malfunction or failure, operators may need to repair or remove a gate. The selection of gate type has considered these types of maintenance issues. The gates chosen for this design (lay flat / sidewinder) tend to avoid the issues typically associated with vertical gates on fishways, for example.

These annual costs are estimated at [redacted] of the capital construction costs at [redacted] in the first year and [redacted] for the subsequent years.

These costs will need to be confirmed as part of the detailed design costing.

In addition power (electricity) costs for operating the fish lock need to be accounted for. An allowance of [redacted] per year should adequately cover this.

Appendix 5: Weir specifications

1. Lock 9 (Kulnine Weir)

1.1. Lock 9 Weir description

Lock and Weir 9, also known as the Kulnine Weir, is located at 765 river km (Table A4- 1). The weir was constructed in 1926 primarily to aid navigation and divert water to Lake Victoria. At the normal operating level of 27.4 m AHD the weir pool extends 63 km upstream to Wentworth Weir (Lock 10) and 30 km upstream in the Great Darling Anabranch (MDBA 2010).

The lock and weir is an MDBA asset operated by the South Australian Water Corporation (SA Water).

The weir diverts water to Lake Victoria, an important storage in the Murray-Darling Basin that contributes significantly to the management of water supply to South Australia. The weir raises the water level high enough to allow gravity diversion to Lake Victoria via the Frenchmans Creek Offtake (located approximately 14 km upstream of the weir at 779 km).

There is one major irrigation diversion from the Lock 9 weir pool, which supplies water to Lake Cullulleraine. The pump is located 500 m upstream of the weir on the left bank.

The lock and weir has three main sections. The lock chamber allows boats to pass from one weir pool to the next while the weir is in place. The fixed weir comprises concrete piers with concrete stoplogs which are used for flow regulation. The navigable pass allows navigation through the structure when the lock and weir are removed. It consists of concrete piers, removable deck units and concrete stop logs.

Lock 9 has a fishway installed at the abutment on the northern (New South Wales) side of the river to allow native fish to migrate upstream.

Table A4- 1: Lock 9 specifications (MDBA 2010)

Year of Completion	1926
Construction	▪ Fixed weir and navigable pass consisting of concrete piers and stop logs ▪ Lock Chamber ▪ Fishway
Distance from mouth	765 km
Length of weir pool	63 km
Weir pool storage at normal operating level	approx 32 GL
Normal operating level	27.4 m AHD
Level of top of piers	28.03 m AHD
Flow at which upstream and downstream pools equalise	49,000 ML/d

During times of high flow or flooding, components of the weir are removed to protect the structure and minimise impacts on flow (MDBA 2010). This involves the complete removal of the weir structure except for the concrete columns. The current operating rules require that the movable components are reinstated as soon as flows allow to minimise the risk that the weir pool will fall below the normal operating level and to minimise the rate of drawdown on the river downstream. The approximate flows of weir removal and reinstatement are shown in Table A4- 2.

Table A4- 2: Lock 9 Weir Removal and Reinstatement Flows (MDBA 2010)

Weir Status	Lowest Flow (ML/d)	Highest Flow (ML/d)
Removal	48,000	58,000
Reinstatement	55,000	65,000

Under the current operating rules weirs can be raised or lowered to facilitate river operations, allow maintenance of the weir or lock, or to assist with environmental watering of wetlands connected to the weir pool (MDBA 2010).

Under normal operations the weir may be raised +0.1 m or lowered -0.2 from the normal operating level without for special approval (MDBA 2010). There should be close liaison between MDBA river operators and SA Water operators. To adjust the weir outside this range requires special approval from the Executive Director River Management Division MDBA and the operating authority (SA Water).

1.2. Lock 9 operating limitations

The design limit to raising the weir at Lock 9 is 27.7 m AHD or +0.3 m (MDBA 2010). This allows for 0.33 m freeboard to the top of the piers. Freeboard of as little as 0.1 m is permitted at other weirs. The weir structure is subject to ongoing review and it is possible that the freeboard requirement at Lock 9 may be altered in the future (pers. comm. Hugh Christie MDBA June 2012).

The top of the fishway walls is 28.10 m AHD. The fishway becomes less effective as the weir level rises and is ineffective but unnecessary when flooded. There is some scope to adjust the settings of the fishway to accommodate higher weir levels, but this is yet to be fully tested.

The access road to Lock 9 from NSW is cut when the weir is raised by more than 0.2 m (pers. comm. David Sly SA Water June 2012) because Carrs and Bunberoo Creeks begin to run.

Fixed crest weirs are constructed on Carrs Creek at Carrs 1, Carrs 2, and stop banks are in place at James 1 and James 2 [Drafting note: also referred to as block banks 3 and 6 ?], all of which hold the Lock 9 weir pool in Carrs Creek. The crests are constructed to 27.67 m AHD (MDBA 2010). If overtopped, there is a high potential for scour and erosion at the toe of the banks and around the banks. A similar scour risk exists if access roads were overtopped (pers. comm. Nigel Rutherford, SA Water, 14 Dec 2012).

Other floodplain waterways, some of which are blocked by stop banks, may also divert water at elevated pool levels.

There is no design limit specified for lowering Lock 9.

2. Specifications – Lock 8 (Wangumma Weir)

2.1. Lock 8 weir description

Lock and Weir 8, also known as the Wangumma Weir, is located 726 river km and 39 km downstream of Lock 9. At the normal operating level of 24.6 m AHD the weir pool extends up to Lock 9. Specifications for the Lock and Weir are presented in Table A4-3.

The lock and weir is an MDBA asset and operated by SA Water. The weir has no major water management function and is operated primarily to aid navigation. It assists with the delivery of environmental water in the Mulcra Island Environmental Flows Project.

The lock and weir has three main sections. The lock chamber allows boats to pass from one weir pool to the next when the weir is in place. The fixed weir comprises concrete piers with concrete stoplogs which are used for flow regulation. The navigable pass allow navigation through the structure when the lock and weir are removed. It consists of concrete piers, removable deck units and concrete stop logs.

Lock 8 has a fishway installed at the abutment on the southern (Victorian) side of the river.

Table A4- 3: Lock 8 specifications (MDBA 2010 and MDBC 2006)

Year of Completion	1935
Construction	▪ Fixed weir and navigable pass consisting of concrete piers and stop logs ▪ Lock Chamber ▪ Fishway
Distance from mouth	726 km
Length of weir pool	39 km
Weir pool storage at normal operating level	Approx. 24 GL
Normal operating level	24.6 m AHD
Level of top of piers	25.70 m AHD
Flow at which upstream and downstream pools equalise	37,000 ML/d

During times of high flow or flooding, components of the weir are removed to protect the structure and minimise impacts on flow (MDBA 2010). The weir removal and reinstatement flows are shown in Table A4- 4.

Table A4- 4: Lock 8 Weir Removal and Reinstatement Flows (MDBC 2010)

Weir Status	Lowest Flow (ML/d)	Highest Flow (ML/d)
Removal	40,000	50,000
Reinstatement	47,000	57,000

Under normal operations the weir may be raised +0.3 m or lowered -0.3 m from the normal operating level without special approval (MDBA 2010) as long as close liaison between MDBA river operators and

SA Water operators is maintained. To adjust the weir outside this range requires special approval from the Executive Director River Management Division MDBA and the operating authority (SA Water).

2.2. Lock 8 operating limitations

The design limit to raising the weir at Lock 8 is 25.6 m AHD or +1.0 m, which allows 0.11 m of freeboard to the top of the piers (MDBA 2010). However, the weir may not be raised to more than 25.15 m AHD, or +0.55 m, unless special conditions are satisfied because (Operation limits.xls 6/9/2007 MDBA):

- the performance of the fishway is reduced when the weir is raised by more than +0.5 m
- the fishway walls may overtop when the weir is raised by more than +0.7 m
- above +0.6 m there is potential for water to pond against the left end of the abutment, potentially endangering the structural integrity of the weir (Mason & Kattou 2006)

The weir may be raised higher if the following conditions are met:

- the structural integrity of the weir is not compromised or put at risk
- if necessary, sandbags or other techniques are applied to ensure there is no potential for water to pond against the left abutment of the weir
- water will not bypass the weir along nearby flood runners
- approval has been granted by the Executive Director, River Management Division MDBA.

There is no design limit specified for lowering Lock 8 however flow to Potterwalkagee Creek at Stoney Crossing ceases if the weir is lowered to more than -0.6 m.