# Western Murray Land Improvement Group

## River Country Biolink

### Conceptual Design Report

September 2023

Mulloon
CONSULTING

# WMLIG – River Country Biolink

## Project Aims and Objectives

- Restore the hydrologic regimes of Sheep Wash and Horseshoe lagoons to the natural or pre-regulation case through works interventions and/or environmental water delivery.
- Establish practices whereby wetland restoration and agricultural productivity coexist and are protected against climate and flow fluctuations.

## Acknowledgement

We acknowledge the Barapa Barapa and Wemba Wemba people, Traditional Owners of the River Country Biolink area and surrounding country; and thank Ant Jones for sharing his knowledge and contributions towards the co-design of the Biolink.

## Please note

This Conceptual Design Report is intended as a summary of initial investigations and activities undertaken to date, including, site inspections and consultation with the landholders and other project stakeholders. The recommendations are based on a conceptual assessment and are made to support the co-design process and future development of detailed designs. As such, the information contained within this report should not be relied upon for construction purposes.

## Photo front page:

Top:  Sheep Wash Lagoon on Gonn Station at Merran Creek offtake

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## Document Control

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|---|---|
| Document Reference | Conceptual Design Report |
| Project | Western Murray Land Improvement Group – River Country Biolink |
| Document Type | Conceptual design |
| Author | Jack Smart, Annabel Manning |

## Revision History

| Date | Version | Name | Comments |
|---|---|---|---|
| 6/09/2023 | Ver 1 | J. Smart, A. Manning | Draft |
| 6/09/2023 | V1 | N. McColl | Edit draft |
| 11/9/2023 | V1 | Jono Forrest | Final review |
| 28/09/23 | V2 | J. Smart | Final (with updates from co-design team) |

## Document Approval

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| Position | Western Murray Land Improvement Group |

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# 1 Background

## 1.1 River Country Biolink

The Western Murray Land Improvement Group (WMLIG) River Country Biolink Project aims to rehydrate landscapes and restore ecosystems within the mid-Murray River delta. Co-designed by the WMLIG, Gonn landholders, ecologists, traditional owners, archaeologists and environmental scientists, the River Country Biolink focuses on restoring wetlands and establishing a contiguous corridor connecting the Wakool and Murray rivers, the Murray Valley National Park and Campbell's Island State Forest through productive agricultural land. The WMLIG intends for the Biolink project to act as a demonstration site for community-led opportunities to fund ecological restoration through environmental market-funded initiatives.

The first stage of this project is focused on two properties within the south-western region of the River Country Biolink: Gonn Station and Moola. The primary focus is restoring the natural hydrologic regimes of Sheep Wash Lagoon (Gonn Pastoral) and Horseshoe Lagoon (Moola). Currently there is a deficiency in the frequency and duration of flow events that engage these two lagoons which disrupts the ecology of the wetlands and threatens biodiversity. This historical change in the hydrological regime has resulted in ecological decline at these site which is expected to continue in the absence of intervention.

## 1.2 Hydrological context

The Merran Creek is a floodrunner of the Murray River which comes off the Little Murray River anabranch downstream of the Barham township. A man-made channel named the "Merran Cutting" enables regulated flows to be delivered into the Merran Creek for irrigation and stock and domestic purposes. Overbank flows enter the Merran system around the Merran Cutting and Neils Creek, which comes off the Little Murray River further downstream.

The hydrology of the Merran Creek and the properties within the Biolink site are unique and driven predominately by upstream influences, that being the flows out of the Goulburn River and the flows in the Murray River downstream of the Barmah Choke, which combined is essentially the flow rate at Torrumbarry Weir (refer Section 2.4 for further details).

## 1.3 Properties

### 1.3.1 Gonn Station – McDonald's

Gonn Station is a sheep and rice enterprise located at Murrabit Rd, Gonn, NSW. It covers an area of 1,069 hectares. The Murray River and Little Murray River, an anabranch of the Murray River, form the southern boundary of Gonn Station and Merran Creek (a tributary of the Murray), flows through the north-east of the property. Situated on the floodplain of the Murray River, the sites primary vegetation consists of tall open forest wetlands dominated by River Red Gums (*Eucalyptus camaldulensis*) and Black Box (*E. largiflorens*) woodland, wet grasslands and marshes. Sheep Wash Lagoon is a key feature of the property and the focal point of landscape rehydration at Gonn Station. A small island located within the lagoon supports local biodiversity, including a breeding turtle population, and protecting the ecology of this site is a key objective of the landholder (S. Crockett, personal communication, August 9, 2023). A further detailed analysis of the hydrology of Sheep Wash lagoon is provided in Section 2.4.

### 1.3.2 Moola – Monk's

Moola is a 661 hectare mixed cropping and livestock enterprise located at Gonn Rd, Gonn NSW. Merran Creek flows throughout Moola and is connected to the Little Murray River via an irrigation channel located on the property's southern boundary. Horseshoe Lagoon is a key feature of the property and is surrounded by tall open forest wetlands of *E. camaldulensis* and *E. largiflorens* as well as riverine grasslands. Flows to Horseshoe Lagoon enter the system via a natural inlet off Merran Creek. An existing irrigation channel provides a potential connection between Horsehoe Lagoon and the Little Murray River. Further details on the hydrology of Moola is outlined in Section 2.4.

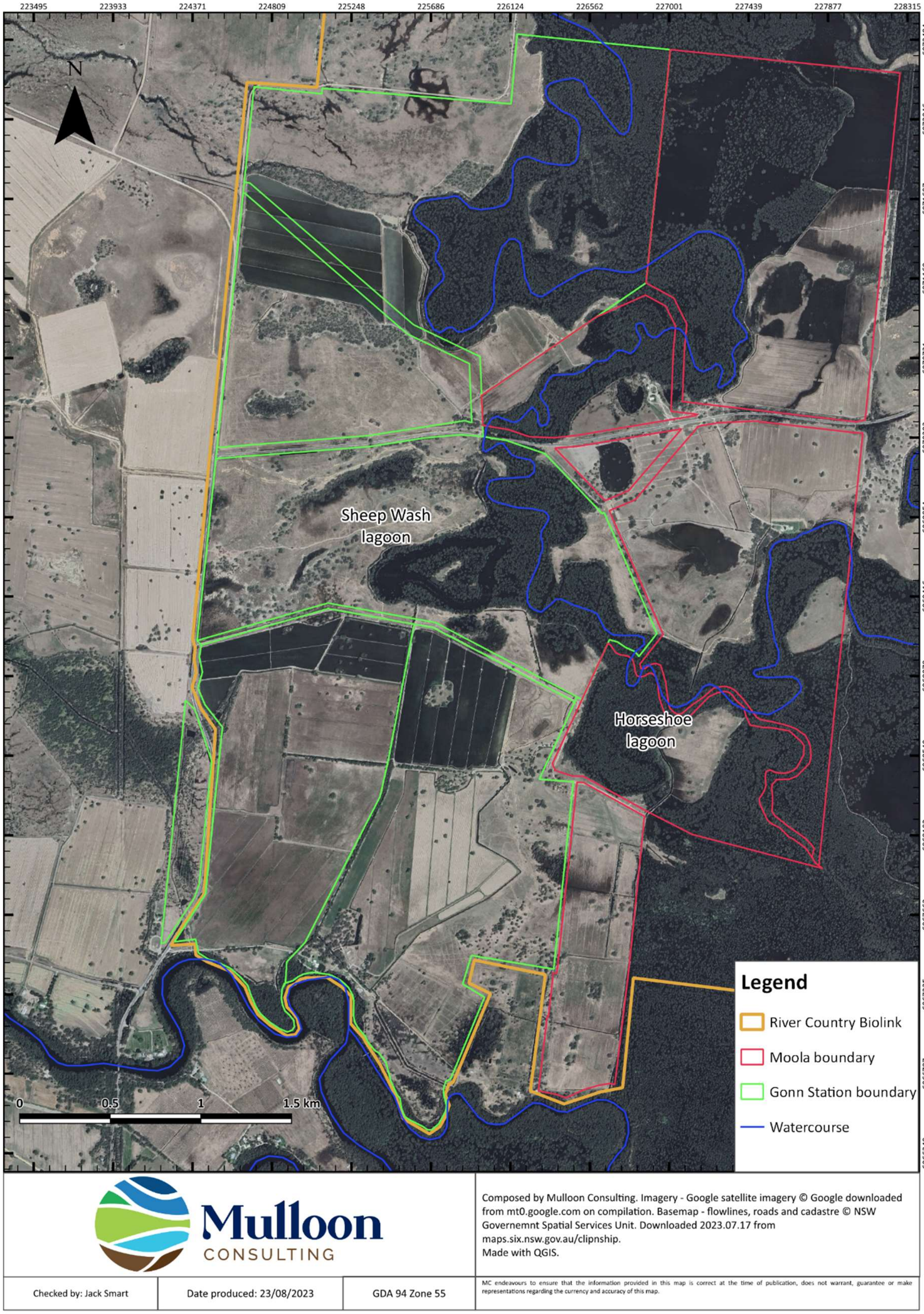


*Figure 1. Property location map of River Country Biolink project site.*

# 2 Site Description

## 2.1 Landform

The project site within the River Country Biolink is located on Merran Creek within the mid-Murray delta, approximately 74 m above sea level. The mid-Murray delta is located downstream of the Barmah Choke which was created by a geological uplift event along the Cadell Fault, forcing the Murray River to change course from what is now the Wakool River to the present day flow course, being the ancestral flow course of the Goulburn River.

Bordered by the Murray River and Little Murray anabranch to the south and the Wakool River to the northeast, the Biolink site provides a corridor linking major river systems, the Murray Valley National Park and Campbell's Island State Forest across productive agricultural land. The site is a flat floodplain intersected by a complex network of wetlands, flood runners, man-made cuttings and irrigation channels (Figure 2).

## 2.2 Climate

The site has a semi-arid, temperate climate[1] experiencing hot dry summers and cool winters. The mean minimum temperature is 4.0°C in July, and the mean maximum temperature is 31.8°C in January. Annual rainfall is approximately 395 mm, while average annual pan evaporation[2] is between 1,400–1,600 mm.

## 2.3 Soils

Soils in the region are complex with high spatial variability over short distances. Generally, soils are moderately deep, medium-heavy clays on alluvium lithology, compacted from saturation and waterlogging during flood periods[3]. Subsoils are a mixture of fine sandy clay loams and sandy clays. Soil profile reports indicate soil type is likely hydrosol[4].

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[1] Climate data for Kerang weather station no. 080023 available at http://www.bom.gov.au/climate/averages/tables/cw_080023.shtml

[2] Average annual, monthly and seasonal evaporation maps available at http://www.bom.gov.au/climate/averages/tables/cw_080023.shtml

[3] Office of Environment and Heritage. 1997. Soil Profile Report: 5, BH h3190 (Ser. Misc. Bore Holes Ninyeuk - WRD Survey (1004206)). Available at https://www.environment.nsw.gov.au/eSpade2Webapp/

[4] Office of Environment and Heritage. 2001. Soil Technical Report: 31, BH828 (Ser. Misc. Bore Holes Wakool 2-WRD (1004136)). Available at https://www.environment.nsw.gov.au/eSpade2Webapp/

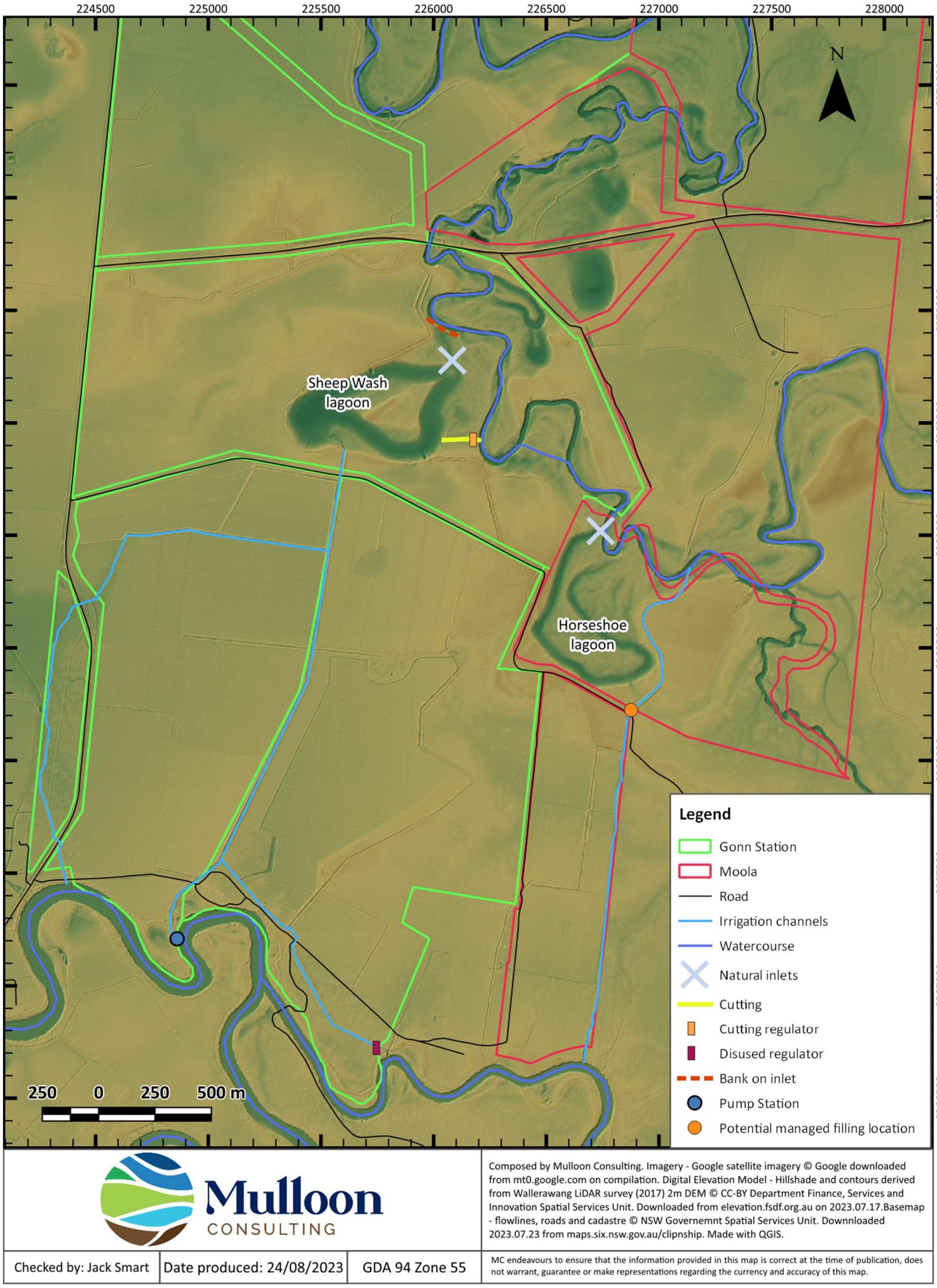


*Figure 2. River Country Biolink project site showing key features and infrastructure.*

## 2.4 Hydrology

### 2.4.1 Merran Creek

The Merran Creek is a floodrunner of the Murray River which comes off the Little Murray River anabranch downstream of the Barham township. A man-made channel named the "Merran Cutting" enables regulated flows to be delivered into the Merran Creek for irrigation and stock and domestic purposes. Overbank flows enter the Merran system around the Merran Cutting and Neils Creek, which comes off the Little Murray River further downstream. The commence to flow rates and levels for these overbank flows (S. Monk, personal communication, August 9, 2023) are summarised in Table 1.

*Table 1. Commence to flow rates and levels for key inflow points to the Merran Creek.*

| Site | Barham Gauge | | Torrumbarry Weir |
|---|---|---|---|
| | Level (m) | Flow Rate (ML/d) | Flow Rate (ML/d) |
| Merran Cutting sills | 5.2 | 20,000 | 25,000 |
| Neils Creek | 5.55 | 22,000 | 30,500 |

The hydrology of the Merran Creek and the properties within the Biolink site are driven predominately by upstream influences, that being the flows out of the Goulburn River and the flows in the Murray River downstream of the Barmah Choke, which combined is essentially the flow rate at Torrumbarry Weir (which is downstream of the Goulburn River junction). During moderate to large flow events, inflows enter the Koondrook and Gunbower Forests immediately downstream of Torrumbarry Weir. The flows that enter Gunbower Forest after making their way through the forest network (factoring in the storage and attenuation effects of the forest) return to the Murray River at Barham. Whereas the flows that enter the Koondrook Forest continue to flow in a north-westerly direction through a multi-floodrunner network, eventually joining the Wakool River system which in turn re-joins the Murray River downstream of Swan Hill. Linked to this is the fact that the flow capacity of the Murray River at Barham is significantly lower than further upstream at Torrumbarry Weir. In summary, the current hydrological regime of the Merran Creek is a combination of:

- Regulated low flow periods: normal regulated flow periods where the flows in Merran Creek are constrained to managed releases through Merran Cutting (combination of irrigation, stock and domestic and baseflows).
- Unregulated overbank flow periods: driven by the frequency, magnitude and duration of River Murray flow events which engage the natural floodrunners into the Merran Creek.

### 2.4.2 Inundation Extents

Modelling of inundation extents has been undertaken as part of the Reconnecting River Country Program (RRCP)[5] for a range of flow scenarios downstream of Yarrawonga Weir. The modelling includes information on flow rates and gauge heights at key locations, including Torrumbarry Weir and Barham as well as details on key assumptions, including Goulburn River outflows. Two inundation extents are mapped for each scenario with the light blue indicating an upper limit

[5] Reconnecting River Country Program inundation extent web viewer, NSW Department of Planning and Environment, Murray River: Yarrawonga Weir to Wakool River, https://experience.arcgis.com/experience/39bf0306c4cf4e73a1b5fcea10d98053/page/App/?views=s2

inundation extent and the darker blue indicating a more typical inundation extent. Output maps from the flow scenarios modelled (15,000 ML/d, 25,000 ML/d, 30,000 ML/d and 40,000 ML/d) are provided in Figures 3–6 below covering the extent of the key Biolink sites associated with the Gonn Station and Moola properties.

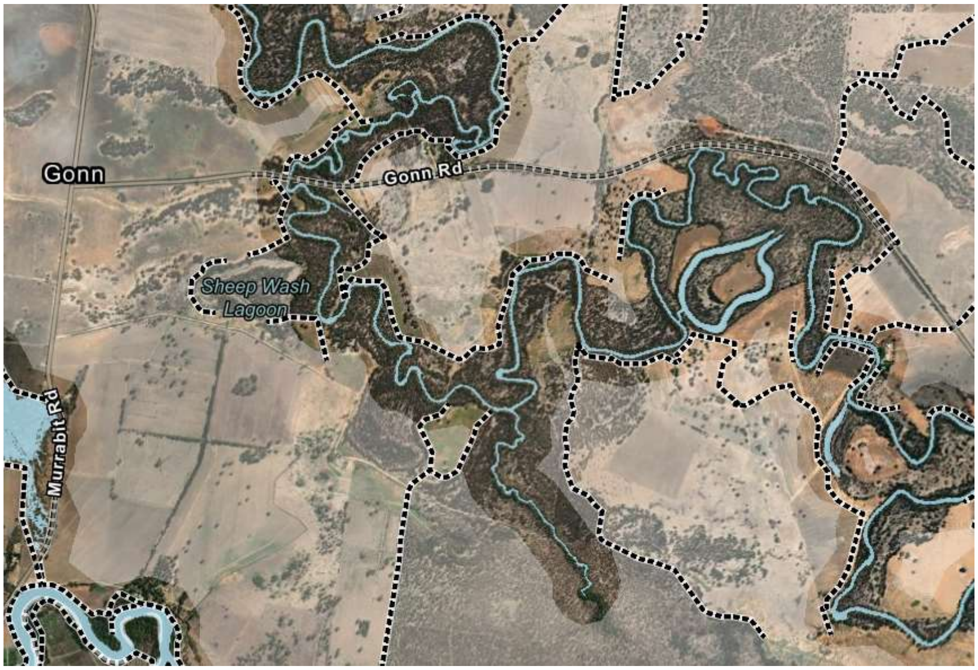


*Figure 3. 15,000 ML/d modelled scenario @ Yarrawonga Weir (equiv. 20,000 ML/d at Torrumbarry Weir).*

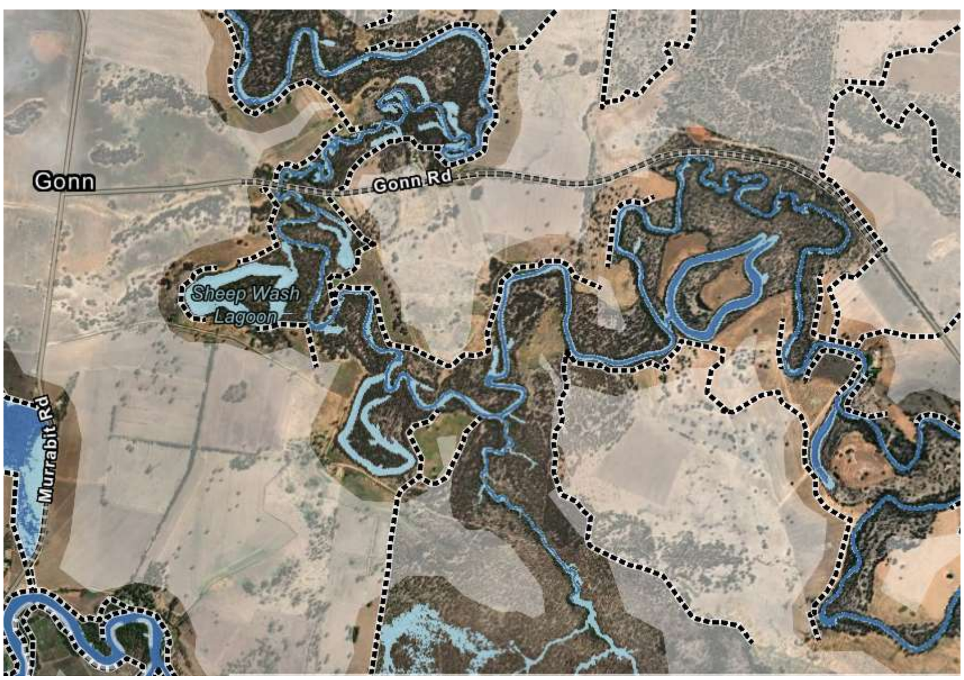


*Figure 4. 25,000 ML/d modelled scenario @ Yarrawonga Weir (equiv. 30,000 ML/d at Torrumbarry Weir).*

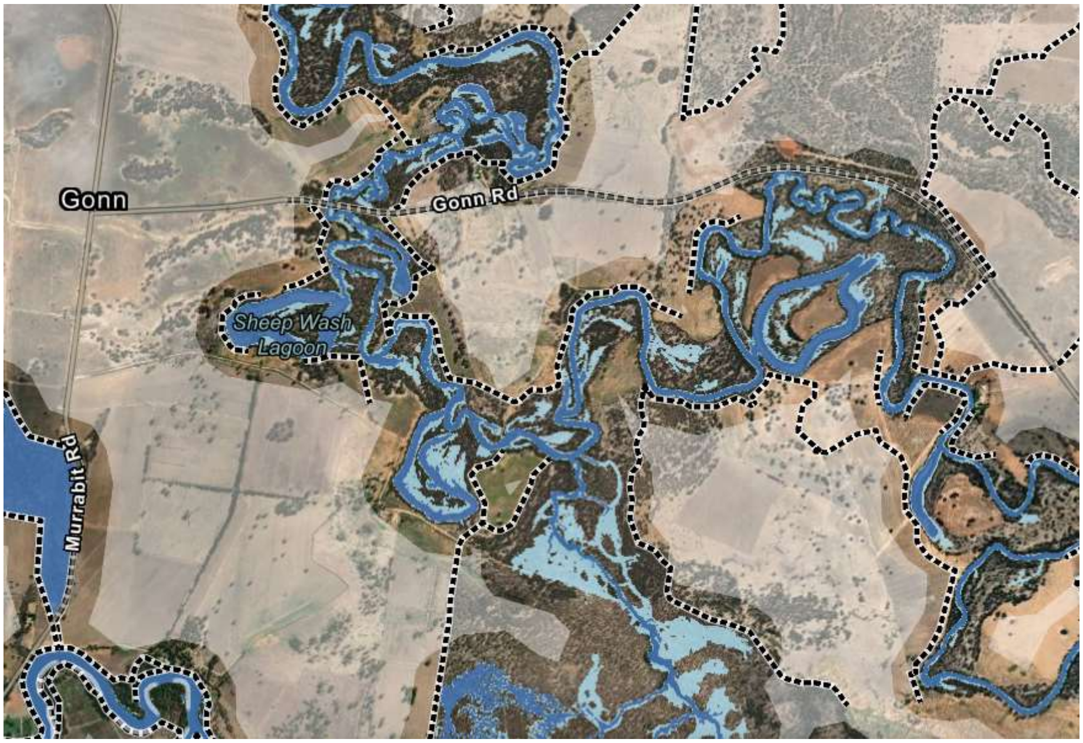


*Figure 5. 30,000 ML/d modelled scenario at Yarrawonga Weir (35,000 ML/d at Torrumbarry).*

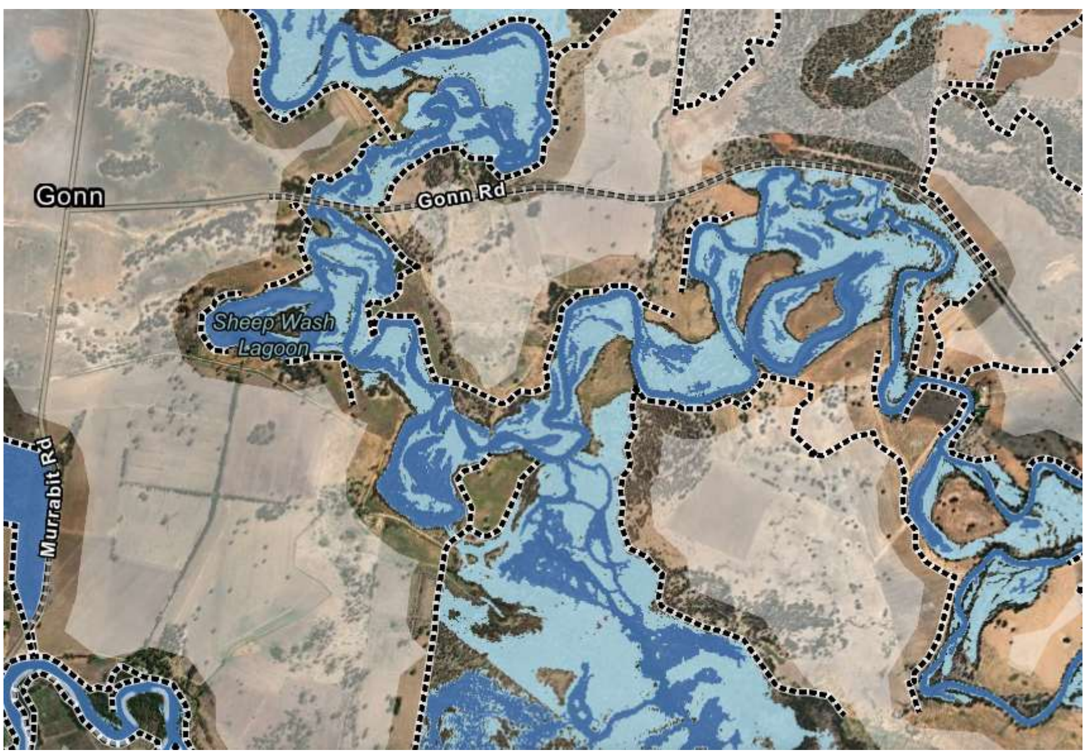


*Figure 6. 40,000 ML/d modelled scenario at Yarrawonga Weir (40,000 ML/d at Torrumbarry).*

As can be seen, the modelling suggests that the Sheep Wash lagoon and the lagoon within Moola (for the purposes of this report to be named "Horseshoe Lagoon") to the southeast of Sheep Wash begin to be inundated when the modelled flows at Yarrawonga Weir are between 25,000 ML/d to 30,000 ML/d. This corresponds to a flow at Torrumbarry Weir of between 30,000 ML/d to 35,000 ML/d.

With the exception of these two lagoons and a few other low points on the floodplain, the modelling suggests that flows within Merrran Creek largely remain within bank for modelled flow events up to the 40,000 ML/d scenario (equivalent to 40,000 ML/d at Torrumbarry Weir) where flows start to spread out across the Merran Creek lower floodplain and appear to start to engage the flood levees on either side of the creek.

### 2.4.3 Frequency and Duration analysis

Based on the inundation extent analysis above, a basic relationship between inundation extent within the Merran Creek at the project site and Murray River flows at Torrumbarry Weir can be inferred as summarised in the table below. This in turn enables an indicative assessment of inundation frequency and duration of flows to be undertaken based on modelled and historical flows at Torrumbarry Weir.

*Table 2. Relationship (indicative) of flow at Torrumbarry Weir and inundation extent in Merran Creek at the project site.*

| Flow at Torrumbarry Weir | Inundation extent in Merran Creek at project site |
|---|---|
| 20,000 ML/d | • In-channel<br>• Lagoon on Merran Park property may start filling around this flow rate. |
| 30,000 ML/d | • In-channel with some minor breakouts onto lower floodplain.<br>• **Sheep Wash lagoon and "Horseshoe lagoon" may start filling around this flow rate.** |
| 35,000 ML/d | • In-channel with break-outs onto lower floodplain areas.<br>• **Sheep Wash lagoon and "Horseshoe lagoon" both inundated at this flow rate.** |
| 40,000 ML/d | • Flows breaking out broadly onto lower floodplain 'riparian' corridor engaging flood levees.<br>• **Sheep Wash lagoon and "Horseshoe lagoon" are both full.** |

Referring to Table 3, frequency and duration of flows at Torrumbarry Weir are provided based on analysis of modelled monthly flows from the Murray–Darling Basin Authority's monthly simulation model for flows between 1891 and 1990. Frequency and duration outputs are provided for a range of flow thresholds based on modelled natural (or pre-regulation), modelled current and modelled climate change scenarios.

*Table 3. Frequency and duration of flows: River Murray at Torrumbarry Weir.*

| River Murray flow threshold value (ML/day) | Average annual duration* (days) that River Murray flows exceed the threshold value | | | Frequency* (% of years) flow peaks above threshold daily flow rate | | |
|---|---|---|---|---|---|---|
| | Natural | Current | Median climate change | Natural | Current | Median climate change |
| 18,000 | 70 | 27 | 24 | 95 | 66 | 61 |
| 20,000 | 63 | 28 | 19 | 90 | 51 | 45 |
| 25,000 | 47 | 21 | 14 | 87 | 44 | 34 |
| 30,000 | 38 | 17 | 10 | 76 | 35 | 28 |
| 35,000 | 29 | 11 | 7 | 65 | 28 | 18 |
| 40,000 | 23 | 8 | 6 | 55 | 23 | 12 |
| 50,000 | 14 | 5 | 3 | 45 | 16 | 9 |
| 57,000 | 4 | 1 | 0 | 23 | 5 | 3 |

Source: Koondrook-Perricoota Environmental Water Management Plan (MDBA, 2012)[6]
* Data is based on modelled monthly flows from MDBA—the monthly simulation model for flows between 1891 and 1990

The frequency-duration outputs in Table 3 can be used to inform an understanding of the frequency and duration of flow events under the natural or pre-regulation scenario and the current scenario. These outputs can then be compared to possible future "relaxed constraints" frequency and duration information provided in the Reconnecting River Country Program inundation extent web viewer[7], which states:

*"The proposed frequency of managed environmental flows under the Reconnecting River Country Program (i.e., flows greater than 15,000 ML/d and up to the upper flow limit) would vary over time depending on water availability, climate, and ecological conditions.*

*Over the long-term,* ***it is anticipated these higher environmental flow deliveries would occur on average about four to five years per decade****, comprising some smaller events and some larger events up to the flow limit.*

***The duration of these higher environmental flow deliveries would be up to seven to 21 days at the peak flow rate*** *(in some years this would be the upper flow limit; in some years smaller flows would be delivered). This would be followed by a gradual reduction in flows back to background flow levels".*

Combining these two information sources, Table 4 and Table 5 provide a comparison of indicative inundation frequencies and durations for the various scenarios.

[6] Original source of table: GHD 2010, Koondrook–Perricoota Forest Flood Enhancement Works Environmental Assessment, March, prepared for Forests NSW and the NSW Office of Water.

[7] Reconnecting River Country Program inundation extent web viewer, NSW Department of Planning and Environment, Murray River: Yarrawonga Weir to Wakool River, https://experience.arcgis.com/experience/39bf0306c4cf4e73a1b5fcea10d98053/page/App/?views=s2

*Table 4. Indicative inundation frequencies for Sheep Wash Lagoon and Horseshoe Lagoon.*

| Flow range at Torrumbarry Weir (ML/d) | Modelled natural or pre-regulation* | Modelled current* | Future relaxed constraints⁺ |
|---|---|---|---|
| 30,000–35,000 | ~ 7 years in 10 | ~3 years in 10 | ~4–5 years in 10 |

* Adapted from Table 2 (Source: “Koondrook-Perricoota Environmental Water Management Plan (MDBA, 2012))

⁺ Source: Reconnecting River Country Program inundation extent web viewer

*Table 5. Indicative duration of flow events that would result in inflows to Sheep Wash Lagoon and Horseshoe Lagoon.*

| Flow range at Torrumbarry Weir (ML/d) | Modelled natural or pre-regulation* | Modelled current* | Future relaxed constraints⁺ |
|---|---|---|---|
| 30,000–35,000 | ~30–40 days | ~10–20 days | ~7–21 days |

* Adapted from Table 2 (Source: “Koondrook-Perricoota Environmental Water Management Plan (MDBA, 2012))

⁺ Source: Reconnecting River Country Program inundation extent web viewer

This analysis shows there is a clear gap in both the frequency and duration of flow events that would be expected to engage Sheep Wash Lagoon and Horseshoe Lagoon between the modelled natural or pre-regulation case and both modelled current and future relaxed constraints scenarios. Even under the likely “future relaxed constraints” scenario there would still be a shortfall in the frequency of events that would inundate the two lagoons of around 2–3 years in 10, and the expected duration of events would be approximately half that of the average modelled event duration. Importantly, this modelling does not consider potential future reductions in rainfall and runoff resulting from climate change and therefore likely represents an optimistic future case.

It is important to note that the duration analysis is looking at the duration of flow events that are sufficient in size to engage the two lagoons. Once flows in the River Murray and Merran Creek recede, water will be held in the lagoons for a longer duration at or below their commence-to-flow levels.

In summary, this analysis shows that:

- There is currently around a **4 years in 10 gap in the frequency of flow events** that would be expected to engage Sheep Wash Lagoon and Horseshoe Lagoon, compared to modelled natural.
- Currently, the **duration of flow events** that would be expected to engage Sheep Wash Lagoon and Horseshoe Lagoon on average are around **half the length** of the modelled natural.
- Future impacts of climate change are expected to further increase the gap in both the frequency and duration of flow events.

***Based on this assessment it is recommended that the primary objective of landscape rehydration at the project site is to restore the hydrological regime of these lagoons as close as possible to the natural or pre-regulation case (through works interventions, environmental water delivery and/or a combination of both) by ‘bridging the gap’ in the frequency and duration of flow events.***

### 2.4.4 Neils Creek

While regulated flows into the Merran Creek are controlled through the Merran Cutting, overbank inflows to Merran Creek from the Little Murray River predominately occur via the Neils Creek. Due to the high flow event at the time of the site inspection it was not possible to access the Neils Creek area. However, given the importance of the Neils Creek floodrunner in distributing overbank flows into the Merran Creek it is considered an important hydrological site with respect to the broader Biolink area. For this reason, inspection of the Neils Creek during low flow period would be informative to understanding the hydrology of overbank flow events. The majority of Neils Creek is located within State Forest immediately to the south of the Biolink boundary.

# 3 Conceptual design development

## 3.1 River Country Biolink mapped areas

The River Country Biolink project has identified focus areas and three corridors within the Biolink project boundary, refer Figure 7 and Figure 8. The focus areas have been prioritised based on their high biodiversity values, potential for regeneration and input from the landholders. Additionally, three corridors have been identified by the landholders, which animals are observed to be using as movement corridors. These indicative corridors present potential opportunities for additional biodiversity outcomes, such as revegetation zones.

The Biolink Areas identified in Figure 7 and Figure 8 are the focus of the landscape rehydration conceptual designs as these are located within the Gonn Station and Moola properties. This includes the following key features/sites:

- Sheep Wash Lagoon
- Horseshoe Lagoon
- Merran Creek – reach from Horseshoe lagoon to Gonn Road

Potential landscape rehydration interventions and opportunities for each of these sites is discussed in Sections 3.2, 3.3 and 3.4.

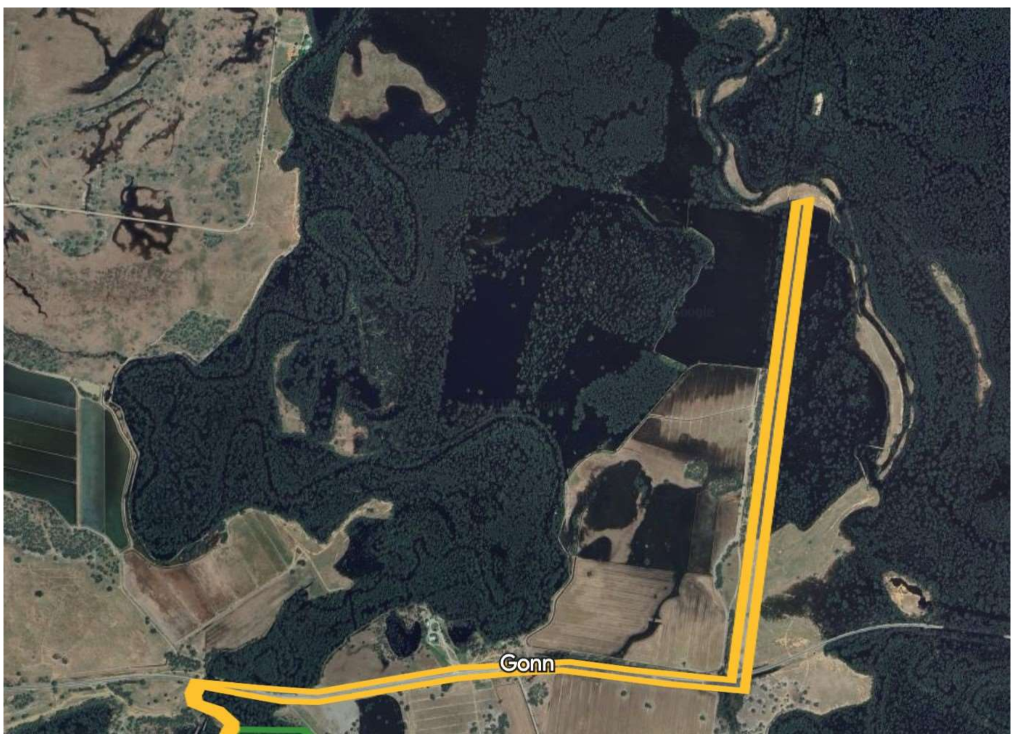


*Figure 7. River Country Biolink focus areas (green) and corridors (yellow) - map 1 of 2.*


*Figure 8. River Country Biolink focus areas (green) and corridors (yellow) - map 2 of 2.*

## 3.2 Sheep Wash Lagoon

### 3.2.1 Key details and current operating arrangements

The Sheep Wash Lagoon is a natural 'oxbow lake' lagoon which would have formed through the natural erosion and depositional processes of the Merran Creek as it has meandered across the floodplain over time with the increasing sinuosity eventually resulting in the stream short-circuiting the wide meander bend, leaving behind the lagoon feature, refer Figure 2.

Naturally, Sheep Wash Lagoon would have filled in most years (refer 2.4.3) and it is expected that with a depth below natural sill of around 1.5m (based on DEM interrogation) it would have maintained some depth of water between years and likely only dried out during successive dry years. Further analysis could be undertaken to verify the historical permanency of the lagoon, including site survey of lagoon depths, field estimates of silt accumulation and cultural/archaeological surveys of Aboriginal habitation.

The natural inflow point to the lagoon is the northern or downstream end of the lagoon, however a historical block bank has been built across this natural inflow point to enable water to be held in the lagoon, refer Figure 10.

Additionally, a historical cutting has been dug connecting the Merran Creek to the southern end of Sheep Wash Lagoon. An old concrete regulator (approximately 1.8 m x 1.8 m) is located on the Merran Creek end of the cutting which enables for the management of inflows and holding of water in the lagoon. The regulator is manually operated with hardwood timber stopboards. At the time of the site inspection the regulator was overtopped by the high flows by approximately 200 mm, refer Figure 11.

From discussions with the landholder, it is understood that the island in the middle of Sheep Wash Lagoon supports a breeding turtle population and protecting this population is an important ecological consideration for the site (S. Crockett, personal communication, August 9, 2023). Increasing the frequency and duration that water is maintained in the lagoon has the potential to help with pest management by cutting off access from predators (e.g. foxes) for greater periods. However, it is likely that this would need to be complimented with other pest management controls, particularly during periods when the lagoon is going through a drying phase, which will likely be required periodically for ecological reasons such as managing the impacts of carp on the lagoon and supporting and maintaining a healthy vegetation community.
At the time of site inspection, river flows were too high to enable field survey of structure and sill levels. Key elevation details from DEM analysis relating to Sheep Wash Lagoon are provided below in Table 6.

*Table 6. Key elevation details (indicative) for Sheep Wash Lagoon.*

| Location | Elevation (mAHD) - Indicative | Equivalent Torrumbarry Weir flow rate (ML/d) |
|---|---|---|
| Northern inlet – natural sill | 71.1 | |
| Northern inlet – top of bank | 73.5 | |
| Sothern cutting – sill level | 71.7 | 25,000–30,000 ML/d |
| Base of lagoon | 69.7 | |
| Regulator sill | TBC | |
| Regulator max operating height | 73.0 | |
| Inundation extent (low) | 71.9 | 30,000–35,000 ML/d |
| Inundation extent (high) | 72.6 | 35,000–40,000 ML/d |

### 3.2.2 Landscape Rehydration opportunities

As outlined in 2.4.3, Mulloon Consulting recommends that the landscape rehydration objective for Sheep Wash Lagoon should be restoring or mimicking the natural or pre-regulation hydrological regime of the wetland. This would involve the managed delivery of water to the site to compliment overbank filling events in order to 'bridge the gap' between the pre-regulation and current hydrological regimes. These arrangements could be managed in partnership with Murray–Darling Wetlands Working Group to facilitate delivery of water to the site. Other complimentary measures, including de-silting the lagoon, could be explored during the detailed design process. Such measures should be enacted prior to the proposed rehydration measures outlined below being implemented.

Based on a preliminary site inspection and discussions with the landholder there is the potential to utilise existing infrastructure to meet these requirements as outlined below and shown in Figure 2.

1. **Existing cutting and regulator**

Utilise the existing cutting and regulator to enable the lagoon to fill during overbank flow events, if need be, close the regulator on the recession of the high flow event to achieve the desired event duration.

If water is delivered to Sheep Wash Lagoon through options 2 or 3 below, the cutting regulator would be closed to enable to the lagoon to be filled and the required event duration to be achieved.

### 2. Inactive regulator and irrigation channel off Little Murray River

There is the potential opportunity to utilise the dis-used regulator off the Little Murray River to deliver flows through existing internal irrigation infrastructure to Sheep Wash Lagoon. It is understood that during high Murray River flows that this regulator is engaged earlier and at lower equivalent flow rates than the cutting regulator at Sheep Wash Lagoon. While the regulator is currently inactive it is still an approved “water supply works” through WaterNSW with the potential to be re-activated.

This regulator may provide for the opportunistic delivery of water to Sheep Wash Lagoon when conditions allow, subject to any licencing approvals requirements and access to appropriate water entitlements (potentially either unregulated or environmental). It is understood that there is currently no flow measurement capacity at this site which would need to be resolved to enable delivery of flows through this site. Murray–Darling Wetlands Working Group may be able to provide advice on requirements and options for metering flows and facilitate their implementation.

### 3. Existing pump station and irrigation channel network

It is recommended that the remaining ‘gap’ not met through options 1 and 2 is achieved through the managed delivery of water via the Gonn Station pump station off the Murray River and the internal irrigation channel system to the lagoon. To meet the target hydrological regime, managed deliveries via the internal irrigation network will likely be required on average every 2–3 years.

Water delivered via this means could be entitlement water, environmental water accessed and delivered for example through the Murray–Darling Wetlands Working Group or a combination of both. An agreement would need to be developed with the landholder to cover the metering and accounting of flows, delivery costs and delivery arrangements.

*Figure 9. Sheep Wash lagoon.*

*Figure 10. Historical bank across the natural inlet to Sheep Wash lagoon.*

*Figure 11. Location of the Sheep Wash Lagoon regulator at the Merran Creek offtake into the Sheep Wash Cutting – structure overtopped at time of site inspection due to high flows (31,0000 ML/d at Torrumbarry Weir on 9/08/2023).*

*Figure 12. Irrigation channel with control gate on Gonn Station which could potentially be utilised for the delivery of environmental water to Sheep Wash Lagoon.*

*Figure 13. Current inactive regulator offtake from the Little Murray River on Gonn Station.*

## 3.3 Horseshoe Lagoon

### 3.3.1 Key details and current operating arrangements

The Horseshoe Lagoon at 'Moola' is a natural 'oxbow lake' lagoon which would have formed through the natural erosion and depositional processes of the Merran Creek as it has meandered across the floodplain over time with the increasing sinuosity eventually resulting in the stream short-circuiting the wide meander bend, leaving behind the lagoon feature, refer Figure 2.

Naturally, Horseshoe Lagoon would have filled in most years (refer 2.4.3). However, unlike the Sheep Wash Lagoon, the natural sill level for the Horseshoe Lagoon is much lower and according to the DEM analysis is a similar level to the adjacent bed level of Merran Creek. Due to the high flows at the time of the site inspection these levels were unable to be verified and it is recommended that levels at the site are ground-truthed prior to commencement of detailed design work.

The significance of the lower commence to fill level for Horseshoe Lagoon compared with Sheep Wash Lagoon is that it likely fills under lower flow conditions in the Merran Creek and therefore more frequently, however, water levels in the lagoon would naturally recede in conjunction with the Merran Creek and therefore the lagoon would retain water for shorter durations. As such, it is likely that Horseshoe Lagoon only held water seasonally, though it would have filled in most years. This suggested hydrological regime is supported by the vegetation at the site with large mature Black Box (*Eucalyptus largiflorens*) fringing the outside bank of the lagoon, indicative of a shorter inundation duration (refer Figure 15).

Unlike the Sheep Wash Lagoon, there is no existing infrastructure associated with the Horseshoe Lagoon and the lagoon remains connected to the Merran Creek at the natural inflow point (refer Figure 2)

*Table 7. Table 7. Key elevation details from DEM analysis.*

| **Location** | **Elevation (mAHD)** | **Equivalent Torrumbarry Weir flow rate (ML/d)** |
|---|---|---|
| Northern inlet (CTF) | 70.25 (requires field validation) | |
| Base of lagoon | 70.25 (requires field validation) | |
| Inundation extent | ~71.8 | 30,000–35,000 ML/d |
| Inundation extent | ~72.7 | 35,000–40,000 ML/d |

*Figure 14. Location of natural inlet to Horseshoe Lagoon – inlet sill not visible at time of site inspection due to high flows (31,0000 ML/d at Torrumbarry Weir on 9/08/2023).*

*Figure 15. Horseshoe lagoon with fringing Blackbox (Eucalyptus largiflorens) bordering the outside bend of the lagoon.*

*Figure 16. Existing irrigation channel on 'Moola' that runs adjacent to Horseshoe Lagoon which could potentially be utilised for the delivery of environmental water to the lagoon.*

### 3.3.2 Landscape Rehydration opportunities

As outlined in 2.4.3, Mulloon Consulting recommends that the landscape rehydration objective for Horseshoe Lagoon should be restoring or mimicking the natural or pre-regulation hydrological regime of the wetland. This would involve the managed delivery of water to the site to compliment overbank filling events in order to 'bridge the gap' between the pre-regulation and current hydrological regimes. These arrangements could be managed in partnership with Murray–Darling Wetlands Working Group to facilitate delivery of water to the site.

Based on a preliminary site inspection and discussions with the landholder there would be the need to install infrastructure at the natural inflow point to the lagoon to support overbank and managed filling of the lagoon, refer Figure 2.

1. **New bank and regulator at natural inflow point**

To facilitate restoration of the natural hydrological regime to the lagoon a new bank and regulator across the natural inflow point would be required, refer Figure 2. The new bank would need to be designed to tie into the high points on either side and the regulator would be sized to enable the safe filling of the lagoon from Merran Creek. It will be important to ensure that the sill level of the structure matches the current commence-to-flow level and the top of the structure designed to meet that maximum inundation height with appropriate freeboard.

The functional requirements and design criteria for the regulator and bank would need to be determined in consultation with the landholder and the co-design team during the detailed design phase. This will require obtaining accurate survey data to confirm key design levels as well as clarifying ecological requirements and operational considerations. A relatively simple solution such as a basic box culvert regulating structure like the Padmans gated box culvert may be sufficient and relatively cost effective. A one-way flow option such as a flood flap gate would likely not be appropriate due to the need to be able to drain the wetland on the completion of watering events to ensure that water isn't retained for excessive durations.

Operationally, the structure would enable the natural filling of the lagoon from the Merran Creek with minimal impact on the hydraulics, holding of water within the lagoon to meet the required watering duration and the safe managed release of flows back to Merran Creek. The structure would also enable water to be held in the lagoon during managed watering events utilising the internal irrigation system as outlined below.

Any approvals and licencing requirements for a new regulator would need to be considered during the detailed design phase. The Murray–Darling Wetlands Working Group may be able to provide advice on the approvals and licencing requirements given their experience in the implementation and operation of similar structures to facilitate environmental watering.

2. **Existing offtake and irrigation channel network**

It is recommended that the remaining 'gap' not met through option 1 is achieved through the managed delivery of water via Moola's offtake from the Little Murray River and internal irrigation system. An existing irrigation channel runs adjacent to the lagoon which could be utilised with minor localised works by the landholder to facilitate delivery of water to the lagoon. To meet the target hydrological regime, managed deliveries via the internal irrigation network will likely be required on average every 2–3 years. New infrastructure on the lagoon's natural inflow point, as described in option 1 above, would be required to support the managed filling of the lagoon.

Water delivered via this means could be entitlement water, environmental water accessed and delivered for example through the Murray–Darling Wetlands Working Group or a combination of both. An agreement would need to be developed with the landholder to cover the metering and accounting of flows, delivery costs and arrangements.

## 3.4 Merran Creek

### 3.4.1 Environmental Flow opportunities

Where possible opportunities should be explored to increase the frequency and duration of flow events down the Merran Creek that support ecological objectives and assist in restoring the hydrological regime of the Merran Creek through the entire Biolink site. The analysis of the hydrology presented in Section 2.4 clearly demonstrates that the current hydrological regime has been substantially altered from the natural or pre-regulation case.

Importantly, the Merran Creek does not exist in isolation and is heavily modified. Firstly, the hydrology of the creek is largely driven by upstream influences. Secondly, flow releases through the Merran Cutting are heavily managed primarily to meet downstream irrigation and stock and domestic demands. Thirdly, the Merran Creek can be used as a carrier to meet demands further down the system including environmental flows. These three factors significantly impact the current hydrological pattern for the Merran Creek as well as imposing significant constraints to restoring a hydrological regime that would meet the ecological needs of the Merran Creek system within the Biolink site.

However, these factors also provide opportunities for the provision of targeted environmental flows that meet the ecological requirements of the Merran Creek or exploring opportunities to tweak the current operations to achieve improved ecological outcomes without impacting deliveries to downstream customers.

It is recommended that options are explored by the co-design team and the Biolink and Merran Creek communities to improve the hydrological regime of the Merran Creek through the delivery of environmental flows or tweaks to existing operations. To support this, consideration should be given to the development of hydrological and ecological priorities for the Merran Creek that could inform the development of operating regimes or hydrographs for a range of hydrological and ecological outcomes (e.g. baseflows, small pulse events, larger flow events). This information could be presented to environmental water holders to seek allocation of flows for the Merran Creek. There would be the need to consult closely with the Little Merran Creek Trust in progressing this work.

Where possible, restoring the hydrological flow regime through improved flow deliveries should be the priority. However, it is highly unlikely that sufficient flows could be returned to the Merran Creek to fully restore the pre-regulation flow regime, particularly when the future impacts of climate change are factored in. As such, consideration is given in Section 3.4.2 to a reach-based solution for the Merran Creek, involving the installation of in-stream structures to improve ponding and rehydration outcomes under lower flows.

### 3.4.2 Reach – Horseshoe Lagoon to Gonn Road

*Table 8. Elevations at downstream and upstream limits of reach 'Horseshoe Lagoon to Gonn Road'*

| Location | Elevation (m/AHD) |
|---|---|
| Thalweg U/S Gonn Rd | 70.03 (requires field validation) |
| Thalweg adjacent Horseshoe lagoon | 70.23 (requires field validation) |

There is the potential to consider a reach-based rehydration outcome to treat Biolink Areas 4 and 5 with an in-stream bed control structure upstream of Gonn Rd. Due to the very low gradient in Merran Creek, a structure with a relatively small height (0.5 m or less) would likely have a significant impact on the inundation of the benches adjacent to the main channel and adjacent low lying areas (including Sheep Wash Lagoon and Horseshoe Lagoon). Indicative flow estimates using Manning's equation are provided in Table 9, note these estimates should be viewed with caution and detailed hydraulic modelling of the reach would be required to confirm expected flow rates and levels.

The key design objective would be to size the structure so the floodplain benches and lagoons would be inundated as close as possible to the natural frequency and duration under the current flow regime. The benefit of this approach is that it is treating the whole reach of the Merran Creek to achieve a reach-based outcome as opposed to treating individual lagoons in isolation.

This approach could potentially be replicated along the entire length of the Merran Creek through the Biolink area. Due to the low channel grade, rehydration using this method could be achieved at the sub-catchment scale cost-effectively, as the number and size of structures would be significantly lower than streams with a higher gradient. However, the regulatory hurdles to implement such a solution would be significant and would require the support of the Little Merran Creek Trust.

There are significant challenges with progressing this option that would need to be considered through the design process:

- Potential to more regularly increase the flooding of low-lying irrigated land adjacent to the Merran Creek upstream of the structure, would require detailed modelling to confirm these potential impacts.
- Impacts to fish passage (structure would need to be designed to facilitate fish passage (presumably would need to allow for full range of species and sizes including Murray Cod).
- Would require regulatory approvals as within a regulated stream.
- Would require stakeholder consultation including the support of the Little Merran Creek Trust.

**Reach details:**

- distance 3,200 m
- drop in elevation = 70.23 – 70.03 = 0.2 m
- slope = $6.25 \times 10^{-5}$ m/m

**Flow estimates for theoretical bed-control structure U/S Gonn Rd**

*Table 9. Indicative flow estimates using Mannings equation.*

| Intervention Type | Top of channel (ML/d) | Bankfull – full riparian flow area (ML/d) |
|---|---|---|
| Existing | 900 | 3,600 |
| 0.3 m structure | 550 | 2,800 |
| 0.5 m structure | 350 | 2,000 |

*Figure 17. Merran Creek immediately downstream of the Gonn Road bridge.*

*Figure 18. Example of an established in-stream 'leaky weir' structure on the Mulloon Creek.*

## 3.5 Complimentary Landscape Rehydration opportunities

Landscape rehydration aims to restore the natural function, fertility and resilience of agricultural landscapes. Within the Biolink area, rehydration opportunities have the potential to restore the hydrological regimes of lagoons and enhance valuable ecosystem services such as biodiversity, nutrient cycling and carbon capture. Rehydration also supports the lateral recharge of adjacent groundwater aquifers which can in turn benefit surrounding terrestrial flora and fauns. Other potential landscape rehydration opportunities to improve ecosystem health and agricultural productivity within the River Country Biolink area may include:

1. **Riparian revegetation**
   Riparian zones bordering waterways and lagoons should have as much vegetation and groundcover as possible to enhance the cycling of nutrients and sediments and maximise filtration to influence water quality. Established riparian recovery zones create wetland microclimates by providing shade to reduce the amount of heat and light reaching a lagoon and provide critical habitat for insects, birds and fish. Further, riparian vegetation assists with bank stabilisation, which will reduce erosion during high flow periods.

2. **Recharge zones**
   Recharge zones are located at the highest points of elevation within a landscape. These areas should be dominated by forest and scrub, allowing biomass and nutrients to accumulate before naturally shifting downslope toward the agriculturally productive mid zone. The establishment of recharge areas can involve new plantations or installing fencing to protect existing native remnant vegetation found on site, such as lignum shrubland and inland riverine forests of *Eucalyptus largiflorens* and *E. camaldulensi*[8].

3. **Contour planting**
   Establishing plantations along contour belts intercepts surface runoff while energy is relatively low, allowing water to spread and infiltrate more broadly across the landscape. By fanning out the water, energy dissipates, and erosion potential is reduced while landscape rehydration is maximised.

4. **Biodiversity values:**
   The Biolink project site runs adjacent to the NSW Central Murray Forests Ramsar wetlands[9], and as such should be considered to have a considerable influence on the functioning and health of the Murray River and its tributaries. There is potential for landholders within the Biolink to establish a Biodiversity Stewardship Agreement (BSA) and obtain biodiversity credits through conservation management. The River Country Biolink falls within the Murray Fans IBRA subregion[10] where biodiversity credits are currently registered as in-demand. To

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[8]NSW Office of Environment and Heritage. (2016). NSW Plant Community Type classification.- Available at https://www.environment.nsw.gov.au/topics/animals-and-plants/biodiversity/nsw-bionet/nsw-plant-community-type-classification

[9]Harrington, B., & Hale, J. (n.d.). (rep.). Ecological Character Description for the NSW Central Murray Forests Ramsar site. Canberra: Department of Sustainability, Environment, Water, Population and Communities.

[10] NSW Office of Environment and Heritage. (2023). Available at https://nswbcst.maps.arcgis.com/apps/webappviewer/index.html?id=4d395e012e304b1090eea3e33e8f9112

pursue the establishment of a BSA, landholders must submit a Stewardship Expression of Interest through the NSW DPE.
It is recommended that any revegetation or vegetation conservation measures progressed as part of the Biolink project seek to maximise overall landscape function and productivity utilising opportunities outlined in points 1–3 above.

### 5. Contours

There may be opportunities to work with landholders to explore opportunities to utilize existing contour irrigation banks to support landscape rehydration outcomes. Any opportunities would need to tie into and align with existing irrigation infrastructure and irrigation practices. Options may include periodic placement of simple check banks to hold water on contour and support infiltration or if possible, utilise contour banks to capture and distribute runoff towards ridgelines. Further consultation with landholders and site inspection would be required to confirm the feasibility of such measures.

### 6. Timing of environmental and irrigation watering activities

While it may not always be possible due to timing issues, water availability or conflicting priorities, where possible, opportunities to align the timing of irrigation watering with environmental watering of adjacent lagoons should be considered to maximise environmental and productive outcomes. An example of this might be aiming to grow a rice crop in adjacent irrigation bays during the same season a filling event of the Sheepwash Lagoon occurs. This implies that there is an additional environmental outcome possible if the broader landscape beyond the boundary of the lagoon is hydrated simultaneously. Practically, increased ponding of water in the irrigation landscape may provide increased habitat and foraging potential for waterbirds and other fauna which may assist in supporting breeding events. Increased movement of birds and other fauna between riparian zones and higher landscape zones may also improve the cycling of nutrients upslope.

# 4 Summary of Recommendations and Next Steps

It is recommended that WMLIG, the landholders at Gonn Station and Moola and the co-design team consider the Landscape Rehydration conceptual design opportunities presented in this report to inform the co-design process for the Biolink project at these two properties. Specific recommendations are summarised below:

*Hydrology*

- It is recommended that the primary objective of landscape rehydration at the project site is to restore the hydrologic regime of these lagoons as close as possible to the natural or pre-regulation case (through works interventions, environmental water delivery and/or a combination of both).
- Given the importance of the Neils Creek floodrunner in distributing overbank flows into the Merran Creek, inspection of the Neils Creek during a low flow period would be informative to understanding the hydrology of overbank flow events into the Merran Creek and the broader Biolink area.

*Conceptual Design Opportunities*

- It is recommended that options to restore the hydrological regime of Sheep Wash Lagoon utilising existing infrastructure, detailed in Section 3.2, are further explored and developed with input from the Biolink co-design team.
- It is recommended that other complimentary measures, including de-silting the Sheep Wash lagoon, are explored during the detailed design process.
- It is recommended that options to restore the hydrological regime of Horseshoe Lagoon utilising a combination of new and existing infrastructure, detailed in Section 3.3, are further explored and developed with input from the Biolink co-design team.
- Prior to progressing any detailed design work for Sheep Wash Lagoon and Horseshoe Lagoon, it is recommended that field survey work is completed to confirm elevations and cross-sectional profiles of key landscape features (e.g. commence-to flow levels, bank levels, etc).
- While the hydrological indicators (e.g. inundation frequency, timing, duration and magnitude) inform the restoration objectives, it is recommended that specific management objectives and arrangements are informed by ecological, traditional owner, archaeological and landholder management considerations through the co-design process.
- It is recommended that options are explored by the co-design team and the Biolink and Merran Creek communities to improve the hydrological regime of the Merran Creek through the delivery of environmental flows or tweaks to existing operations. To support this, consideration should be given to the development of hydrological and ecological priorities for the Merran Creek that could inform the development of operating regimes or hydrographs for a range of hydrological and ecological outcomes (e.g. baseflows, small pulse events, larger flow events).
- In parallel with considering the targeted intervention opportunities at the two lagoons and improved flow opportunities for the Merran Creek, it is recommended that the merits of a reach-based solution, as detailed in Section 3.4, are considered and explored by the co-design team. This option may represent a longer-term rehydration goal or opportunity for the full Biolink site.

- It is recommended that opportunities to integrate the complimentary Landscape Rehydration opportunities, detailed in Section 3.5, are considered by the landholders and Biolink co-design team. Mulloon Consulting can provide advice on integration of these methods to support improved landscape function and rehydration across the Biolink site, such as providing input to revegetation plans or modification of existing infrastructure.

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