



Issues Paper

# Gellibrand River FLOWS study

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Prepared for  
**Barwon Water**  
July 2026





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

Artwork by Melissa Barton, a proud Boorooberongal clan (grey kangaroo people) woman of the Dharug Nation. This piece was commissioned by the Alluvium Group, and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for country and the waterways within.

Alluvium Consulting recognises and acknowledges Gulidjan, Gadubanud and Kirrae Whurrong Peoples, whose continuing custodianship, knowledge and connection to Country guide this work. The FLOWS study provides an important opportunity for all involved to deeply listen and be informed by Traditional Owners in the development of recommendations to support flow-dependent values in the Gellibrand catchment.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for Barwon Water under the contract titled Gellibrand River FLOWS study.

*Barwon Water acknowledges Gadubanud, Gulidjan and Kirrae Whurrong Traditional Custodians and pays respect to all First Nations peoples who hold enduring Cultural and ancestral connections, and ongoing responsibilities for caring for Country. Barwon Water recognises the formal role of Eastern Maar Aboriginal Corporation while honouring the broader and continuing relationships that many First Nations communities maintain with these unceded lands and waterways.*

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| <b>Issued to:</b>   | Jared Scott, Barwon Water                                                                                                                                                                                                                                                                                                                                           |
| <b>Authors:</b>     | <b>Environmental Flows Technical Panel:</b> Paul Boon (Dodo Environmental), Ross Hardie (Alluvium), Dion Iervasi (Austral Research and Consulting)<br><b>Technical advisors:</b> John Sherwood (Austral Research and Consulting), Rebecca Sheldon (Austral Research and Consulting)<br><b>Alluvium project team:</b> Amanda Wealands, Jessica Bolden, Gabby Vinyard |
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# Foreword from Eastern Maar Aboriginal Corporation

**“Meerreeng, Parreeyt pa Moorrnong (Land, Water and Sky) are foundational life-giving and balancing components of the greater Maar bio-cultural landscape.**

**With respect and adherence to Maar law/lore, which centres a reciprocating relationship with these elements, they each remain the key definers of what and who the Eastern Maar are.**

**Collectively, our Meerreeng, Parreeyt, Moorrnong, Allam Meen, Bunjil, pa Maar (Land, Water, Sky, Ancestors, Creator and People) are the Dreaming.**

**The Spirit of our ancestors is in the Meerreeng we walk upon, and parreeyt is used to travel through meerreeng.**

This relationship with Meerreeng, Parreeyt pa Moorrnong is manifested in our strong, ongoing, and continuously evolving and living culture, unmovable identity, and our inherent obligation to care for Country.

Parreeyt (water) is part of our spirit and dreaming, it is a living entity. Eastern Maar are the voice for Parreeyt, and the Gellibrand River. It is in this relationship with all Parreeyt that we relate to it as we would a family member, as with individual relationships with an Elder and/or a newborn infant. With a sense of concern, caution, reverence, and calm optimism. Therefore, Parreeyt is Sacred. And with that sacredness comes an obligation to act as its advocate, its guardian, its community, its family.

Our values, relationship and principles with all Parreeyt, will promote and achieve broader environmental and biodiversity targets: cleaner water, greater water security and longer-term economic benefits in the context of real climate change and other current and impending pressures. These principles also elevate Parreeyt for its spiritual importance to the broader community, offering a greater perspective to Australian society of its significance within the context of the localised bio-cultural landscape in which they live. This relationship with Parreeyt has broader and long-term benefits for all Victorians.

Eastern Maar intends to lead a recovery of biocultural values along the Gellibrand River (which sits on the border of three Maar language groups which are Kirrae Whurrong, Gulidjan, and Gadabanud), which holds a strong cultural connection and obligation to Maar. It is the intent of Eastern Maar’s input into this study to share our position on the harm the effects of colonisation have had on the waterway, to articulate why and promote the opportunity for a greater collaborative biocultural values-based approach for the future, and to understand that all Parreeyt flows are bio-cultural and require a reset on how decisions are made.

The Gellibrand River is rich in intangible and tangible cultural heritage dating back thousands of years with Eastern Maar peoples having a strong kinship connection with the waterway and how it managed or cared for. These methods include a holistic approach to caring for and being on Country. Eastern Maar have participated in this study to support the healing of the River.

- Immediate action is needed to keep the River's water in the River by less River water extraction, less groundwater extraction, and less Parreeyt being held back by water authorities.
- Healing of the catchment with more native vegetation and cool burns.
- The natural seasons and cycles including ongoing natural flows for all native aquatic species, enough flow for right season estuary openings for migratory aquatic species, and water for culturally significant species both flora and fauna

These actions support Eastern Maar's self determination to be on Country and care for Parreeyt.

# Executive Summary

This Issues Paper is the second of three reports produced for the Gellibrand River FLOWS study. The FLOWS study is being undertaken by Alluvium Consulting on behalf of Barwon Water and overseen by a Steering Committee of representatives from Barwon Water, Corangamite Catchment Management Authority (CCMA), the Victorian Department of Energy, Environment and Climate Action (DEECA), Eastern Maar Aboriginal Corporation (EMAC) and Wannon Water. The study updates the environmental flow recommendations for freshwater reaches of the Gellibrand River system and its major tributaries, replacing the original Earth Tech (2006) FLOWS study. It applies the FLOWS method Edition 2 (DEPI 2013), incorporating elements of the 2024 method review (Alluvium 2024), and is guided by advances in ecological understanding, changes in Victorian water policy, and the growing role of Traditional Owners in waterway management.

The Gellibrand catchment is located on the border of three Maar language groups, Gulidjan, Gadubanud and Kirrae Whurrong on the western side of Cape Otway, Victoria. The catchment covers approximately 115,000 ha, drains from the Otway Ranges to the Southern Ocean near Princetown, and encompasses the nationally important Princetown Wetlands and Gellibrand estuary. The study covers eight freshwater reaches – Love Creek (Reach 1), Gellibrand River upper, mid and lower (Reaches 2a, 2b, 4), Lardner Creek (Reach 2c), Arkins and First Creeks (Reach 3a), Carlisle River (Reach 3b), and Kennedys Creek (Reach 5) – as well as the Gellibrand estuary (Reach 6). Lardner Creek and Arkins and First Creeks are new reaches added to this study in recognition of their ecological significance and their role as water supply sources.

## Catchment values and condition

The Gellibrand catchment supports high ecological values including state significant populations of River blackfish, nationally threatened Australian grayling (endangered, Environment Protection and Biodiversity Conservation Act 1999), Platypus (vulnerable in Victoria), Spiny crayfish, diverse native fish assemblages, and high macroinvertebrate diversity. The Gellibrand estuary is listed as an endangered ecological community under the EPBC Act 1999 and supports nationally important wetlands and EPBC-listed migratory waterbirds.

The catchment faces significant and ongoing threats. Water system development – including the West Gellibrand and Olangolah reservoirs, extraction at Arkins and First Creek weirs, the North and South Otway pump stations, farm dams, and other surface water and groundwater extraction activities – has substantially reduced summer low flows across the catchment. The impact of water system development is more pronounced during the December – May low flow period where modelled reductions in 80th exceedance percentile flows range from 13% in Reach 2b (Gellibrand River mid) to 61% in Reach 1 (Love Creek) and 57% in Reach 5 (Kennedys Creek), when flows are most critical for aquatic fauna survival and water quality. Recruitment of River blackfish in the mainstem appears to have declined significantly since the 1990s, and is a priority concern for this study.

Non-flow threats including stock access to waterways, weed infestation of riparian zones, high turbidity and post-fire sedimentation which also present material risks to ecological values that environmental flows alone cannot address. The January 2026 Carlisle/Gellibrand bushfire affected Reaches 2b (including Site 2b) and 4, and broader parts of the catchment, with post-fire sedimentation already observed at Site 2b by March 2026.

Outputs from the Gellibrand SOURCE model (HARC 2025) suggest that flows across the catchment will decline further by 2040, with median monthly flow reductions of 10–30% across both low-flow and high-flow periods under a 2040 medium climate scenario. These projected changes are material to the long-term adequacy of any flow recommendations developed in this study.

## Policy and strategic context

The FLOWS study is aligned with, and in part driven by, a strong policy mandate to improve summer flows in the Gellibrand River. Key policy instruments include Action 8-9 of the Central and Gippsland Region Sustainable Water Strategy (improve summer flows in the Gellibrand River) and Action 6-15 (support Eastern Maar Aboriginal Corporation applications for unallocated water in the Otway Basin). The flow recommendations to be produced in Stage 2 of the FLOWS method could inform any potential future review of Bulk Entitlements and passing flow rules in the catchment.

The study is being conducted within a shifting policy landscape with respect to Traditional Owner water rights and management authority. Water is Life (DELWP 2022), the Eastern Maar Nation Statement, and the Eastern Maar Country Plan together establish a framework in water management and decision-making.

## Environmental objectives

Environmental objectives and flow objectives have been developed for three groups of values – aquatic fauna, vegetation, and geomorphology – with a separate set of objectives for the Gellibrand estuary carried forward and revised from the 2008 EEFA study (Lloyd et al. 2008).

For **aquatic fauna**, ten environmental objectives address the maintenance or improvement of native fish assemblages (including River blackfish, Australian grayling, Short-finned eel, Tupong and Lamprey), freshwater crayfish, Platypus, Rakali, and aquatic macroinvertebrates. Flow objectives target the maintenance of low flow habitat and water quality during summer and autumn, freshes to support fish movement, recruitment and habitat flushing, and – in the mainstem reaches with floodplain connectivity – overbank flows to inundate off-channel habitats. The importance of autumn and spring freshes for migratory species, including Australian grayling and juvenile Short-finned eels, is well supported by recent research and is a key driver of flow objectives across the mainstem reaches.

For **vegetation**, seven environmental objectives address the maintenance and, where possible, improvement of algal biofilms, submerged and floating-leafed plants, water-dependent mosses and ferns, damp microclimates in riparian zones, emergent aquatic plants, riparian vegetation condition, and seasonal inundation of floodplain wetland depressions. Many vegetation threats are non-flow in nature, and the objectives recognise that complementary management actions (fencing, weed control, riparian revegetation) will be required alongside environmental flows to achieve meaningful improvements in vegetation condition.

For **geomorphology**, four objectives target the prevention of gross sediment accumulation in channel habitats, maintenance of pool depth, maintenance of gravel bar condition for algae production, and floodplain development through overbank flows. Geomorphic objectives have been developed primarily in service of the aquatic fauna and vegetation objectives they underpin.

For the **Gellibrand estuary**, a workshop held in November 2025 produced revised low flow objectives framed around the functioning of the estuary as an Intermittently Open and Closed Estuary (IOCE), differentiating between objectives for open and closed mouth conditions. Revised low flow magnitude recommendations cannot be set at this stage as insufficient information exists to determine appropriate thresholds; further dedicated investigation outside the FLOWS study is required. The higher-magnitude flow objectives from the 2008 EEFAM study are carried forward unchanged.

## Next steps

Following sign-off on the environmental objectives, the study will proceed to Stage 2 – the development of quantified environmental flow recommendations. Stage 2 will involve hydraulic model development at each study site, flow recommendation workshops with the Environmental Flows Technical Panel, and performance assessment of current and future flow scenarios against the recommendations. Flow recommendations will be tested against the 2040 medium climate scenario using the seasonally adaptive approach (DEPI 2013) to understand how often recommendations can be met under projected future conditions. The Final Report will present reach-by-reach flow recommendations, performance against those recommendations, supporting recommendations for complementary management actions, and monitoring priorities.

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# 1 Introduction

The purpose of this Gellibrand River FLOWS study is to update the environmental flow recommendations for freshwater reaches of the Gellibrand River and its major tributaries. The project is driven by concerns regarding the health and ongoing protection of the Gellibrand River system and the adequacy of the existing flow recommendations, given the age of the original FLOWS study (Earth Tech 2006a-c) and advances in ecological understanding and management practices since 2006. Several factors have changed, which could also conceivably affect the determination of flow recommendations for the Gellibrand River:

1. Changes in Victorian and regional water strategy and policy. This includes:
  - a. Development of *Water is Life: Traditional Owner Access to Water Roadmap*, and a partnership approach between DEECA and Traditional Owners for water management.
  - b. An action led by Wannon Water to improve summer flows in the Gellibrand River (Western Region Sustainable Water Strategy 2011 and Central and Gippsland Region Sustainable Water Strategy, DELWP 2022)
  - c. Consideration and understanding of climate change and its impacts
2. Improved understanding of the Gellibrand catchment and its values and threatening processes.
3. Changes to the FLOWS method itself, including seasonal adaptiveness of recommendations, and consideration of climate change. The FLOWS method was updated in 2013 (FLOWS method ed.2, DEPI 2013) and further reviewed in 2024 (Alluvium 2024). The 2006 Earth Tech Gellibrand River FLOWS study used the original 2002 FLOWS method and was one of the first investigations in Victoria to apply the FLOWS approach.

The objectives of the Gellibrand River FLOWS study are to:

- Use a transparent, science-based approach (FLOWS method ed. 2, incorporating key elements from the 2024 method review) to assess the flow requirements of the Gellibrand River and its major tributaries.
- Examine the flow-dependent environmental values and objectives of the system and determine the flow regime required to meet these objectives.
- Identify key system constraints and risks, including climate change risks.

This Gellibrand River FLOWS study will also provide advice on complementary actions to increase the effectiveness of flow recommendations and enhance river health. Flow recommendations may inform *potential* future agency projects such as a review of Bulk Entitlements, passing flow rules, Sustainable Diversion Limits (SDLs), Permissible Consumptive Volumes (PCVs), take and use licencing, restrictions and rostering.

## 1.1 Project governance

### Alluvium Project Team

The investigation was co-ordinated by Alluvium Consulting (Amanda Wealands, Jessica Bolden and Gabby Vinyard). Responsibilities include coordination of the Environmental FLOWS Technical Panel (EFTP), project outputs, and working with the Project Steering Committee and the Project Advisory Group

to ensure that outputs incorporate agency and community feedback. The Alluvium project team contributes expertise on the FLOWS methodology, catchment management, hydrology and hydrologic analysis, hydraulic modelling, community engagement and facilitation.

### **Environmental Flows Technical Panel**

The Environmental Flows Technical Panel (EFTP: Ross Hardie, Professor Paul Boon and Dr Dion Iervasi) is a multidisciplinary panel with expertise in geomorphology, vegetation and aquatic ecology. The EFTP's role is to describe the current understanding of the Gellibrand system, to set the locations of reach boundaries and compliance sites, to devise environmental objectives, hydraulic criteria and flow recommendations.

Honorary Associate Professor John Sherwood will contribute to the review of the estuary summer / autumn low flow recommendation and provide insight on the implications of freshwater flow recommendations for the estuary. Dr Jon Fawcett has provided technical advice on groundwater. Rebecca Sheldon has provided technical advice on aquatic ecology.

### **Project Steering Committee**

The Project Steering Committee (PSC) consists of representatives from Barwon Water, Wannon Water, Corangamite Catchment Management Authority, the Victorian Department of Energy, Environment and Climate Action (DEECA), Southern Rural Water and Eastern Maar Aboriginal Corporation. The PSC oversees project implementation, direction and scope, and assists with reviewing project deliverables. The PSC determines the spatial scope of the FLOWS study and is informed by the Project Advisory Group (PAG).

### **Traditional Owners**

The Gellibrand catchment is located on the border of three Maar language groups, Gulidjan, Gadubanud and Kirrae Whurrong. This study seeks to recognise and reflect the unique relationship that First Peoples hold with their cultures, lands and waters. All named waterways in the Gellibrand catchment (200 m buffer either side of the waterway) are recognised Areas of Cultural Heritage sensitivity (ACHRIS 2025), as is the Great Otways National Park, through which many of the waterways flow.

The Eastern Maar Aboriginal Corporation (EMAC) is a Prescribed Body Corporate, managing native title which encompasses the Gellibrand catchment. Eastern Maar Aboriginal Corporation is also the Registered Aboriginal Party representing the rights and interests of Traditional Owners. EMAC is represented on the Project Steering Committee.

The PAG includes Traditional Owners who are not represented by EMAC.

### **Project Advisory Group**

The PAG consists of 15 representatives, each with a strong connection to the Gellibrand catchment. The PAG was selected through an open Expression of Interest process in January 2025. The PAG's role is to provide input and feedback throughout the design and development of the FLOWS Study. This is obtained via workshops, and through the receipt of feedback on draft project deliverables (site, issues and final recommendations papers).

## 1.2 Purpose of this report

This *issues paper*, is the second of three reports produced for the FLOWS study. This paper documents the objective setting process for environmental flows recommendations for freshwater reaches of the Gellibrand River and its major tributaries. It outlines the updated environmental values and threats in the Gellibrand system, reach hydrology, the catchment policy and strategic context, environmental objectives for flow-dependent environmental values and reach-specific environmental flow objectives.

This paper is preceded by the Gellibrand River FLOWS study Site Paper (Alluvium 2025) and further informed by:

- Site visits and assessments (March 2025 and October 2025)
- Workshops with EMAC,
- Workshops with the PAG,
- The PSC,
- Gellibrand estuary low flow objectives workshop (held November 17, 2025)

This report captures the outcomes of Stage 1 of the FLOWS method. The next report for the study will comprise the outcomes from Stage 2 of the FLOWS method – environmental flow determination.

## 1.3 Report structure

|                  |                                                                                                                                                                                                                                                                                                                                                                         |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Section 1</b> | <u>Introduction</u><br>Outlines the project background, scope and method.                                                                                                                                                                                                                                                                                               |
| <b>Section 2</b> | <u>Spatial scope</u><br>Describes the broader spatial context of the study area and how the system operates.                                                                                                                                                                                                                                                            |
| <b>Section 3</b> | <u>Study reaches and site descriptions</u><br>Describes reach flow-dependent values, hydrology, groundwater connections and water quality, from desktop review and site inspection.                                                                                                                                                                                     |
| <b>Section 4</b> | <u>Catchment scale threats and issues</u><br>Describes reach and catchment scale threats to flow-dependent values.                                                                                                                                                                                                                                                      |
| <b>Section 5</b> | <u>Policy and strategic objectives</u><br>Overviews relevant policies and strategies, to inform setting of environmental objectives.                                                                                                                                                                                                                                    |
| <b>Section 6</b> | <u>Environmental flow objectives</u><br>Details the environmental objectives, alignment with strategy and policy and flow objectives.                                                                                                                                                                                                                                   |
| <b>Section 7</b> | <u>Estuary environmental flow objectives</u><br>Details the revision of estuary low flow objectives and carries forward the 2008 EEFA estuary objectives.                                                                                                                                                                                                               |
| <b>Section 8</b> | <u>References</u>                                                                                                                                                                                                                                                                                                                                                       |
| <b>A1 - A5</b>   | <u>Appendices:</u> <ol style="list-style-type: none"> <li>1. Aquatic fauna recorded in the Gellibrand catchment</li> <li>2. Streamflow gauges in the Gellibrand catchment</li> <li>3. The Gellibrand River Source Model</li> <li>4. Assumptions and limitations of applying the FLOWS method</li> <li>5. Available water quality data from streamflow gauges</li> </ol> |

## 2 Spatial scope

The Gellibrand catchment is located on the border of three Maar language groups, Gulidjan, Gadubanud and Kirrae Whurrong on the western side of Cape Otway, Victoria. The headwaters of the Gellibrand River are in the northern slopes of the Otway ranges. The Gellibrand River and tributaries flow through the Otway Plains in the mid and lower catchment, and meet the Southern Ocean in the Twelve Apostles Marine National Park, near Princetown (Dwyer and Lester 2021).

The catchment covers an area of approximately 115,000 ha (Moss and Clifton 2018) and has a high mean annual rainfall of 1012mm (Park and Roberts 2023). The Gellibrand estuary (receiving waters for Gellibrand River freshwater flows) is home to wetlands of national importance (the Princetown Wetlands).

### 2.1 Study reaches

This FLOWS study comprises eight freshwater reaches and the Gellibrand estuary (Figure 1). Reach descriptions are overviewed in Table 1 and detailed in Section 3.

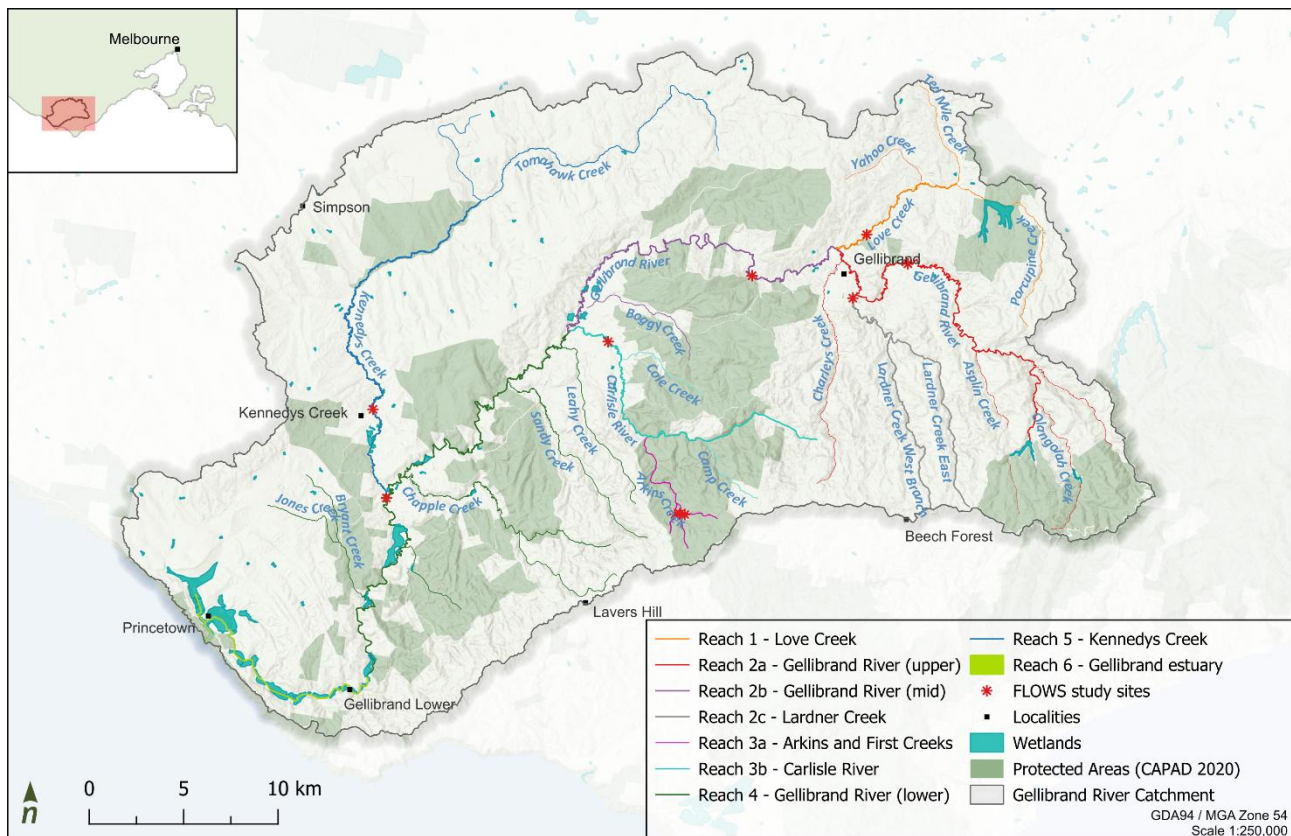


Figure 1. Gellibrand River FLOWS study reaches and sites.

Table 1. Gellibrand River FLOWS study reaches and sites.

| Reach number | Waterway name            | Reach boundaries                                                                                                                       | Site                                                                                                                                                                                                    |
|--------------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1            | Love Creek               | Love Creek and upstream tributaries to confluence with Gellibrand River                                                                | Wonga road crossing of Love Creek, downstream of bridge (38°30'12.0"S 143°33'06.3"E)                                                                                                                    |
| 2a           | Gellibrand River (upper) | Downstream of West Gellibrand Dam, to confluence with Love Creek                                                                       | End of Ashes Road, downstream (38°30'59.4"S 143°34'38.2"E)                                                                                                                                              |
| 2b           | Gellibrand River (mid)   | Confluence with Love Creek to confluence with Carlisle River                                                                           | Gellibrand Gauge 235227, off Gellibrand River Road (38°31'29.0"S 143°28'58.6"E)                                                                                                                         |
| 2c           | Lardner Creek            | Lardner Creek (including West and East branches) to confluence with the Gellibrand River                                               | Yaughar Bushland Reserve (downstream Gellibrand East Road Bridge) (38°32'01.6"S 143°32'40.3"E)                                                                                                          |
| 3a           | Arkins and First Creeks  | First Creek, Arkins Creek West and Arkins East branches and Arkins Creek to confluence with Carlisle River                             | First Creek diversion weir (38°38'20.5"S 143°26'23.3"E)<br>Arkins Creek West branch diversion weir (38°38'19.7"S 143°26'33.4"E)<br>Arkins Creek East branch diversion weir (38°38'20.5"S 143°26'45.1"E) |
| 3b           | Carlisle River           | Carlisle River and upstream tributaries (excluding creeks of Reach 3a) to confluence with the Gellibrand River                         | Gauge 235200C, upstream of Gellibrand River Road bridge (38°33'27.3"S 143°23'47.5"E)                                                                                                                    |
| 4            | Gellibrand River (lower) | Between the confluence of Carlisle River and the upstream extent of the Gellibrand estuary (approximately the Great Ocean Road Bridge) | South Otways Pump Station, downstream of Kennedys Creek confluence (38°38'04.8"S 143°15'50.0"E)                                                                                                         |
| 5            | Kennedys Creek           | Kennedys Creek and upstream tributaries to confluence with Gellibrand River                                                            | Upstream of Kennedys Creek Road bridge crossing (38°35'32.1"S 143°15'15.4"E)                                                                                                                            |
| 6            | Gellibrand estuary       | Great Ocean Road bridge to estuary mouth                                                                                               | N/A                                                                                                                                                                                                     |

Lardner Creek (Reach 2c), and Arkins and First Creeks (Reach 3a) are new reaches for this Gellibrand River FLOWS study. The spatial extent of reaches 1, 2a, 2b, 3 (now 3b), 4, 5 and estuary are as per the 2006 FLOWS study (Earth Tech 2006a-c).

Sites 1, 2a and 4 have shifted relative to the 2006 FLOWS study for improved accessibility, safety, physical features and representativeness of the broader reach.

## 2.2 Water resource management and system operation

Understanding how the Gellibrand River system is managed – who holds entitlements, where water is extracted, what operating rules govern those extractions, and what infrastructure constraints exist – is essential context for interpreting the hydrological analyses in Section 3 and for ensuring that the environmental flow recommendations developed in Stage 2 are implementable. This section summarises the key agencies, entitlements and operational constraints relevant to each reach. Full details of Bulk

Entitlement conditions, take-and-use licence rosters and groundwater management areas are provided in the Site Paper (Alluvium 2025, Appendix A).

## Agency roles and responsibilities

**Barwon Water** manages urban water supply for Colac and surrounding communities from the upper Gellibrand catchment. Barwon Water holds two Bulk Entitlements in the Gellibrand system: the Bulk Entitlement (Gellibrand) Conversion Order 1997, which authorises take from Lardner Creek at the Lardner Creek pump station; and the Bulk Entitlement (Colac) Amendment Order 2003, which authorises take from West Gellibrand Reservoir and Olangolah Reservoir. West Gellibrand Reservoir (capacity 1,860 ML) is the main storage on the West Branch of the Gellibrand River and its operation directly affects downstream flows in Reaches 2a, 2b and 4. Olangolah Reservoir (capacity 129 ML) is located on Olangolah Creek, a tributary of the Gellibrand River.

**Wannon Water** manages urban water supply for south-west Victoria from the lower Gellibrand catchment. Wannon Water holds the Bulk Entitlement (Otway System) Conversion Order 1998, which authorises take from the Arkins Creek West and East Branch diversion weirs and First Creek diversion weir (Reach 3a), as well as the North Otway and South Otway pump stations on the Gellibrand River (Reach 4). The Otway System Bulk Entitlement supplies towns including Carlisle River, Simpson, Cobden, Camperdown, Lismore, Derrinallum, Terang, Noorat, Glenormiston, Allansford, Warrnambool and Koroit. There are no major instream storages in the lower Gellibrand catchment. Wannon Water also holds a groundwater licence to extract up to 6 ML/day (1,800 ML/year) from bores in the Carlisle River catchment. Carlisle River groundwater extraction provides an important operational tool, enabling Wannon Water to reduce surface water extractions at the North Otway Pump Station during periods of low surface flow.

The three Bulk Entitlements in the Gellibrand system are summarised in Table 2.

**Table 2. Bulk entitlements in the Gellibrand system (reproduced from the Gellibrand River FLOWS study Site Paper, Alluvium 2025)**

| Bulk Entitlement                                      | Water authority | Volume (ML/year) | Key town(s) supplied                                                                                                        | Location of extraction                                                                                |
|-------------------------------------------------------|-----------------|------------------|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Bulk Entitlement (Gellibrand) Conversion Order 1997   | Barwon Water    | 60               | Gellibrand                                                                                                                  | Lardner Creek pump station                                                                            |
| Bulk Entitlement (Otway System) Conversion Order 1998 | Wannon Water    | 12,580           | Carlisle River, Simpson, Cobden, Camperdown, Lismore, Derrinallum, Terang, Noorat, Glenormiston, Allansford and Warrnambool | Arkins Creek West, Arkins Creek East, First Creek, North Otway Pump Station, South Otway Pump Station |

| Bulk Entitlement                              | Water authority | Volume (ML/year) | Key town(s) supplied | Location of extraction                                                                |
|-----------------------------------------------|-----------------|------------------|----------------------|---------------------------------------------------------------------------------------|
| Bulk Entitlement (Colac) Amendment Order 2003 | Barwon Water    | 5,400            | Colac                | Olangolah Reservoir (up to 5.0 ML/day); West Gellibrand Reservoir (up to 17.0 ML/day) |

**Southern Rural Water (SRW)** manages take-and-use licences in the Gellibrand system – totalling approximately 4,770 ML/year – under the Otway Coast Basin Local Management Plan 2014. For the management of direct pumping licences, the Gellibrand River is divided into three zones: (1) below the North Otway Pump Station; (2) upstream of the North Otway Pump Station, excluding Carlisle River; and (3) Carlisle River. Each zone has its own five-stage restriction roster, applied using daily and seven-day rolling average flow thresholds during periods of low flow. SRW also manages water in the Gellibrand Groundwater Management Area (GMA), the Newlingbrook GMA and the Paaratte GMA. The Permissible Consumptive Volume for the Gellibrand GMA is currently 0 ML/year; for the Newlingbrook GMA it is 1,977 ML/year; and for the Paaratte GMA it is 4,606 ML/year.

Under the Victorian *Water Act 1989*, the Minister delegates authority to Southern Rural Water to administer the regulations around licensing that protect groundwater resources. From time to time, Southern Rural Water is able to offer additional water for sale from its storages or through groundwater and surface water opportunities. New groundwater or surface water entitlements are available where the current licensed volume is lower than the specified limit. The current licenced volume for the Newlingbrook GMA and Paaratte GMA are both lower than the Permissible Consumptive Volume and an expression of interest process ran by Southern Rural Water, is currently underway for this unallocated water.

**Corangamite CMA** has statutory waterway management functions across the catchment, is responsible for developing and implementing the Corangamite Regional Catchment Strategy and Corangamite Waterway Strategy, and is the regulator for artificial openings of the Gellibrand estuary. Corangamite CMA is also a delivery partner in the Central and Gippsland Region Sustainable Water Strategy Action 8-9 to improve summer flows in the Gellibrand River.

**DEECA** coordinates the development of sustainable water strategies for the region, produces annual Victorian Water Accounts, and undertakes long-term water resource assessments. DEECA also collects environmental contributions that fund water-related environmental activities.

## Operational implications by reach

The nature and degree of operational influence on the flow regime varies across the study reaches. Key operational features relevant to the development of flow objectives and flow recommendations are summarised below.

**Reach 1 - Love Creek** – has a high density of farm dams (11.2 ML/km<sup>2</sup>, 105 dams with a combined estimated volume 170.3 ML).

**Reaches 2a and 2b (Gellibrand River upper and mid)** are located downstream of West Gellibrand Reservoir and Olangolah Reservoir. The operation of these storages – including seasonal release patterns

and outlet capacity constraints – directly shapes the flow regime in these reaches. While passing flows are required under the Bulk Entitlement (Colac) Amendment Order 2003, the volumes, timing and seasonal distribution of releases can differ from the unimpacted flow regime.

**Reach 2c (Lardner Creek)** is subject to Barwon Water's Bulk Entitlement (Gellibrand) Conversion Order 1997, which enables the Authority to take a share of flow up to 60 ML/day from Lardner Creek at the Lardner Creek pump station. The current passing flow rules state that when flow at pump station is below 0.43 ML/day, Barwon Water is authorised to take all flow in the creek. When flow is above 0.43 ML/day, Barwon Water can take a maximum of 0.43 ML/day. Analysis of daily mean gauged flows in Lardner Creek (at the offtake, gauge 235210), suggest that flows below 0.43 ML/day are very rare. Two legitimate periods (8 days in March 1968, and 1 day in February 1961) saw Lardner Creek flows fall below 0.43 ML/day (i.e. 9 days in over 60 years of daily data).

Current extraction volumes are limited and the reach retains a largely intact flow regime relative to the unimpacted condition (Section 3.2.4). This near-natural character is ecologically significant, providing important habitat conditions and natural flow seasonality into the Gellibrand River mainstem. The largely intact regime also presents a specific risk in the context of applying the FLOWS method: that environmental flow recommendations could be set lower than the current flow regime. Environmental flow recommendations for Reach 2c will therefore adopt precautionary framing, including consideration of a maximum allowable degree of alteration from the unimpacted mean annual flow regime and requirements related to sediment transport dynamics.

**Reach 3a (Arkins and First Creeks)** presents the most significant operational constraint in the study. All three Reach 3a creeks – Arkins Creek West Branch, Arkins Creek East Branch and First Creek – are diverted at weirs for supply to the North Otway pipeline under the Otway System Bulk Entitlement. Critically, the Bulk Entitlement (Otway System) Conversion Order 1998 does not stipulate passing flows below any of these weirs. As a result, all three waterways cease to flow downstream of the weirs whenever flows fail to overtop the weir crest (due to low inflows or permitted extraction by Wannon Water). This arrangement represents a complete interruption of the natural flow regime below the weirs for a substantial portion of the year and is the primary flow-related threat to values in this reach. The absence of passing flow obligations also means that quantified low flow recommendations developed in Stage 2 would have no current mechanism for implementation, and their primary purpose will be to inform any potential future amendment to the Bulk Entitlement.

**Reaches 3b, 4 and 5 (Carlisle River, Gellibrand River lower and Kennedys Creek)** are affected by take-and-use licences managed by SRW [including Wannon Water's Carlisle River bores, where 10% of extracted groundwater is estimated to come from the Gellibrand River (HARC 2025)], and Reach 4 is additionally affected by the North and South Otway pump stations operated by Wannon Water. The three-zone SRW restriction roster provides some low-flow protection for licensed pumping, but the Bulk Entitlement pump stations are not subject to equivalent restriction triggers under the same framework.

HARC (2025) identified a high density of farm dams in Kennedys Creek (9.62 ML/km<sup>2</sup>, with 1247 individual dams and a combined volume of 2590 ML).

**Gellibrand estuary** tributaries Latrobe Creek and Boggy Creek have the highest density of farm dams of all Gellibrand subcatchments assessed by HARC (HARC 2025) – 16.2 ML/km<sup>2</sup>, with 507 individual dams and an estimated combined volume of 938.4 ML.

## Infrastructure barriers to fish passage

Infrastructure associated with water supply operations constitutes a significant barrier to fish passage throughout the catchment. This is directly relevant to the connectivity objectives developed for migratory species in Section 6. Following a barrier assessment conducted in 2010 (Ryan et al. 2010), Corangamite CMA removed a number of instream barriers. However, substantial infrastructure barriers to fish passage remain, including West Gellibrand Reservoir and Olangolah Reservoir, and the diversion weirs in Arkins Creek West Branch, Arkins Creek East Branch and First Creek. Stevensons Falls is a significant natural fish barrier in the upper Gellibrand catchment (Reach 2a) and may provide some upstream refuge benefit for native fish from predation by Brown trout.

The extent to which environmental flow recommendations can achieve connectivity objectives is therefore constrained by existing infrastructure in several reaches, particularly Reach 3a. Supporting recommendations in Stage 2 should identify complementary infrastructure and management actions – including fish passage investigations at remaining barriers – that would be needed alongside environmental flows to achieve the migratory connectivity objectives in full.

### 3 Study reaches and site descriptions

This section outlines site descriptions for each study site, based on desktop review (discussed in detail in the Site Paper, Alluvium 2025), preliminary site inspections in March 2025 and the site assessments undertaken in October 2025. Aquatic fauna species recorded in each FLOWS study reach are further documented in Appendix 1 and summarised in Sections 3.1 to 3.9. Vegetation descriptions are based on 2005 modelled Ecological Vegetation Classes (EVCs) and key functional groups observed during the site visits.

#### A note on hydrologic analyses

Reach hydrologic analyses employed modelled outputs from the harmonised Source hydrological model for the Gellibrand catchment (HARC 2025) for the streamflow gauge nearest to each FLOWS study site. Gauge numbers and locations are provided for reference in Appendix 2.

The Source model was developed to represent system inflows, demands and operating rules and their variability in space and time. Model development and calibration is described in detail in HARC 2025 and overviewed in Appendix 3.1.

**Note:** ‘development’ refers to ‘water system development in the catchment’ – i.e. urban and rural demands (e.g. groundwater and surface water extraction, and the impacts of farm dams, plantation forestry etc.), and broader river operations (storage, flow routing etc.).

While the FLOWS method is largely agnostic to the ‘source’ of water, all sources have been considered (either explicitly or implicitly) in the development of the Source model. This included consideration of the known impacts of Barwon Water’s historic groundwater pumping activities at the Barwon Downs borefield, and Wannon Water’s pumping activities at the Carlisle River bores. However, it is noted that within the Gellibrand catchment groundwater contributions come from a number of different sources (i.e. different aquifer systems, or from interflow or bank storage processes), and whilst these don’t impact the flow recommendations, these would need to be considered as part of any future management interventions.

In addition, the timing and magnitude of interflow and bank storage processes can also be driven by the frequency and duration of high flows and/or floods, so whilst these are a form of groundwater input, they may not be representative of groundwater conditions more broadly.

The hydrologic analyses presented herein focus on three Source model outputs:

1. Modelled unimpacted level of development (LOD) under a historical climate i.e. modelled flows had the catchments water system never been developed
2. Modelled current level of development under a historical climate and
3. Modelled current level of development under a 2040 medium climate projection.

The Project Advisory Group has raised concerns about aspects of the Source model inputs and assumptions, including groundwater representation, farm dam identification and gauge data quality. These concerns have been reviewed in detail by the EFTP and HARC and are addressed in Appendix 3.2. The review confirms that the concerns raised do not alter the use of the model for this study or the

outcomes of the modelling. The Source model remains the best available tool for deriving current and unimpacted daily flow time-series for the Gellibrand catchment, and modelling uncertainty is documented and carried through to the flow recommendations in Stage 2 in accordance with the FLOWS method (DEPI 2013, Appendix B). The EFTP acknowledges that hydrological modelling involves inherent uncertainty and they will continue to communicate these limitations throughout the study.

## How to read the hydrologic plots

For each reach, the following hydrologic plots are presented:

- (A) **Box and whisker plots of total monthly flows** (unimpacted level of development (LOD), historical climate scenario, for modelled years 1900 – 2022) to illustrate flow seasonality and variability in each calendar month. The plots use Source modelled unimpacted level of development (LOD), in a historic climate. Green asterisks represent mean monthly flow.
- (B) **Median monthly flow plots**, which show three development and climate scenarios: (orange) current LOD in a historic climate, (blue) unimpacted LOD in a historic climate, and (dashed purple) current LOD under a 2040 medium climate projection.
- (C) **Flow duration curves** comparing unimpacted LOD with current LOD (historical climate, years 1900 – 2022) across the December – May and June – November periods, to examine the impact of development on flows. Scenarios shown are unimpacted (dashed lines) and current LOD (solid lines), for the periods of December – May (blue), and June – November (green).

20<sup>th</sup> and 80<sup>th</sup> exceedance percentile flow magnitudes, and the differences in the magnitudes of these flows due to the current LOD, are presented in tables for each reach.

### Interpretation of flow duration curves

Flow duration curves are used to demonstrate the variability and exceedance frequency of flows across nominated seasons. December – May, and June – November flow duration curves are provided for each study reach, based on Source modelled unimpacted LOD (dashed lines) and current LOD (solid lines).

Flow magnitudes (Y-axis) are presented on a log<sub>10</sub> scale. The X-axis represents the percentage of days, within the nominated season, the flow magnitude is equalled or exceeded.

An 80<sup>th</sup> exceedance percentile flow is the flow rate that is equalled or exceeded on 80% of days during the analysed season. The X<sup>th</sup> exceedance percentile flow rate is therefore the flow rate that is equalled or exceeded on X percent of days. A given flow rate can be reframed as an exceedance percentile flow to understand how often the flow rate is equalled or exceeded.

Separation of modelled unimpacted LOD and current LOD flow duration curves indicates an impact of development on flows. The degree of separation and the exceedance percentiles at which separation occurs provides insight as to the magnitudes of flows that are impacted by development and the extent to which they are impacted.

The FLOWS method has now been applied for a number of decades across a very wide range of Victorian waterways. An informal meta-analysis of flow recommendations reveals that some more-or-less consistent patterns emerge: low flow recommendations are commonly of the order of the 80<sup>th</sup> exceedance percentile flow, and freshes are commonly of the order of the 20<sup>th</sup> exceedance percentile flow. Bankfull and overbank flows are rarer events and have low exceedance percentiles.

## **A note on assumptions and limitations of the FLOWS method**

This issues paper focusses on Gellibrand catchment issues rather than assumptions and limitations of the FLOWS method and modelled inputs. Key assumptions and limitations of the FLOWS method are provided in Appendix 4. These will be addressed in the body of the recommendations report, where they are most relevant to the setting of flow recommendations. As noted above, uncertainties of the Source model are described in Appendix 3.2. Project and model assumptions, limitations and uncertainties will be discussed in the recommendations report.

### 3.1 Reach 1 - Love Creek

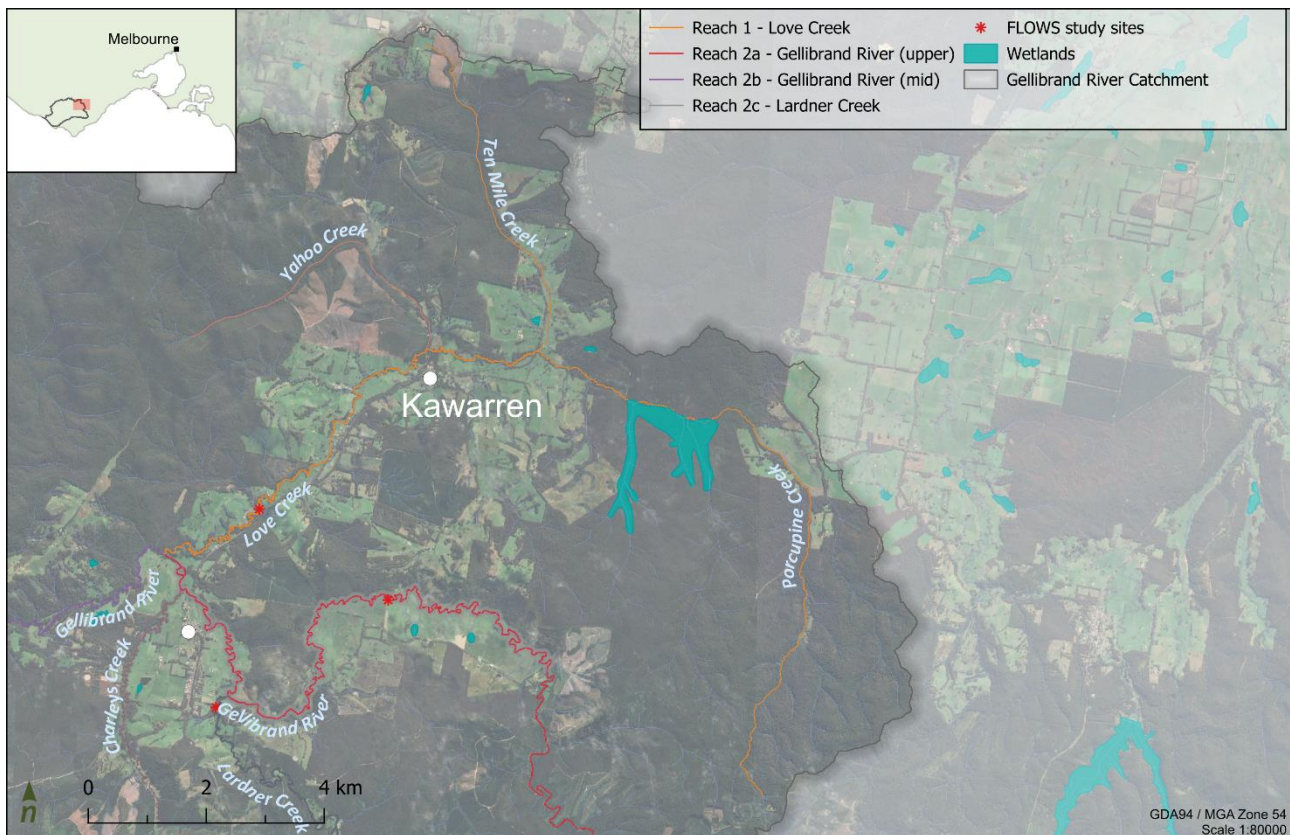


Figure 2. Site 1, Love Creek (left) looking downstream from Wonga Road bridge on 24 March 2025, (centre) cross section 8 looking upstream on 29 October 2025 (right) looking downstream from cross section 8 on 29 October 2025.

### 3.1.1 Aquatic fauna

Reach 1 supports native fish species, including Common galaxias, Ornate galaxias, River blackfish, Spotted galaxias, Southern short-finned eels and Tupong. Spiny crayfish have also been identified. Reach 1 supports a very high diversity of aquatic macroinvertebrates (28 taxa) (CCMA 2024).

Platypus have previously been recorded in Love Creek ([Atlas of Living Australia](#)). Platypus habitat observed during the site assessment included pools and small riffles and possible Platypus burrows. The reach contains instream wood and flow diversity, creating fast and slow flowing habitat niches for a variety of aquatic fauna.

### 3.1.2 Vegetation

Reach 1 contains a narrow band of EVC 18 Riparian Forest (BCS variously Vulnerable or Least Concern in Otway Plain bioregion), surrounded by terrestrial forests including EVC 45 Shrubby Foothill Forest and EVC 16 Lowland Forest. Some minor tributaries are lined by EVC 198 Sedgy Riparian Woodland (Depleted in Otway Plain bioregion). Observations of vegetation values at site 1 from the preliminary site visit (March 2025) and EFTP site assessment (October 2025) are provided in Table 3.

**Table 3. Observations of vegetation at Site 1**

|                                                                                                         |                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | Parts of the Love Creek catchment had a wet microclimate proximal to the waterway.                                                                                                                                                                                                        |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | Algal biofilms occur on submerged surfaces and play critical roles in aquatic food webs.                                                                                                                                                                                                  |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                                                                                            |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | Very few observed (noting the water was exceptionally turbid), except for sporadic Water Ribbons ( <i>Cyanogeton procerum</i> ) and a starwort, possibly Round Water-starwort ( <i>Callitriche muelleri</i> ).                                                                            |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Very few emergent reeds, rushes or sedges observed.<br><br>Sporadic distribution of water-dependent mosses and small ferns on exposed CWD and along lower banks.<br><br>Patches of an exotic semi-aquatic iris, possibly Yellow Flag-iris ( <i>Iris pseudacarus</i> ), were present.      |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Very narrow band of EVC 18 Riparian Forest, mostly revegetated (only one or two trees wide) and partly fenced.<br><br>Blackwood, Eucalyptus and Olearia overstorey.<br><br>Riparian zone is limited to canopy trees, with highly depauperate shrub-layer and ground-layer (highly weedy). |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | Adjacent billabong with connected outflow, presumed no streamflow connection.                                                                                                                                                                                                             |

### 3.1.3 Geomorphology

Reach 1 is partially confined with floodplain pockets and is comprised of a sand bed stream with instream large wood. The channel is inset into the floodplain with some instream physical features. During the site visit, Love Creek contained side bars but few instream geomorphic features. Some bank undercutting and slumping was observed (October 2025).

### 3.1.4 Hydrology

Reach 1 - Love Creek has a 'true' high flow season from June to October, a 'true' low flow season from December to April, with 'transition' months (months with flows that are neither high nor low, and difficult to assign to a true high or low flow period) in May and November (Figure 3a). The impact of development is more pronounced during the low flow months than during the high flow month (i.e. the unimpacted and current LOD median flow curves deviate during December to April) (Figure 3b). The impact of development on low (summer / autumn) flows is revealed in the flow duration curve (Figure 3c), where clear deviation of the unimpacted and current LOD curves is observed across the entire range of flows, with increasing deviation at higher exceedance percentile flows (blue dashed vs solid lines). A 61% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows, and a 26% decrease in 20<sup>th</sup> exceedance percentile flows is modelled for December - May (Table 4, Figure 3). During June - November, development has modest impacts on high exceedance percentile flows (compare green dashed vs solid lines in Figure 3c, and Table 4).

These modelled data suggest that development significantly impacts flows in Love Creek during December - May, particularly on low magnitude flows. Impacts on low flows during June - November are less pronounced.

Climate change is modelled to have a significant impact on flows during winter - spring (Figure 3b).

**Table 4. Impacts of development on 80% and 20% exceedance percentile flows in Reach 1.**

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December - May  | 2.44                    | 0.94                 | -61%                                          |
|                       | June - November | 9.19                    | 7.99                 | -13%                                          |
| 20%                   | December - May  | 6.94                    | 5.16                 | -26%                                          |
|                       | June - November | 60.36                   | 60.08                | -0.5%                                         |

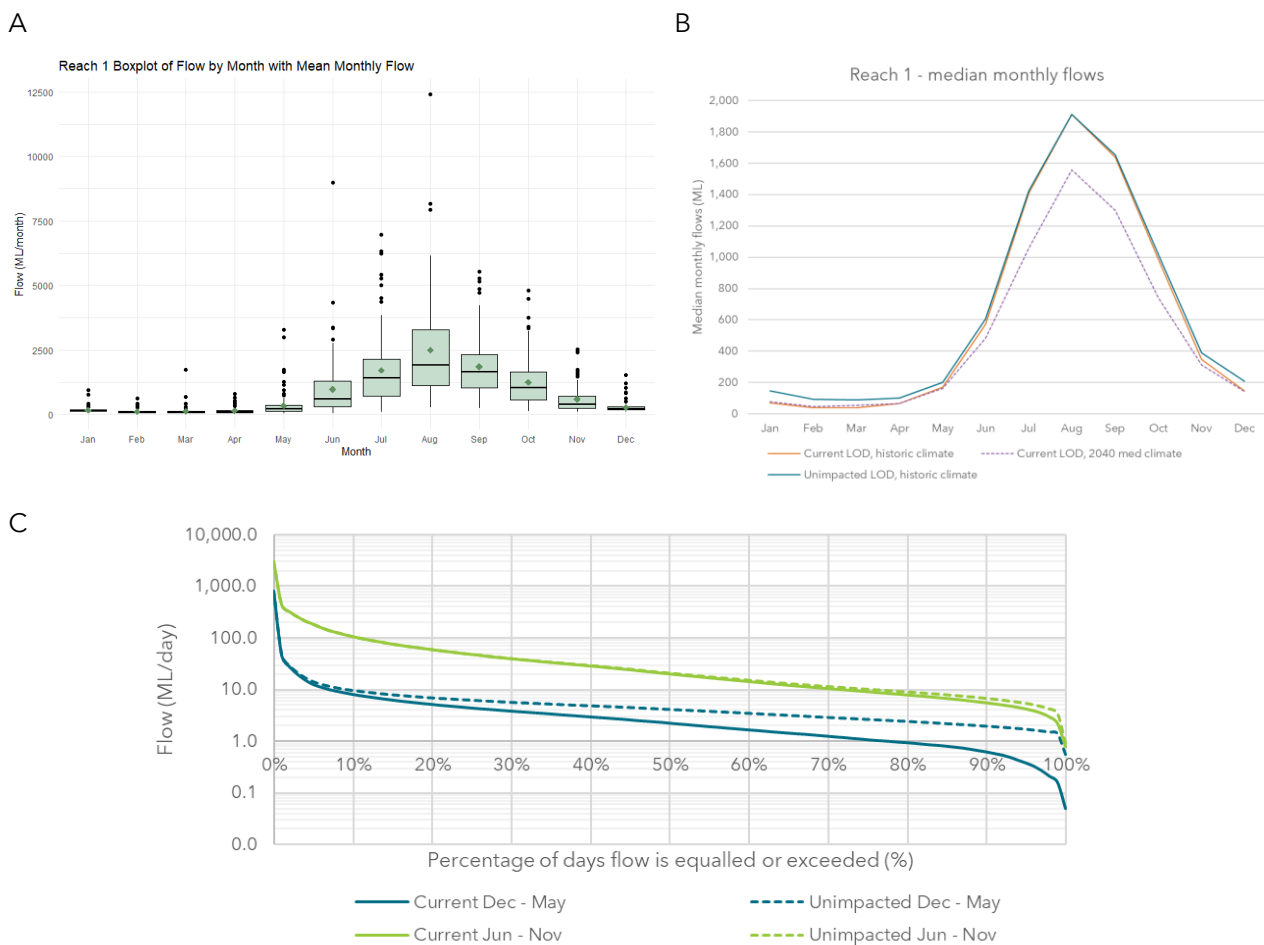


**Figure 3. Hydrologic analysis Reach 1 - Love Creek - Source modelled hydrologic data.**

### 3.1.5 Groundwater connections

In the upper portions of Ten Mile Creek and Yahoo Creek that feed into Love Creek, the Quarternary Sediments are underlain by the Lower Tertiary Aquifer (LTA) and receive groundwater inflows from the LTA (BlueSphere Environmental 2024). Love Creek itself does not receive direct groundwater inputs from the LTA. Groundwater discharge from the LTA into Yahoo Creek has been impacted by Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield. This has also led to flow on effects on Love Creek.

The impacts of historic groundwater pumping activities to Yahoo Creek and the flow on effects of this on Love Creek have been incorporated in the Source model and routed through downstream reaches (HARC 2025).

The Quarternary Sediments in the lower portions of Ten Mile Creek, Yahoo Creek and Love Creek itself overlie the Lower Mid-Tertiary Aquifer (LMTA). Little is known about the groundwater surface water interactions and variability between the LMTA and these waterways. However, these reaches do not receive direct groundwater inputs from the LTA.

Little is known about the magnitude and temporal and spatial variability of groundwater interactions between the Quaternary Aquifer and Reach 1 in general. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data.

The Bureau of Meteorology Groundwater Dependent Ecosystem (GDE) Atlas identifies the locations of potential aquatic GDEs throughout the Gellibrand catchment (<https://www.bom.gov.au/water/groundwater/gde/map.shtml>). High and moderate potential aquatic GDEs have been identified in the Love Creek catchment, but the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.1.6 Water quality

Love Creek is known to have higher salinity than other Gellibrand reaches, particularly during low flows (CCMA 2020), possibly due to groundwater inputs. Water quality monitoring was undertaken at eight occasions from 2015 - 2017 in Love Creek at Jukes (WaterWatch site LOV021). Low turbidity, reactive phosphate and neutral pH levels were recorded at most times (CCMA 2020a, Dwyer and Lester 2021). Low dissolved oxygen saturation (<50% saturation) was observed in February 2017 and thought due to be due to low creek flows (CCMA 2020).

Water quality monitoring has been undertaken at Site CO\_LOV020 - love creek at Vance Bridge on thirteen occasions from 2015 - 2017. Water quality was generally good, with low oxygen saturation in February 2017, in agreement with the Love Creek at Jukes site (WaterWatch site LOV021).

Nutrient (nitrogen and phosphorus) spikes have been recorded, with nutrient load trends related to livestock levels. Several pesticides have been detected in Love Creek waters via a citizen science campaign, including wood preservative 2,4,6-Trichlorophenol, microbicide 2-Phenylphenol, fungicide Biphenyl, insecticide Terbacil, and herbicides Hexazinone and Simazine (Cacciatore et al. 2026).

## 3.2 Reach 2a - Gellibrand River Upper

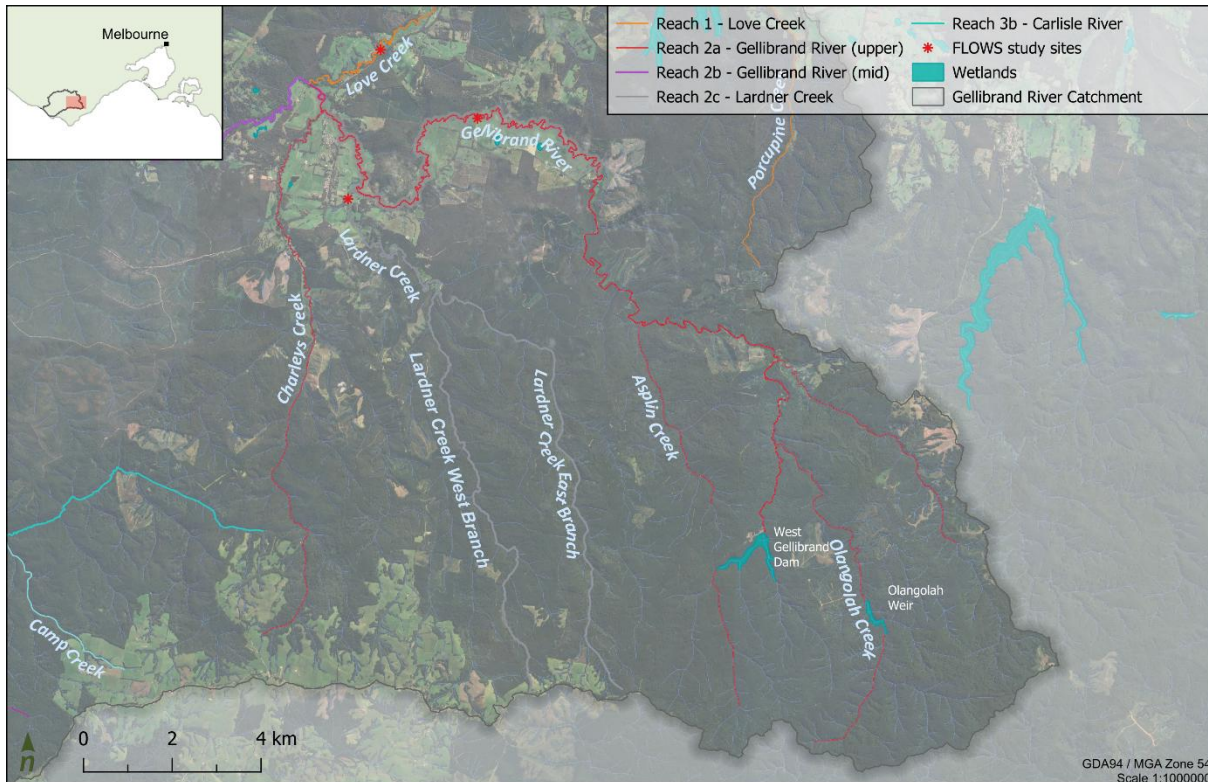


Figure 4. Site 2a (left) looking downstream from cross section 11. Image taken 29 October 2025. (right) looking downstream from cross section 8. Image taken 29 October 2025.

### 3.2.1 Aquatic fauna

The native fish assemblage in Reach 2a includes Broad-finned galaxiids, Short-finned eels, Flat-headed gudgeon, River blackfish, Australian grayling, Spotted galaxias, Tupong and many small-bodied fish. Platypus and Spiny crayfish are both present. The PAG noted Rakali, Mussels, Otway black snail and Hairy burrowing crayfish (groundwater dependent).

Stevensons Falls is a significant natural fish barrier and may provide refuge for native fish from Brown trout if not already present in the area, but most of the reach is located downstream of Stevensons Falls.

Reach 2a has a variety of instream habitat for macroinvertebrates, such as instream macrophytes and large woody debris, including log jams. A relatively high abundance of aquatic invertebrates has been reported in this reach (Becker and Robson 2010, cited by Dwyer and Lester 2021).

Holes were observed in the lower bank above the water line in October 2025, possibly Platypus burrows.

### 3.2.2 Vegetation

Reach 2a - Gellibrand River (upper) consists of EVC 18 Riparian Forest (variously Vulnerable or Least Concern in Otway Plain bioregion) and EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex (BCS of Depleted) along the stream, surrounded by the terrestrial EVC 23 Herb-rich Foothill Forest.

**Table 5. Observations of vegetation at Site 2a**

|                                                                                                         |                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | Upper reach 2a has a wet microclimate                                                                                                                                                                                                                                                                                  |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | Algal biofilms occur on submerged surfaces and play critical roles in aquatic food webs.                                                                                                                                                                                                                               |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                                                                                                                         |
| <b>Submerged and floating-leaved plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | Very few observed (noting the water was very turbid), except for an occasional starwort [possibly Round Water-starwort ( <i>Callitriche muelleri</i> )] and Eelweed ( <i>Vallisneria australis</i> ).<br><br>Conditions are probably suitable for Water Ribbons ( <i>Cyanogeton procerum</i> ) elsewhere in the reach. |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Very few emergent reeds, rushes or sedges observed, but some common taxa such as dock ( <i>Rumex</i> spp.) and knot-weeds ( <i>Persicaria</i> spp.) were present on benches.<br><br>Some small, water-dependent mosses and ferns grew on exposed CWD and along lower banks.                                            |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Very narrow band of EVC 18 Riparian Forest and EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex, mostly revegetated (only one or two trees wide) and partly fenced.<br><br>Riparian zone is limited to canopy trees, with highly depauperate shrub-layer and ground-layer (highly weedy).                        |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | None observed.                                                                                                                                                                                                                                                                                                         |

### 3.2.3 Geomorphology

Reach 2b is partially confined and inset within the floodplain. It includes deep pools and abundant large wood. The bank material appears to be comprised of clay materials, limiting the potential for erosional adjustments.

Several bank slumps and shallow sand bars were observed on the site visit (October 2025).

### 3.2.4 Hydrology

Reach 2a - Gellibrand River (upper) has a 'true' high flow period that extends from June - October, and a true low flow period from December - April (Figure 5a). May and November serve as transition months (Figure 5a). As shown in Figure 5b, development is modelled to impact median monthly flows in all months of the year (note separation of the orange and blue curves in all months). As a proportion of monthly flows, the greatest impacts of development occur during summer - autumn months. Flows in the month of May are the most impacted (27% decrease), and August flows the least impacted (2% decrease) by development (Figure 5b). Climate (dashed purple line) is modelled to impact flows in all calendar months, with greatest reductions in flows predicted to occur over high flow months (modelled 29% decrease in 2040 flows in July and August, Figure 5b). The flow duration curve (Figure 5c) shows a consistent impact of development on the entire range of flow magnitudes in December - May, while impacts in June - November affect lower magnitude flows (i.e. greater separation of curves occurs at lower flow magnitudes / higher exceedance percentiles). The magnitudes of 20% and 80% exceedance percentile flows, and differences in the magnitudes of these percentile flows with development, are presented in Table 6.

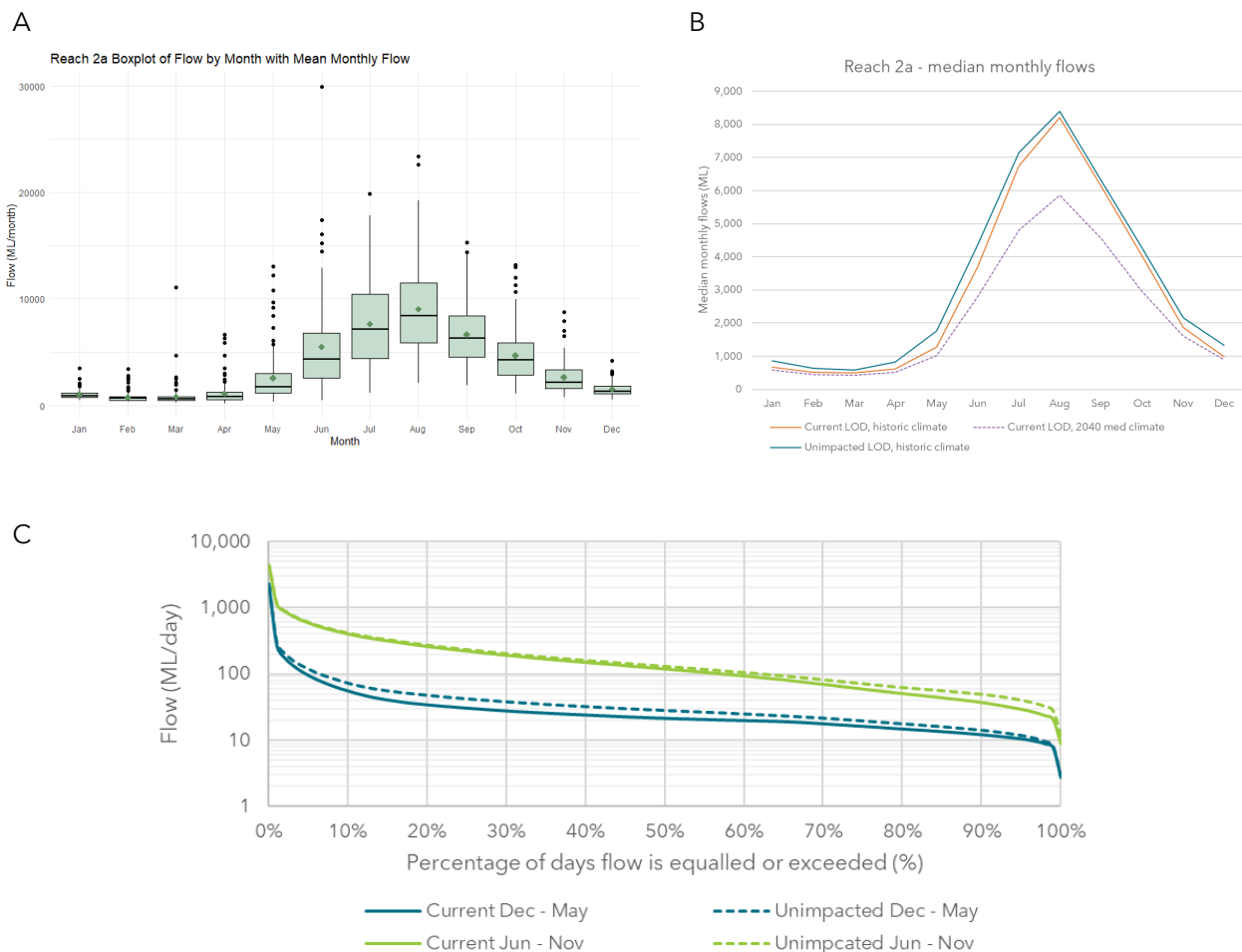


Figure 5. Hydrologic analysis Reach 2a - Gellibrand River (upper) - Source modelled hydrologic data

Table 6. Impacts of development on 80% and 20% exceedance percentile flows in Reach 2a

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December – May  | 17.6                    | 14.7                 | -17%                                          |
|                       | June – November | 61.8                    | 50.7                 | -18%                                          |
| 20%                   | December – May  | 47.7                    | 34.2                 | -28%                                          |
|                       | June – November | 270.1                   | 260.9                | -3%                                           |

### 3.2.5 Groundwater connections

The Gellibrand River from downstream of James Access bridge to the confluence with Love Creek (within Reach 2a of the FLOWS study), is known to receive groundwater discharge from the LTA. At Bunkers Hill (Reach 2b), Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield are estimated to have reduced low flows by 3-6% (BlueSphere Environmental 2024).

The impacts of historic groundwater pumping activities to the Gellibrand River have been incorporated in the Source model and routed through downstream reaches (HARC 2025).

Atkinson et al. (2015) used a tracer approach to quantify total groundwater inflows in the Gellibrand River between James Access and Bunkers Hill (within reach 2b), finding that total groundwater contributions accounted for 10-50% of the flows recorded at Bunkers Hill. Total groundwater contributions were also found to vary spatially and seasonally, with groundwater discharge accounting for 10-20% of the flows recorded at Bunkers Hill between June and September and up to 40-50% between January and April. This study also indicated that 50-90% of total groundwater contributions occur in a 5.2 km stretch of the Gellibrand River extending from Lardner Creek, with the remaining discharge primarily occurring between James Access and Ashes Road.

Little is known about the magnitude and temporal and spatial variability of groundwater interactions between the Quaternary Aquifer and the Gellibrand River. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data. The BOM GDE Atlas shows high potential aquatic GDEs in Reach 2a, noting that the Atlas does not distinguish the source(s) aquifer that supply groundwater to these systems.

### 3.2.6 Water quality

Monthly 'spot' water quality data has been recorded for the Gellibrand River at Upper Gellibrand (Gauge 235202) since January 1990. Water quality is typically good (turbidity mean 7.65 NTU, Salinity mean 144 EC, pH mean 7.0, Dissolved Oxygen 9.7 mg/L), noting that this gauge is located in the upper catchment and in a forested area.

A citizen science campaign detected several pesticides in the Gellibrand River in Reach 2a, including wood preservative 2,4,6-Trichlorophenol, microbicide 2-Phenylphenol, fungicide Biphenyl, Herbicide

Hexazinone and Simazine, and Insecticide Terbacil (Cacciatore et al. 2026). Pesticides were also detected in Reach 2a tributary Charleys Creek (Cacciatore et al. 2026).

### 3.3 Reach 2b - Gellibrand River (mid)

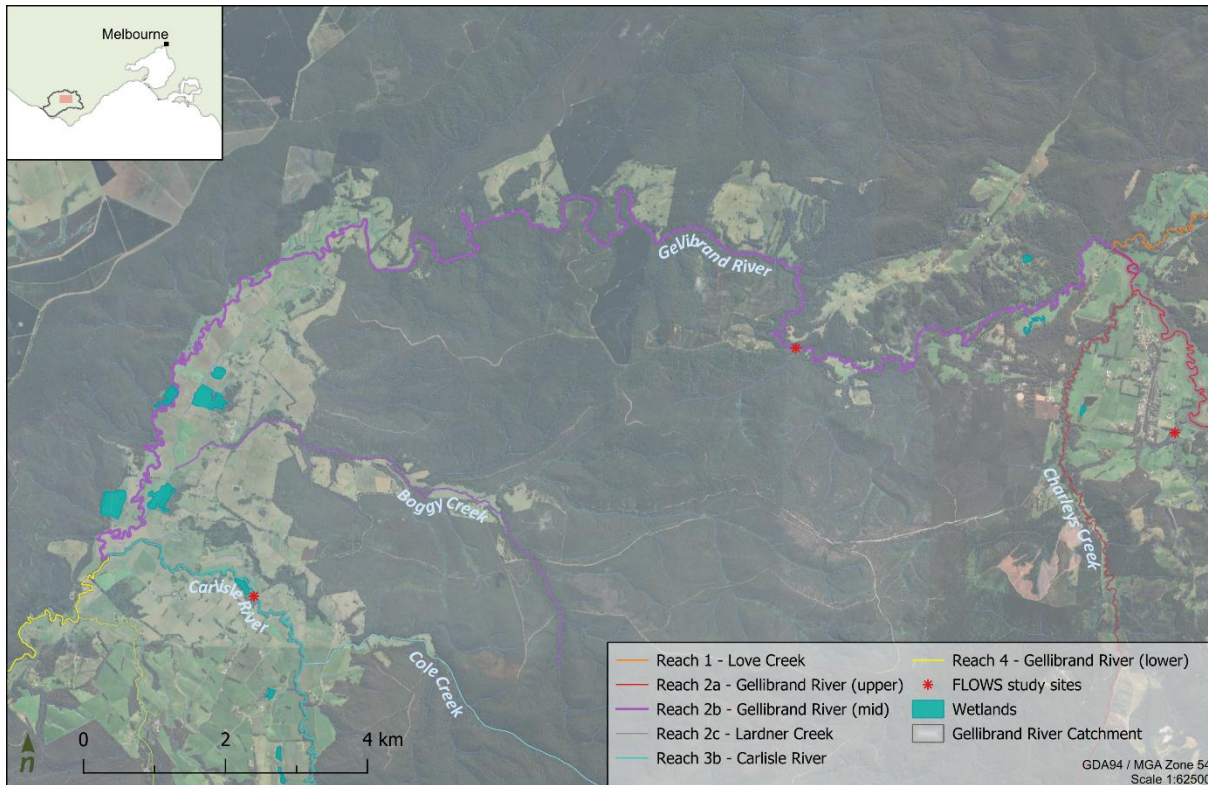


Figure 6. Site 2b rock riffle looking downstream (left) observed at low flow in March 2025 (right) observed at high flow on 28 October 2025



**Figure 7. Site 2b (left) looking downstream from cross section 7 (centre) looking upstream from cross section 5 (right) inflowing backwater creek in foreground at cross section 3**

### 3.3.1 Aquatic fauna

Reach 2b has a diverse native fish assemblage of nine species, including freshwater resident and migratory species such as Australian grayling and River blackfish. Platypus and Spiny crayfish are also present, and the PAG has noted the presence of Rakali and Mussels.

The conservation-listed Otway stonefly (*Eusthenia nothofagi*) has been reported in the Gellibrand River (Doeg, 1997, cited by Dwyer and Lester 2021), although the broader distribution in the catchment is unknown.

The Otway black snail is also found within the Gellibrand catchment, and although not flow-dependent, is dependent upon a wet microclimate (SWIFFT 2025).

Macroinvertebrates are presumed present, but surveys using the National Waterbug blitz method have not been reported for the reach.

On the October 2025 site visit abundant large woody debris was observed, both instream and on banks. Instream boulders, cobbles and rock bars provide fast flowing riffle habitat, while slow flowing pool habitats were observed upstream. Inflowing backwater creeks, drainage lines and swampy areas were found upstream at Site 2b. Possible Platypus burrows were observed.

### 3.3.2 Vegetation

Reach 2b – Gellibrand River (mid) supports EVC 18 Riparian Forest (variously Vulnerable or Least Concern in Otway Plain bioregion) and EVC 198 Sedgy Riparian Woodland (Depleted in the Otway Plain bioregion) along the stream, surrounded by the terrestrial EVC 45 Shrubby Foothill Forest and EVC 202 Shrubby Wet Forest. Note that EVC 198 Sedgy Riparian Woodland is mapped as widespread along the tributaries of this reach.

**NOTE:** Site visit observations were made in October 2025. Reach 2b (and Site 2b) were severely affected by the Carlisle / Gellibrand fire in January 2026 (see Section 4.3). Flow recommendations will be developed based on observations of vegetation values observed during the 2025 site visit.

**Table 7. Observations of vegetation at Site 2b**

|                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | A wet microclimate was observed                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | Algal biofilms occur on submerged surfaces and play critical roles in aquatic food webs.                                                                                                                                                                                                                                                                                                                                               |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | Very few observed (noting the water was exceptionally turbid), except for the occasional presence of an unidentified, submerged, broad-leafed plant (potentially Water hyssop ( <i>Bacopa</i> spp.)).                                                                                                                                                                                                                                  |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Very few emergent reeds, rushes or sedges observed except for small patches of Giant Sedge ( <i>Cyperus exaltatus</i> ), Tall Sedge ( <i>Carex appressa</i> ) and unidentified rushes ( <i>Juncus</i> spp.) on benches.<br><br>Patches of an exotic, semi-aquatic iris, possibly Yellow Flag-iris ( <i>Iris pseudacarus</i> ), were present.<br><br>Some small, water-dependent mosses and ferns on exposed CWD and along lower banks. |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Riparian zone along this reach is intact (if previously logged), extending to native forest cover.<br><br>In sections the riparian zone is highly weedy, especially in the shrub- and ground-layers.                                                                                                                                                                                                                                   |
| <b>Wetlands</b><br>(Anabranched, Billabongs)                                                            | None observed.                                                                                                                                                                                                                                                                                                                                                                                                                         |

### 3.3.3 Geomorphology

Reach 2b is partially confined with an exposed rock bar and large upstream pools. Upstream from the rock bar, the waterway contains floodplain pockets, and the cross section includes depositional benches, a sand bed and presence of large wood. The site appears stable with no sign of contemporary erosional or depositional channel change. Somewhat undercut banks were observed, with ferns growing on the toe of the bank. A post-fire inspection of Site 2b identified substantial deposition of sand in drainage lines.

### 3.3.4 Hydrology

In Reach 2b - Gellibrand River (mid), the true high flow period extends from June - October, and the true low flow period extends from December - April (Figure 8a). May and November serve as transition months (Figure 8a). Median monthly flows for the historical climate are more significantly impacted by development during the low flow period compared to the high flow period (note separation of blue and orange curves in Figure 8b).

Figure 8b also provides an indication of the modelled impacts of the 2040 medium climate scenario on median monthly flows for the current LOD. Under the 2040 medium climate scenario, median monthly

flow decreases in summer are projected to range from 10% in January to 28% decrease in August (Figure 8b).

Development is modelled to impact December - May flows across the entire flow range, with flow decreases of 18% and 17% for 80% and 20% exceedance percentile flows, respectively (Figure 8c, Table 8). The Impact of development on June - November flows is more modest, with a modelled 2% decrease in the magnitude of 20<sup>th</sup> exceedance percentile flows, and a 9% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows (Figure 8c, Table 8).

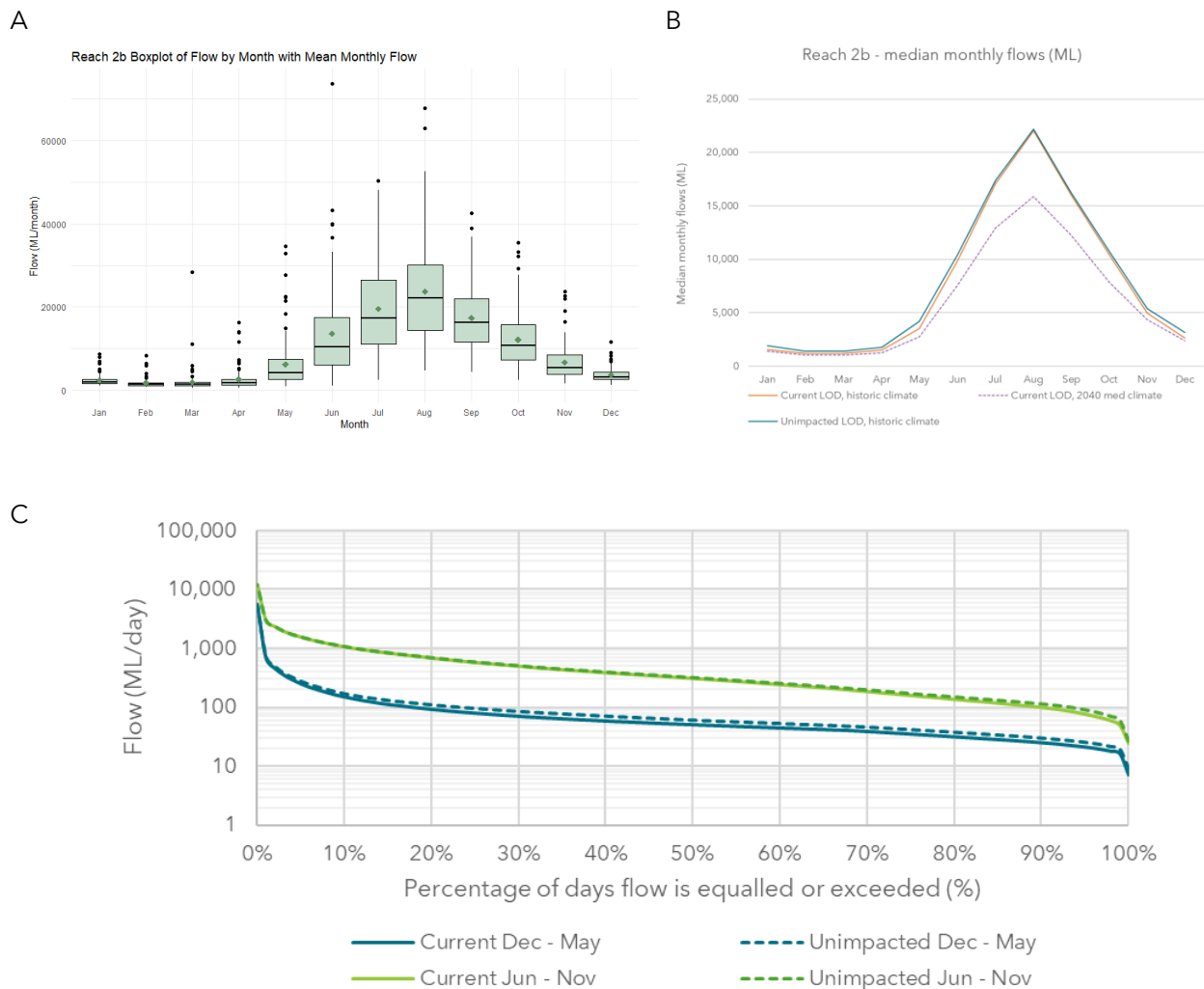


**Figure 8. Hydrologic analysis Reach 2b - Gellibrand River (mid) - Source modelled hydrologic data**

Table 8. Impacts of development on 80% and 20% exceedance percentile flows in Reach 2b

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December – May  | 38.4                    | 32.0                 | -18%                                          |
|                       | June – November | 151.4                   | 137.1                | -9%                                           |
| 20%                   | December – May  | 112.0                   | 93.2                 | -17%                                          |
|                       | June – November | 703.0                   | 691.9                | -2%                                           |

### Gauge status and implications for Stage 2 – determining environmental flow recommendations

The Bunkers Hill streamflow gauge (235227), which is the primary compliance gauge for Reach 2b, was destroyed in the January 2026 bushfire approximately six weeks after the EFTP site assessment and cross-section survey were completed. The gauge has since been reinstated. The gauge was offline during the survey work, that was delayed due to the January 2026 fires. As such, flow rates during the survey work were estimated by relating the surveyed water levels (mAHD) to the elevation of the gauge reference point (mAHD) and the corresponding depth on the gauge boards near cross section 12, and then identifying the corresponding depth from the rating table. Stage 2 hydraulic modelling for this reach will document the implications of the gauge outage period for model calibration confidence, consistent with the uncertainty reporting requirements of the FLOWS method (DEPI 2013, Appendix B).

### 3.3.5 Groundwater connections

The understanding regarding groundwater – surface water interactions along Reach 2b are mainly limited to the upper sections of Reach 2b, as outlined in section 3.2.5. Little is known about the magnitude and temporal and spatial variability of groundwater interactions in the lower parts of this reach. However, previous assessments indicate that the Gellibrand River is a predominantly gaining stream (i.e. receives groundwater inputs from the surrounding systems) between Bunkers Hill and Burrupa (GHD, 2013).

The impacts Barwon Water's historic groundwater pumping activities to the flows in Reach 2b have been incorporated in the Source model and routed through downstream reaches (HARC 2025). Other groundwater contributions to streamflow are captured/embedded in the streamflow data. The BOM GDE Atlas shows high potential aquatic GDEs in Reach 2b, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.3.6 Water quality

Continuous dissolved oxygen concentrations were briefly recorded at the Bunkers Hill streamflow gauge from 2008 – 2009. The record is incomplete but showed a period of poor dissolved oxygen concentrations (3 – 5 ppm) in February 2009 (Appendix 5). Monthly 'spot' water quality measurements have been recorded at Bunkers Hill since 1990. Water quality is typically good (pH mean 7.0, Dissolved Oxygen mean 9.2 mg/L, salinity mean 234  $\mu$ S/cm, turbidity mean 13 NTU), notwithstanding spot readings of high salinity (maximum 2399  $\mu$ S/cm in June 2008) and high turbidity (maximum 243 NTU in August 2022).

A citizen science campaign detected several pesticides in the Gellibrand River in Reach 2b, including wood preservative 2,4,6-Trichlorophenol, microbicide 2-Phenylphenol, fungicide Biphenyl, Herbicide Hexazinone and Simazine, and Insecticide Terbacil (Cacciatore et al. 2026). Pesticides were also detected in Reach 2b tributary Boggy Creek (Cacciatore et al. 2026).

### 3.4 Reach 2c - Lardner Creek

For the map, please refer to the Reach 2a map in Section 3.2.



Figure 9. Site 2c (left) looking downstream from cross section 7 (centre) undercut banks on right bank downstream of cross section 10 (right) looking downstream from cross section



Figure 10. Bank erosion at Lardner Creek stream depth gauge

### 3.4.1 Aquatic fauna

Fish species such as Common galaxias, Short-finned eel, Tupong and Lamprey have been present (historic records for these species exist from 1999, NatureKit). Key aquatic fauna species predicted to occur include Spiny crayfish, River blackfish, Australian grayling and Platypus. The Otway black snail (*Victaphanta compacta*) and Hairy burrowing crayfish (*Engaeus sericatus*) have been found (NatureKit) but are broadly water dependent (wet climate and groundwater dependent, respectively), not flow-dependent.

Macroinvertebrates are presumed present, but surveys using National Waterbug blitz method have not been reported for the reach.

During the site visit, the landholder noted a history of illegal netting in the reach.

Limited extractions and close to natural flows may mean that Lardner Creek functions as an important habitat for aquatic values in the context of the broader Gellibrand catchment.

### 3.4.2 Vegetation

The major types of native vegetation surrounding Reach 2c – Lardner Creek are EVC 18 Riparian Forest (Least Concern) along the larger creek lines, EVC 30 Wet Forest (Least Concern) and EVC 201 Shrubby Wet Forest (Least Concern) along the minor creek lines, EVC 45 Shrubby Foothill Forest (Least Concern) in more elevated areas and EVC 16 Lowland Forest (Depleted).

**Table 9. Observations of vegetation at Site 2c**

|                                                                                                         |                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | A wet microclimate was observed in the upper catchment                                                                                                                                                                                                                          |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | None observed, but algal biofilms are likely to be present on submerged surfaces.                                                                                                                                                                                               |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                                                                                  |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | Very few observed, except for occasional presence of an unidentified, submerged, narrow-leafed plant, possibly Small Spike-rush ( <i>Eleocharis pusilla</i> ).<br><br>Conditions are probably suitable for Water Ribbons ( <i>Cyanogeton procerum</i> ) elsewhere in the reach. |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Very few emergent reeds, rushes or sedges observed.<br><br>Very patchy distribution of water-dependent mosses and small ferns on exposed CWD and along lower banks.                                                                                                             |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Very narrow band of EVC 18 Riparian Forest, mostly revegetated (only one or two trees wide) and mostly fenced.<br><br>Riparian zone is limited to canopy trees, with highly depauperate shrub-layer and ground-layer (highly weedy).                                            |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | A billabong / depression was observed in the adjacent paddock with outflow to the creek. Directly connected stream flow (i.e. inflow) to billabong not presumed.                                                                                                                |

### 3.4.3 Geomorphology

Reach 2c - Lardner Creek is defined by a partially confined meandering single thread, sand bed stream with a bed width of three to five metres, a top width of approximately 20 metres and a channel depth of approximately 3.5 metres. Channel has both adjoining floodplain pockets and valley margins and has banks comprising clay, silt and sand. Stream channel has moderate levels of large wood, providing channel bed form and hydraulic habitat diversity and has depositional benches on the inside of meander bends. Rock observed in the bed of the river near the road bridge appears to be a legacy of road and bridge protection works and does not appear to be related to bedrock outcrops.

During the site visit (October 2025) the landholder noted that willows were removed in the 1990s, and the site was fenced and revegetated with overstorey species. Ongoing significant bank erosion was observed during the visit, with three recent bank slumps taking revegetated blackwoods and eucalypts into the stream. Revegetation is now at the bank edge in most places.

### 3.4.4 Hydrology

Reach 2c - Lardner Creek has a 'true' high flow period that extends from June - October and a 'true' low flow period that extends from December - April. May and November are flow transition months (Figure 11a).

Development is modelled to have a small to negligible impact on monthly flows (Figure 11a, b) and flow duration curves (Figure 11c, Table 10) in Lardner Creek. The overlap of unimpacted and current LOD median monthly flow curves and flow duration curves suggest that even with the current level of extraction, Lardner Creek has a largely 'free flowing and natural' flow regime. This is because the annual extraction of 60 ML from Lardner Creek under the bulk entitlement is a fraction of the creek's average annual flows of 25 GL.

Climate change is modelled to impact Lardner Creek flows in all months (Figure 11b). The impact of climate change is most visible during the high flow period, with up to 24% decreases in flow in October. Similar proportional decreases in flow occur in the low flow and transition months, with 24% decreases in median monthly flows also occurring in April and May.

**Table 10. Impacts of development on the magnitudes of 80<sup>th</sup> and 20<sup>th</sup> exceedance percentile flows in Reach 2c**

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December - May  | 7.0                     | 6.9                  | -2%                                           |
|                       | June - November | 38.0                    | 37.9                 | <1%                                           |
| 20%                   | December - May  | 28.1                    | 28.0                 | <1%                                           |
|                       | June - November | 155.03                  | 154.98               | <1%                                           |

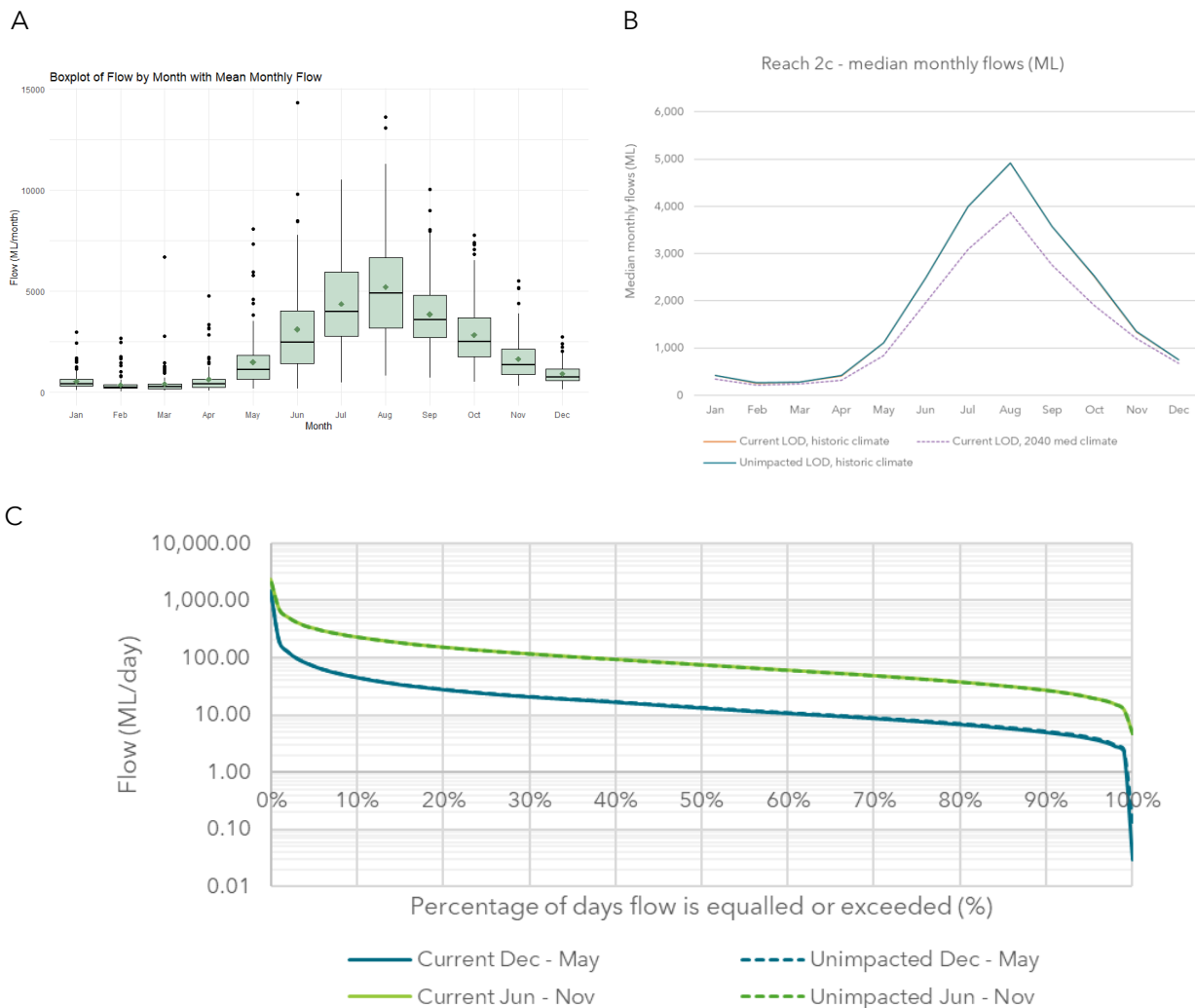


**Figure 11. Hydrologic analysis Reach 2c - Lardner Creek - Source modelled hydrologic data**

### 3.4.5 Groundwater connections

The quaternary sediments along Lardner Creek are primarily underlain by the Otway Group Aquifer (OGA). To our knowledge, little is known regarding the magnitude and spatial and temporal variability of groundwater - surface water interactions between the Quaternary Aquifer, OGA and the Gellibrand River. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data.

The BOM GDE Atlas shows high potential aquatic GDEs in Reach 2c, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.4.6 Water quality

Salinity (as electrical conductivity) and turbidity (NTU) have been continuously monitored at the Lardner Creek gauge since 2004 (Appendix 5). Salinity and turbidity are typically low.

### 3.5 Reach 3a - West Arkins, East Arkins and First Creeks

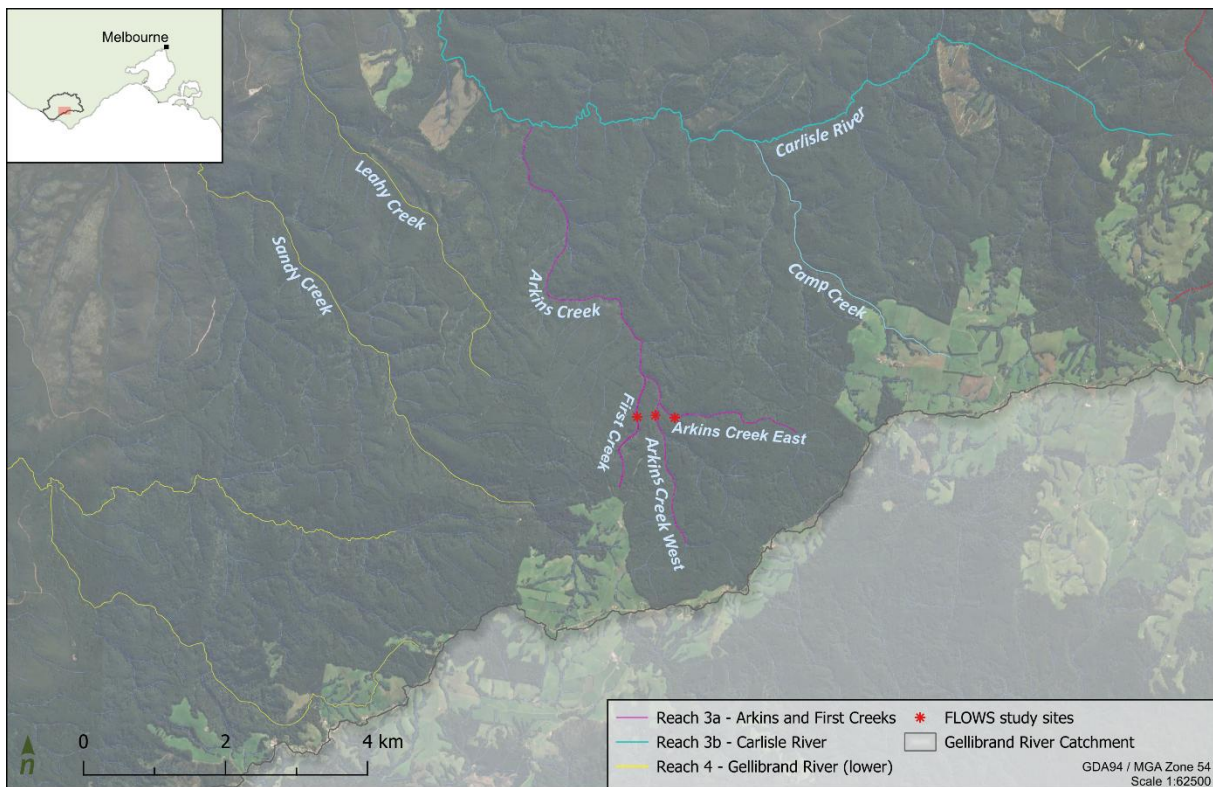


Figure 12. First Creek (left) below the weir (right) above the weir. Images taken 27 July 2025.



Figure 13. Arkins Creek West Branch (left) lower weir (centre) downstream of bridge (right) upper weir. Images taken 21 July 2025.



Figure 14. Arkins East Creek (left) looking upstream toward the weir and wheel (right) downstream of the weir.

### 3.5.1 Aquatic fauna

Crayfish burrows (formed by burrowing crayfish, spp. not determined) were observed in Arkins Creek West and Arkins Creek East. Arkins Creek West and Arkins Creek East are anticipated to support Spiny crayfish (*Euastacus yarraensis*), Climbing galaxias (*Galaxias brevipinnis*) and various small macroinvertebrates. Several aged (~1980s) records of fish species including Blackfish, Lamprey, Galaxias, Short-finned eel and Trout also exist (NatureKit Victoria).

Platypus habitat is present in both Arkins Creek branches, which require flow for the provision of food, habitat and connectivity. One Platypus has been recorded (in the 1980s) in the Arkins Creek East catchment.

Fauna values in First Creek are anticipated to be predominantly forest-dependent, rather than streamflow dependent. An Otway black snail (*Victaphanta compacta*) was observed by a project team member representative at the First Creek site.

Macroinvertebrates are presumed present, but surveys using National Waterbug blitz method have not been reported for the reach.

### 3.5.2 Vegetation

First Creek at the diversion weirs is surrounded by wet forest EVC (EVC 30, Bioregional conservation status of least concern). Arkins Creek East and Arkins Creek West are surrounded by EVC 30 Wet Forest, located in some cases directly along the creek lines and in others on the hillsides along the waterways.

**Table 11. Observations of vegetation at Site 3a**

|                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | A wet microclimate was observed.                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | Algal biofilms abundant on submerged surfaces and play critical roles in aquatic food webs.                                                                                                                                                                                                                                                                                                                                       |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | None observed and unlikely to occur in these types of headwater streams.                                                                                                                                                                                                                                                                                                                                                          |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | No emergent reeds, rushes or sedges observed, but Tall Sedge ( <i>Carex appressa</i> ) may occur in other parts of the reach. If present, it will be very patchy.<br><br>Most critical fringing plants are water-dependent mosses and small ferns, such as Hard Water-fern ( <i>Blechnum wattsii</i> ) growing on exposed CWD and along lower banks.<br><br>Sedges are likely too sparsely distributed to be a significant value. |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Largely intact (if previously logged) EVC 30 Wet Forest and EVC 31 Cool Temperate Rainforest.<br><br>Recruitment is unlikely to be flow-dependent, but survival of adults probably requires wet subsoils and hyporheic zone linked to continuous base flows.                                                                                                                                                                      |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | None observed and unlikely to occur, given geomorphometry and position in the landscape.                                                                                                                                                                                                                                                                                                                                          |

### 3.5.3 Geomorphology

Arkins and First creeks are steep and bedrock confined waterways, with no observed depositional features such as floodplains, benches or bars. Sediment (e.g., silt, sand and gravel) is supplied from hillsides to the waterways and transported through the system, leaving behind rocks and boulders. Waterways have few physical features that could be surveyed and used for developing hydraulic-based flow recommendations.

### 3.5.4 Hydrology

The EFTP was provided with a single flow dataset representing inflow to the combined Arkins Creek and First Creek weirs. The flow data has been split for the three Reach 3a creek branches (Arkins Creek West, Arkins Creek East and First Creek) based on the relative areas of each sub-catchment. The shape of curves are therefore the same across each Reach 3a creek, differing by magnitude. It is important to note that modelled data are for inflow to the weirs, not outflow downstream of the weirs. Consequently, the data does not accurately reflect the impacts of development on flow. For this reason, the project team have elected to not present modelled current LOD data here. Data for a modelled unimpacted LOD is presented in Figure 15 – Figure 17.

Reach 3a creeks have a true high flow period from June to October and a true low flow period between January and April. May, November and December appear to be transition months (Figure 15a-c). Note that the shape of each curve and the outliers are consistent across each of the creeks, owing to the single dataset from which the flows were derived.

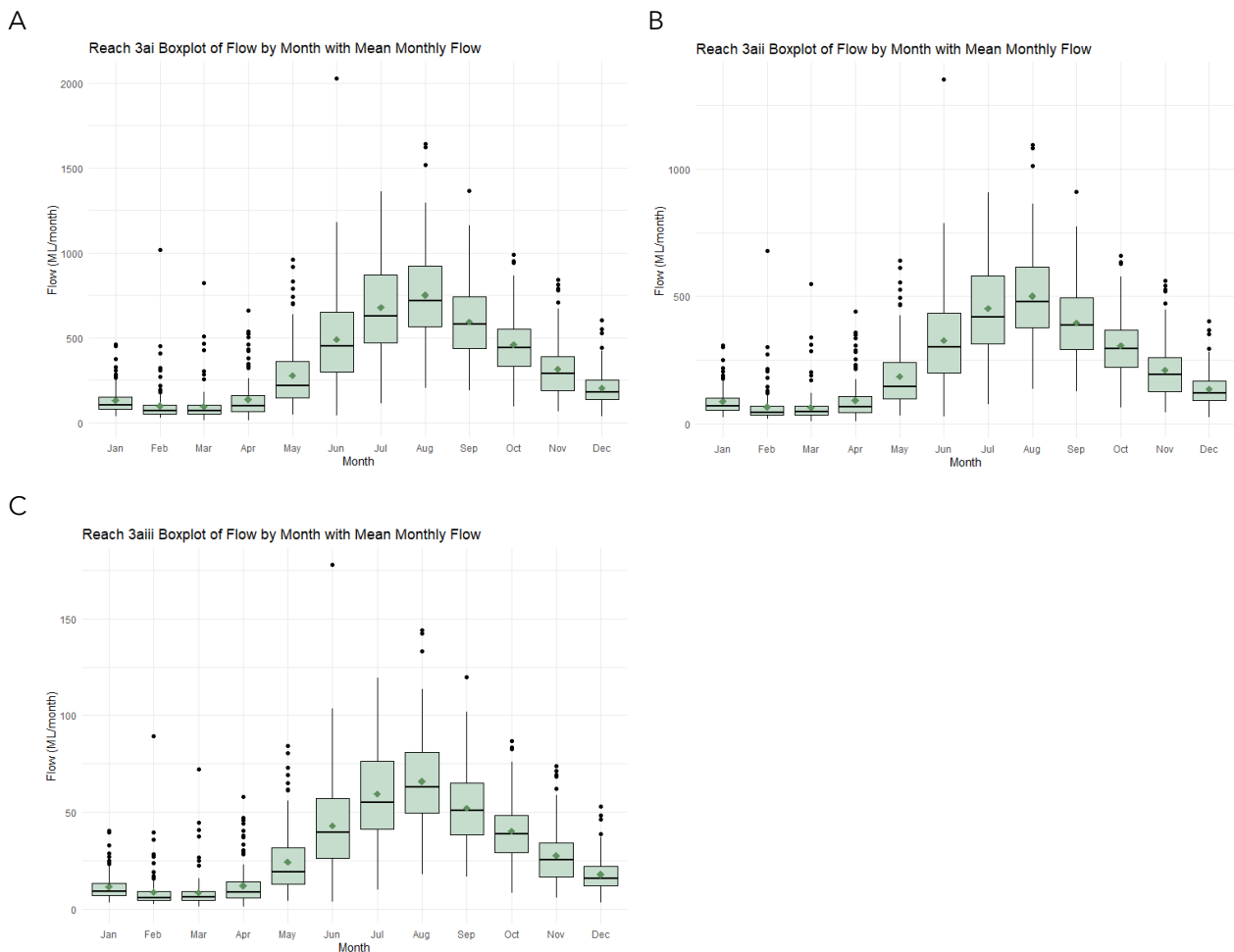


**Figure 15. Boxplots of monthly flows in (a) Arkins Creek West Branch, (b) Arkins Creek East Branch and (C) First Creek. Boxplots are based on modelled unimpacted level of development flows, historic climate. Green asterisk represents mean monthly flows.**

The modelled impact of climate change (2040 medium projection) on flows in the three creeks is presented in Figure 16. Climate change is predicted to impact median flows during all months, ranging from a 7% decrease in flows in November to a 21% decrease in flows in April.

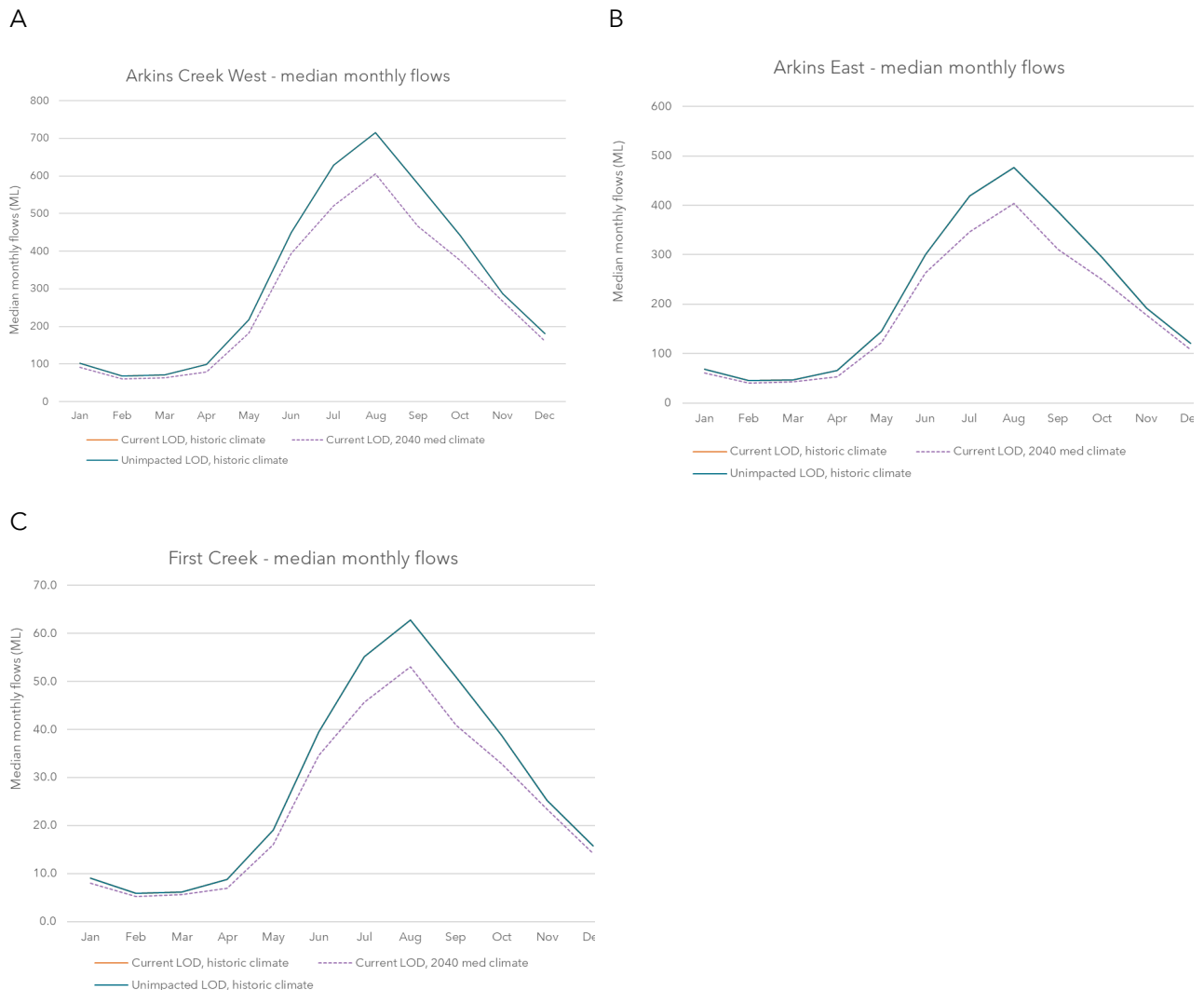


**Figure 16. Median monthly flows with a current LOD under a historic climate and 2040 medium climate scenario.**

Flow duration curves for modelled flow in Reach 3a creeks are provided in Figure 17. Note that current LOD and unimpacted LOD curves perfectly overlap as the model is calculated for inflow to the weirs, not outflow from the weirs. 80<sup>th</sup> and 20<sup>th</sup> exceedance percentile flow magnitudes are provided for each creek in Table 12.

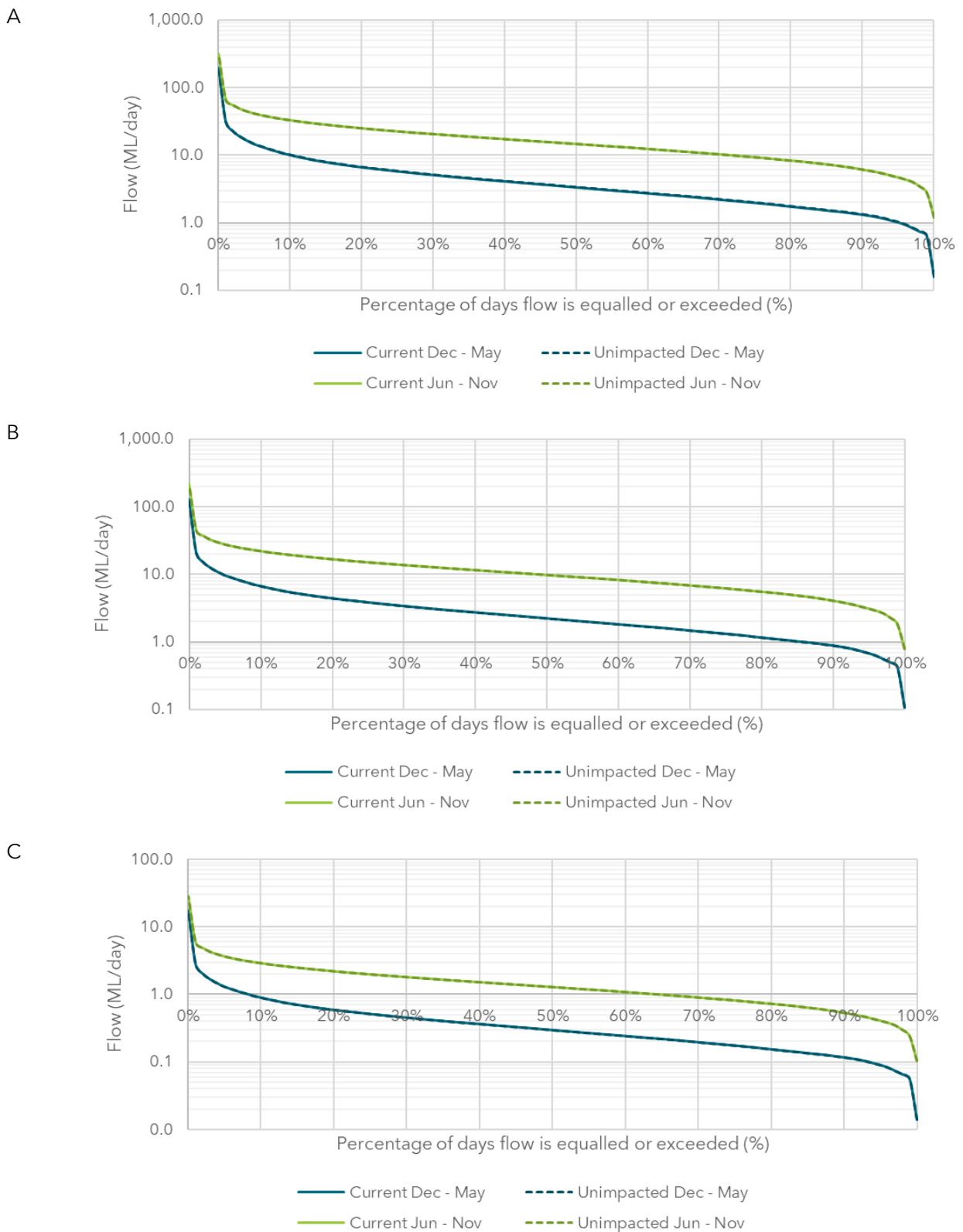


**Figure 17. Reach 3a flow duration curves for unimpacted (dashed lines) and current LOD (solid lines), for the periods of December - May (blue), and June - November (green). (A) Arkins Creek West Branch, (B) Arkins Creek East Branch and (C) First Creek.**

Table 12. Magnitudes of 80th and 20th exceedance percentile flows in Reach 3a creeks.

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) West Arkins | Unimpacted LOD (ML/day) East Arkins | Unimpacted LOD (ML/day) First Creek |
|-----------------------|-----------------|-------------------------------------|-------------------------------------|-------------------------------------|
| 80%                   | December – May  | 1.75                                | 1.16                                | 0.15                                |
|                       | June – November | 8.32                                | 5.55                                | 0.73                                |
| 20%                   | December – May  | 6.66                                | 4.44                                | 0.58                                |
|                       | June – November | 25.07                               | 16.7                                | 2.20                                |

Note: Current LOD and differences in flow magnitudes are not presented in the table, as the modelled data do not reflect flows downstream of weirs.

The Bulk Entitlement (Otway System) Conversion Order 1998 does not stipulate passing flows below any of the diversion weirs. While the modelled current LOD data do not reflect the impact of development, it is understood that all Reach 3a creeks cease to flow downstream of the weirs when the weirs are not overtopped by inflow (see Figure 18 for Arkins Creek West Weir and Figure 12 for First Creek weir).



Figure 18. (A) West Arkins Creek below weir (24/05/2024, R. Herben CCMA), (B) West Arkins Creek below weir (21/09/2021, R. Herben CCMA)

## Methodological approach for Stage 2 – determining environmental flow recommendations

The steep, bedrock-confined physical form of Arkins Creek West Branch, Arkins Creek East Branch and First Creek precludes the development of stable one-dimensional HEC-RAS hydraulic models, which are the standard tool used in the FLOWS method to relate flow rate to water depth and velocity at key habitat features. The confined channel form and absence of depositional instream features also limits the application of hydraulic criteria for higher magnitude flow components. Accordingly, the EFTP will apply a hydrological approach to the setting of low flow recommendations for all three Reach 3a creeks, using Source modelled unimpacted inflow to the weirs as the primary reference. This approach is a recognised

adaptation of the FLOWS method where site conditions preclude hydraulic modelling (DEPI 2013, Section 1.1), and the assumptions and limitations of this approach are documented in Appendix 4.

It is important to note that flow recommendations for Reach 3a will be set for inflow conditions at the weirs, not for downstream conditions. Under the current Bulk Entitlement (Otway System) Conversion Order 1998, there is no mechanism to require passing flows below the weirs. The primary purpose of Stage 2 flow recommendations for this reach is therefore to establish a technically defensible basis for any future amendment to the Bulk Entitlement to introduce passing flow obligations downstream of the weirs. Until such an amendment is in place, the ecological values downstream of the weirs – including wet microclimate maintenance, baseflow-dependent fauna, and longitudinal connectivity – cannot be protected through environmental flow delivery alone.

### 3.5.5 Groundwater connections

Arkins Creek and its tributaries flow over the Otway Group Aquifer (OGA). To our knowledge, little is known regarding the magnitude and spatial and temporal variability of groundwater – surface water interactions between the OGA and these tributaries. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data.

The BOM GDE Atlas shows high potential aquatic GDEs in Reach 3a, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.5.6 Water quality

Wannon Water has monitored a myriad of water quality parameters (primarily heavy metals, contaminants and *Escherichia coli*) in Arkins West, Arkins East and First Creeks since 2024. Water quality is typically very good, mean pH = 7.0, and turbidity is typically very low (mean 2.8 NTU), consistent with the location of these weirs in the upper forested catchment, protected from public access.

### 3.6 Reach 3b - Carlisle River

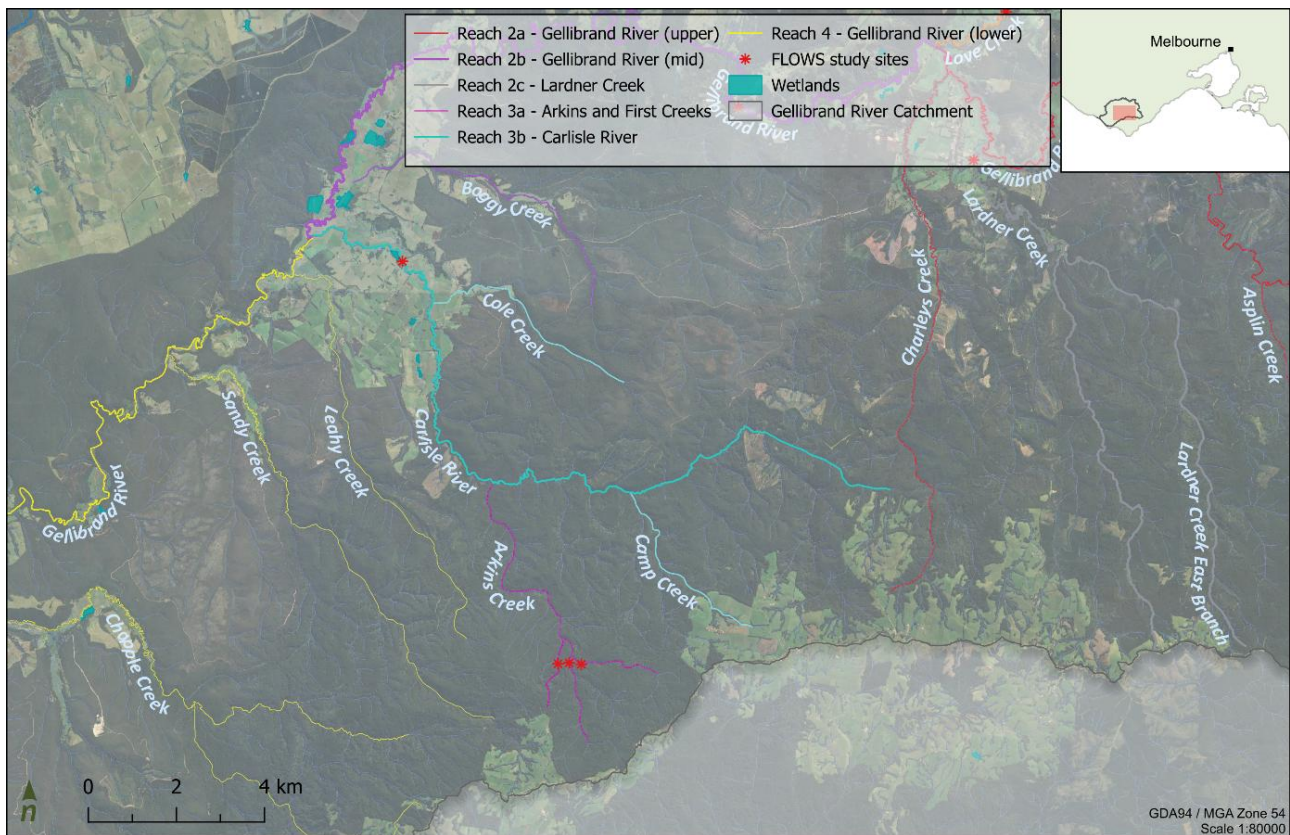


Figure 19. Site 3b (left) log jam downstream of cross section 2 (centre) exposed sand bed upstream of cross section 6 (right) looking downstream from cross section 10.

### 3.6.1 Aquatic fauna

The main fish species of significance in the Carlisle River are River blackfish and Australian grayling, along with Short-finned eel, Short headed lamprey, Spotted galaxias, Common galaxias and other small-bodied fish. Platypus have been recorded, and mussels were reported by the PAG.

Thirteen invertebrate taxa were identified as part of the Waterbug Blitz (<https://www.waterbugblitz.org.au/>) with a SIGNALT score of 4.2, indicating impacted conditions (CCMA 2024).

Reach 3b was observed on the site visit to contain copious large woody debris, with log jams and fast and slow flowing habitat niches (consistent with that reported by the PAG). The water was moderately turbid.

### 3.6.2 Vegetation

Reach 3b – Carlisle River is mostly cleared but has narrow strips of EVC 18 Riparian Forest (variously Vulnerable or Least Concern in Otway Plain bioregion) and EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex (BCS of Depleted) along the stream.

It is surrounded by cleared agricultural land in the lower sections and by dense forests in the upper sections, variously the terrestrial EVC 45 Shrubby Foothill Forest, EVC 48 Heathy Woodland and EVC 201 Shrubby Wet Forest.

**Table 13. Observations of vegetation at Site 3b**

|                                                                                                         |                                                                                                                                                                                                                             |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wet microclimate</b>                                                                                 | A wet microclimate is expected in the upper reach.                                                                                                                                                                          |
| <b>Algae</b><br>(Algal biofilms, Phytoplankton)                                                         | None observed but likely to be present on submerged surfaces.                                                                                                                                                               |
| <b>Floating plants</b><br>(Azolla, Duckweeds)                                                           | None observed.                                                                                                                                                                                                              |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | None observed but conditions may be suitable for Water Ribbons ( <i>Cyanogeton procerum</i> ) elsewhere in the reach.                                                                                                       |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Very few emergent reeds, rushes or sedges observed.<br>Very patchy distribution of water-dependent mosses and small ferns on exposed CWD and along lower banks.                                                             |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Very narrow band of EVC 18 Riparian Forest, mostly revegetated (only one or two trees wide) but unfenced.<br>Riparian zone is limited to canopy trees, with highly depauperate shrub-layer and ground-layer (highly weedy). |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | None observed.                                                                                                                                                                                                              |

### 3.6.3 Geomorphology

The Carlisle River channel had an incised stream appearance with a low (5:1) width depth ratio, bed approximately three metres below the floodplain and a 15-metre top width (5w:1d ratio). The cross section had limited instream features and no active depositional benches. No bedrock was evident in the bed or banks.

Erosion and bank slumping were observed as prevalent on the site visit (October 2025), with bank slumps taking revegetated overstorey plants into the stream. Revegetated banks are being undercut by erosion, and the creek width may increase as a result of slumping and undercutting.

### 3.6.4 Hydrology

Reach 3b – Carlisle River has a true high flow period from June to October and a true low flow period from December to April (Figure 20a). May and November serve as transition months between high and low flow periods.

In Reach 3b, the median monthly flows for the historical climate are more significantly impacted by development during the true low flow months (ranging from a 27% to 36% decrease in flows with development) compared to true high flow months (ranging from a 5% to 11% decrease in flows with development) (Figure 20b). It is presumed that the impacts of development are due to extractions from Arkins and First Creek weirs.

The plot also provides an indication of the projected impacts of the 2040 medium climate scenario on median monthly flows for the current LOD (Figure 20b). Under the 2040 medium climate scenario, median monthly flow decreases are projected to range from 8% in January to 26% in November (Figure 20b).

Flow duration curves for December – May and June – November periods are presented in Figure 20c. During December – May, the impact of development is greater on lower magnitude flows than higher magnitude flows, with a 38% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows and 28% decrease in the magnitude of 20<sup>th</sup> exceedance percentile flows (Figure 20c, Table 14). During June – November, development is modelled to have a more pronounced impact on lower magnitude flows (23% decrease in 80<sup>th</sup> exceedance percentile flows) than higher magnitude flows (5% decrease in 20<sup>th</sup> exceedance percentile flows) (Figure 20c, Table 14).

**Table 14. Impacts of development on the magnitudes of 80th and 20th exceedance percentile flows in Reach 3b**

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December – May  | 8.5                     | 5.2                  | -38%                                          |
|                       | June – November | 55.4                    | 42.5                 | -23%                                          |
| 20%                   | December – May  | 37.7                    | 27.3                 | -28%                                          |
|                       | June – November | 236.4                   | 224.2                | -5%                                           |

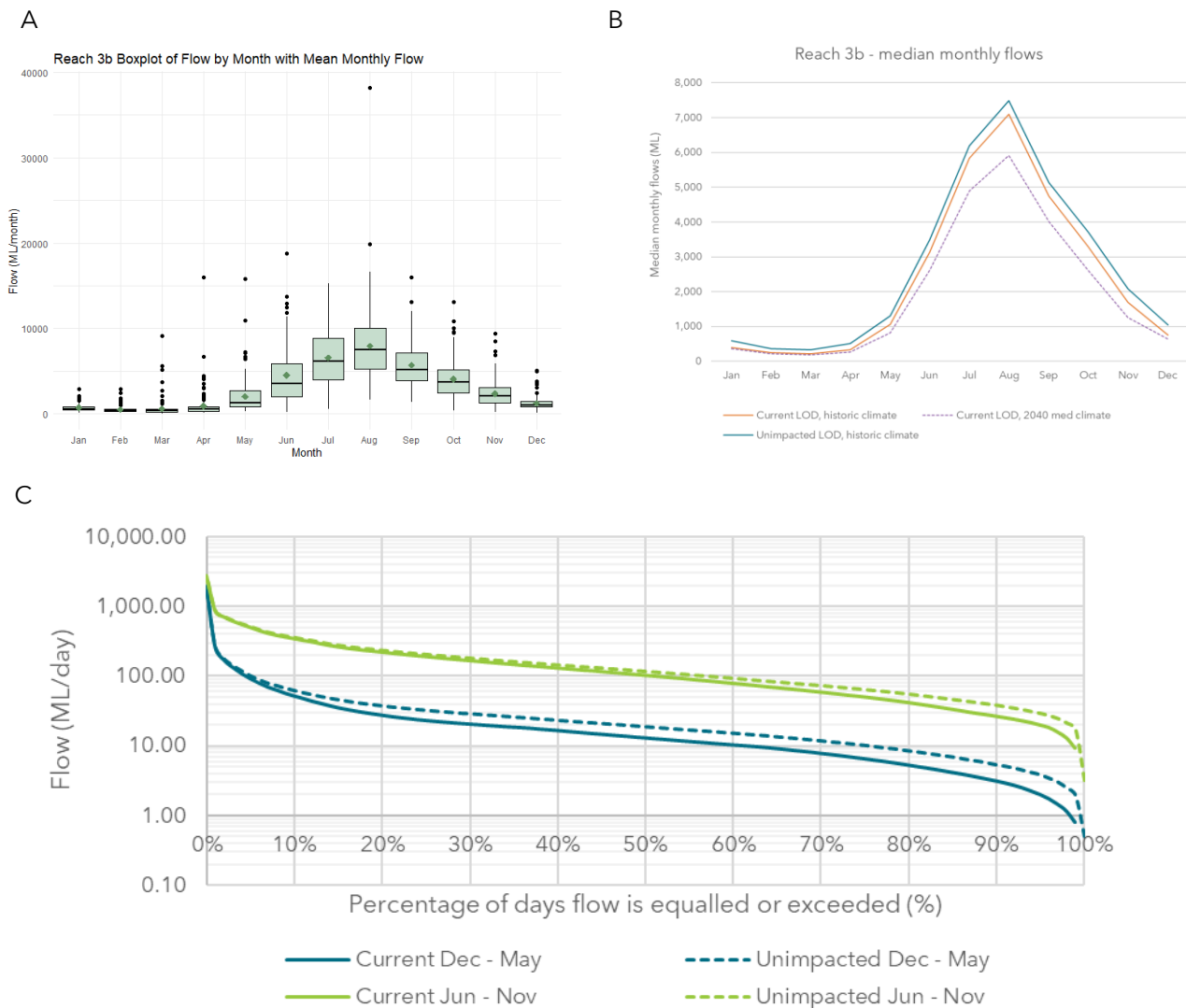


Figure 20. Hydrologic analysis Reach 3b - Carlisle River - Source modelled hydrologic data

### Gauge status and implications for Stage 2 - determining environmental flow recommendations

Flow data from the Carlisle River gauge (235200C) was not publicly available at the time of the EFTP site assessment and survey. Data has been requested from Southern Rural Water and is expected to be available for use in Stage 2 hydraulic model development and calibration. The availability of this data will be confirmed in the Stage 2 hydraulic modelling report.

### 3.6.5 Groundwater connections

The upper portions of Carlisle River flow over the Otway Group Aquifer (OGA). The lower portions of the Carlisle River flow over Quaternary Sediments that are underlain by the LTA. Little is known regarding the magnitude and spatial and temporal variability of groundwater - surface water interactions along Carlisle River. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data.

The BOM GDE Atlas shows high and moderate potential aquatic GDEs in Reach 3b, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.6.6 Water quality

Water quality monitoring has been undertaken at Carlisle River by the WaterWatch program (CO\_CRL080). Water quality was moderate to good at most times with low salinity, turbidity, reactive phosphorus and median neutral pH. Low oxygen concentrations have been observed at times of low river flows (2013 and 2016). Increases in river flows are associated with improved oxygen saturation; however, turbidity and reactive phosphate levels also increase with flows (CCMA 2020). According to a citizen science summary report (CCMA 2024), long-term WaterWatch data indicated excellent electrical conductivity, pH and reactive phosphorus levels in Carlisle River, with good turbidity.

## 3.7 Reach 4 - Gellibrand River (lower)

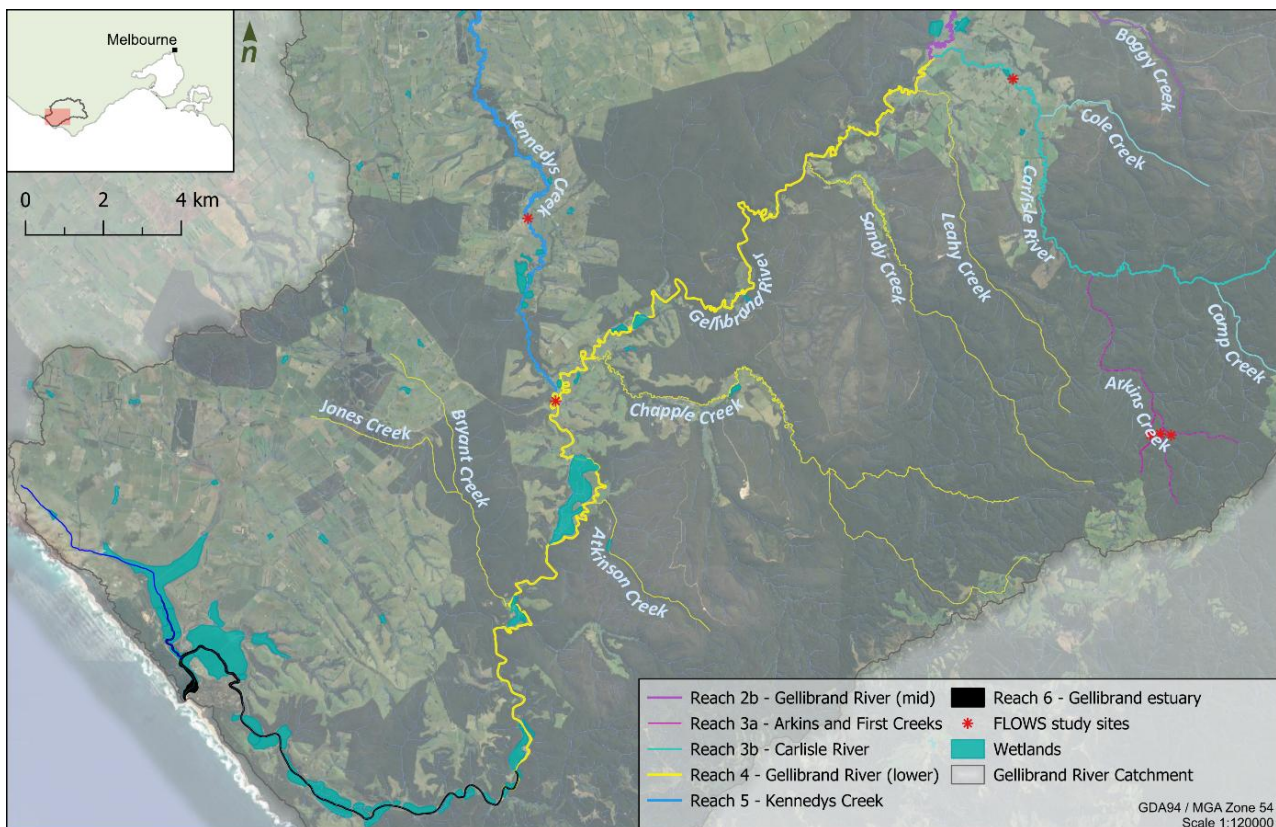




Figure 21. Site 4 (left) looking downstream from cross section 9 (centre) Platypus pool looking upstream from cross section 6B (right) looking upstream from cross section 8

3.7.1 Aquatic fauna

Significant fish species present in Reach 4 include River blackfish and Australian grayling, while other species include Short-finned eel, Short headed lamprey, Spotted galaxias, Common Galaxias and other small-bodied fish.

Freshwater crayfish and Platypus have been identified (Earth Tech 2006b). Platypus were sighted by the PAG and the EFTP during the site visit in October 2025.

Macroinvertebrates were identified by Becker and Robson (2010) at four sites in Carlisle River (site specific richness and taxonomic details were not included in the paper), but surveys using National Waterbug blitz method <https://www.waterbugblitz.org.au/>) have not been reported for the reach.

During the site visit (October 2025), the Gellibrand River was highly turbid (chocolate brown in colour). Sandy benches and large woody debris were observed. A flood runner wetland runs alongside the right bank on both sides of the bridge at Site 2b. Frogs were heard calling from the wetland.

3.7.2 Vegetation

Reach 4 consists of EVC 18 Riparian Forest (BCS variously Vulnerable or Least Concern in Otway Plain bioregion), surrounded by a range of terrestrial forest EVCs. Site 4 is largely cleared and used for cattle grazing. The site has a discontinuous riparian overstorey, typically eucalypts.

Table 15. Observations of vegetation at Site 4

|                                                 |                                                                                                                                                                  |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Algae</b><br>(Algal biofilms, Phytoplankton) | Supports algal biofilms on submerged surfaces and instream vegetation, including diatoms. (visible in March 2025, but limited by high turbidity in October 2025) |
| <b>Floating plants</b>                          | None observed.                                                                                                                                                   |

|                                                                                                         |                                                                                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Azolla, Duckweeds)                                                                                     |                                                                                                                                                                                                    |
| <b>Submerged and floating-leafed plants</b><br>(Pondweeds, Water Ribbons, Eelweed)                      | None observed (noting the water was exceptionally turbid).<br><br>Floating-leafed plants such as Water Ribbons ( <i>Cycnogeton procerum</i> ) may be present in other parts of the reach.          |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Common Reed ( <i>Phragmites australis</i> ) abundant alongside and in channel.<br><br>Occasional unidentified rushes ( <i>Juncus</i> spp.) on benches and in riparian zone.                        |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Almost non-existent except for isolated Manna Gum ( <i>Eucalyptus viminalis</i> ) along banks.<br><br>Highly weedy and unfenced; topography clearly adversely affected by cattle access to stream. |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | Large wetland depression alongside right-hand bank.                                                                                                                                                |

### 3.7.3 Geomorphology

Reach 4 is defined as an alluvial, unconfined, meandering and single channel, continuous stream system. The site has in-channel depositional bars and benches, with benches comprised of silts and sands.

During the site visit (October 2025), the Gellibrand River was highly turbid and chocolate brown in colour. Sandy benches and large woody debris were observed, and a flood runner wetland runs alongside the right bank on both upstream and downstream of the bridge at Site 2b.

The site is unfenced, with stock directly accessing both banks of the river. Pugging and erosion were evident.

### 3.7.4 Hydrology

Reach 4 – Gellibrand River (lower) at the South Otway pump station demonstrates standard flow seasonality patterns of the broader Gellibrand catchment, with a true high flow winter period from June to October and a true low flow period from December to April (Figure 22a). May and November serve as flow transition months (Figure 22a).

For Reach 4, the median monthly flows for the historical climate are more significantly impacted by development during the true low flow months (ranging from a 25% to 34% decrease) compared to true high flow months (ranging from a <2% to 7% decrease) (Figure 22b). May and November experience 17% and 11% decreases in monthly flow with development, respectively.

Figure 22b also provides an indication of the projected impacts of the 2040 medium climate scenario on median monthly flows for the current LOD. Under the 2040 medium climate scenario, median monthly flow decreases in the low flow period are projected to range from 13% in December to 25% in April. Median monthly flows are projected to decrease throughout the low flow period too, ranging from a 19% decrease in July to a 22% decrease in October. May and November are modelled to experience decreases of 23% and 14% in median monthly flows, respectively, in a 2040 climate scenario.

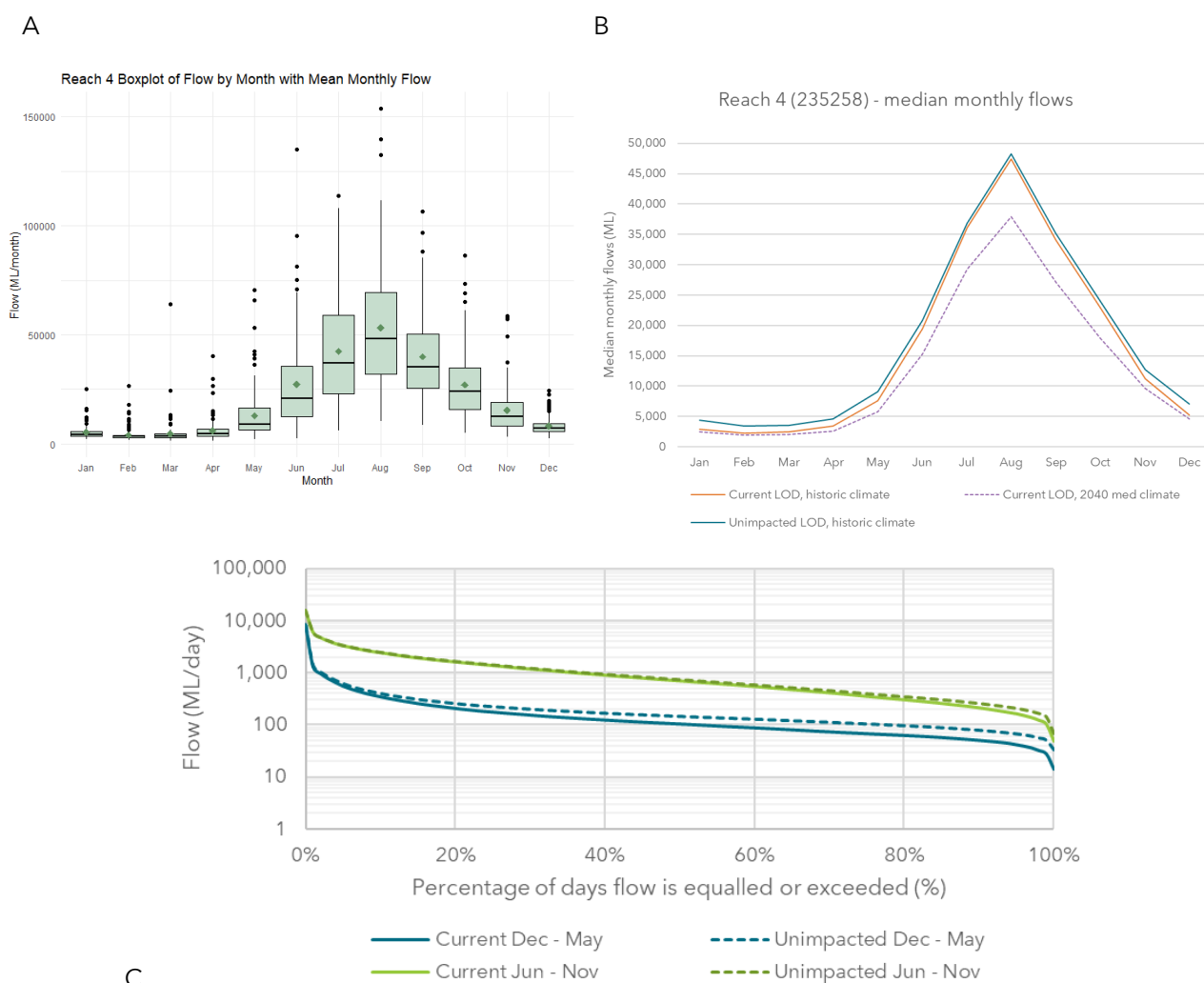


**Figure 22. Hydrologic analysis Reach 4 - Gellibrand River (lower) - Source modelled hydrologic data**

The impacts of development are more pronounced during low flow months than high flow months (Figure 22b, c and Table 16), with the unimpacted and current LOD monthly median flow curves separating during low flow months and flow duration curves separating as exceedance percentiles increase. Development is modelled to cause a 36% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows during the December - May period and a 20% decrease in 20<sup>th</sup> exceedance percentile flows during the same period (Table 16). A 2% decrease in 20<sup>th</sup> percentile flows is observed during June - November (Table 16).

**Table 16. Impacts of development on the magnitudes of 80th and 20th exceedance percentile flows in Reach 4**

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow (%) |
|-----------------------|-----------------|-------------------------|----------------------|--------------------|
| 80%                   | December - May  | 96.7                    | 62.0                 | -36%               |
|                       | June - November | 344.6                   | 299.5                | -13%               |
| 20%                   | December - May  | 258.0                   | 205.9                | -20%               |
|                       | June - November | 1543.8                  | 1606.1               | -2%                |

## Gauge status and implications for Stage 2 – determining environmental flow recommendations

South Otway Pump Station gauge 235258 is located at Site 4. Under current rating table maintenance arrangements, reliable flow records at this gauge is limited to approximately 93.5 ML/day – below the flow magnitudes relevant to freshes and high flow components at this reach. Survey flow data collected during the October 2025 site assessment has been provided to DEECA, and ALS are undertaking flow measurements at higher water levels to support future rating table updates. The implications of these rating limitations for hydraulic model calibration and compliance assessment at Reach 4 will be documented in the Stage 2 hydraulic modelling report, consistent with the FLOWS method uncertainty reporting requirements (DEPI 2013, Appendix B).

### 3.7.5 Groundwater connections

The Quaternary Sediments within Reach 4 are underlain by the LTA. Our understanding regarding the specific groundwater – surface water interactions within Reach 4 primarily are localised to the area around Wannon Water’s Carlisle River bores – that is understood to access around 10% of its total volume from the Gellibrand River (GHD, 2014). While little is known regarding the magnitude and spatial and temporal variability of groundwater – surface water interactions below this, groundwater contribution estimates from the Gellibrand River at Carlisle stream gauge (WMIS site 235208) indicate that total groundwater contributions to this site can be in the order of 20-30% during low flow months. More broadly, previous assessments indicate that the Gellibrand River is a predominantly gaining stream (i.e. receives groundwater inputs from the surrounding systems) between Bunkers Hill and Burrupa (GHD, 2013). However, declines in the baseflow index at the Gellibrand River at Carlisle streamgauge (WMIS site 235208) and Burrupa streamgauge (WMIS site 235224) during summer – autumn indicate that intermediate flow processes (such as interflow and bank storage returns) form a significant component of the total groundwater contributions (GHD, 2013).

The impacts of groundwater pumping activities at the Carlisle River bores to the Gellibrand River have been incorporated in the Source model and routed through downstream reaches (HARC 2025). Other groundwater contributions to streamflow are captured/embedded in the streamflow data.

The BOM GDE Atlas shows high potential aquatic GDEs in the Gellibrand River in Reach 4 and high and moderate potential GDEs in Reach 4 tributaries, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.7.6 Water quality

Water quality monitoring was undertaken by WaterWatch from 2012 – 2017 at site CO\_GEL011 at the pumping station bridge (North Otway pump station). Salinity, turbidity, reactive phosphate and pH were generally good, with increasing electrical conductivity and decreasing oxygen saturations during low flows and turbidity and reactive phosphate levels increase with higher flows (CCMA 2020). The water in Reach 4 during the October 2025 site visit was highly turbid.

Water quality monitoring by the WaterWatch program was undertaken at Burrupa from 2013 – 2019. Trends at Burrupa were similar to those at site CO\_GEL011.

Continuous monitoring of water quality parameters (salinity, turbidity, dissolved oxygen and chlorophyll- $\alpha$ ) occurs at the Burrupa streamflow gauge 235224 (Appendix 5). The continuous data generally concur

with the WaterWatch data, where turbidity and chlorophyll-a levels are positively correlated with streamflow, and lower dissolved oxygen concentrations coincide with low flow.

Historical spot water quality data is available for the Gellibrand River at Carlisle River (235208, 1976 - 1990). Spot water quality has been monitored at the Burrupa gauge (235224) since 1990. Key Spot parameters are as follows: dissolved oxygen concentrations (mean 8.9 mg/l, min 5.7 ml/L), salinity (mean 281  $\mu\text{S}/\text{cm}$ , with a max 1500  $\mu\text{S}/\text{cm}$  in September 2000), neutral pH (mean 7.0, min 5.7, max 8.5) and turbidity (mean 18 NTU, max 108 NTU). It is noted that spot measurements may miss peak events and significant short-term water quality issues.

### 3.8 Reach 5 - Kennedys Creek

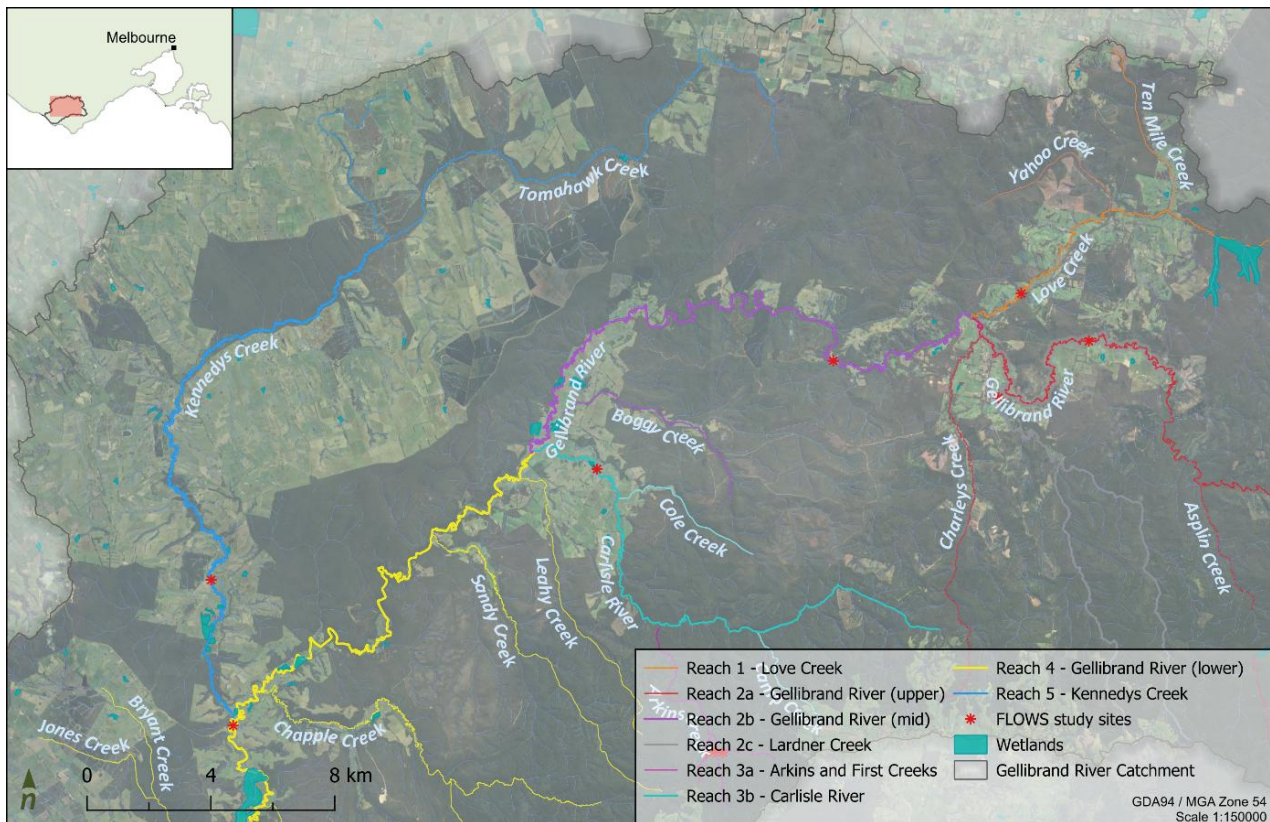




Figure 23. Site 5 (left) Water ribbons in fast flowing section (centre) billabong depression (right) flow through dense Phragmites

### 3.8.1 Aquatic fauna

Reach 5 supports fewer native species than other reaches of the Gellibrand catchment and it is noted that the sub-catchment is largely cleared, with little riparian vegetation. There are no known fish barriers to prevent species from accessing the reach, and preliminary site inspections to assess the habitat values of the reach suggest there was suitable habitat to support a wide range of species.

Platypus and Spiny crayfish have been recorded in the reach. Macroinvertebrates are presumed present, but surveys using National Waterbug blitz method (<https://www.waterbugblitz.org.au/>) have not been reported for the reach.

The PAG noted instream wood and flow diversity (fast and slow flowing habitat niches) in Kennedy's Creek.

### 3.8.2 Vegetation

Much of the broader Kennedy's Creek catchment is cleared for agricultural use. Reach 5 is located in EVC 18 Riparian Forest (Vulnerable in Warrnambool Plain bioregion), surrounded by terrestrial EVC 23 Herb-rich Foothill Forest. Site 5 is surrounded by cleared land used for agricultural purposes.

Table 17. Observations of vegetation at Site 5

|                                                 |                                                                                                                                                                                                  |
|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Algae</b><br>(Algal biofilms, Phytoplankton) | Algal biofilms on submerged surfaces were observed in the preliminary site visit in March 2025. Algal biofilms were not observed in October 2025 (visibility was strongly limited by turbidity). |
| <b>Floating plants</b><br>(Azolla, Duckweeds)   | None observed.                                                                                                                                                                                   |
| <b>Submerged and floating-leafed plants</b>     | Almost none observed, except for occasional Water Ribbons ( <i>Cycnogeton procerum</i> ).                                                                                                        |

|                                                                                                         |                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (Pondweeds, Water Ribbons, Eelweed)                                                                     | <i>Vallisneria</i> spp., was observed in March during the preliminary site visit.                                                                                      |
| <b>Fringing emergent macrophytes</b><br>(flow-dependent ferns, Knot-weeds, Reeds, Rushes, Sedges)       | Common Reed ( <i>Phragmites australis</i> ) abundant alongside and in channel.                                                                                         |
| <b>Riparian zone</b><br>(Canopy-layer trees, Shrub-layer plants, Ground cover herbs, forbs and grasses) | Highly variable across different parts of the reach. Some parts have no functioning native riparian zone; others have a narrow zone, albeit highly weedy and unfenced. |
| <b>Wetlands</b><br>(Anabranches, Billabongs)                                                            | Small wetland depression alongside left-hand bank.<br><br>Topography and landscape position suggest there may be other examples elsewhere along the reach.             |

### 3.8.3 Geomorphology

Defined as an unconfined, alluvial and single channel, continuous stream with a pool riffle stream bed profile and instream timber. A billabong depression is present at Site 5.

Downstream of the Kennedys Creek Road bridge, the channel is trapezoidal shaped with a sandy bottom.

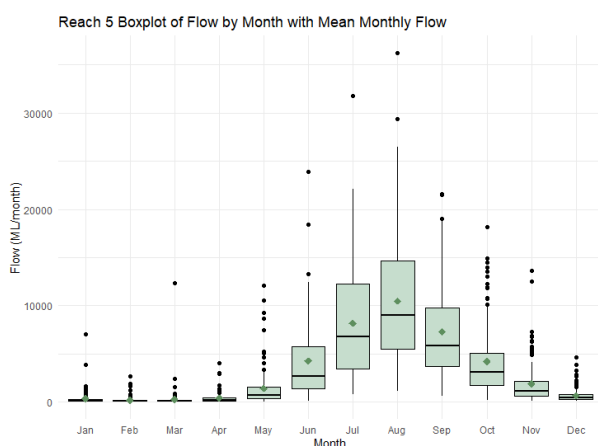
### 3.8.4 Hydrology

Reach 5 – Kennedys Creek demonstrates typical flow seasonality patterns with a high flow period from June to October, a low flow period from December to April and with May and November serving as flow transition months (Figure 24a).

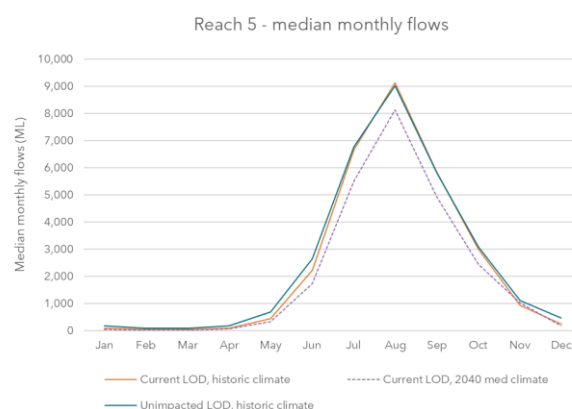
For Reach 5, the median monthly flows for the historical climate are substantially impacted by development during the true high flow months (ranging from a 46% to 55% decrease, Figure 24b). Minor impacts of development are modelled during true low flow months (July – October), a minor increase in monthly flows projected with development in August and September (1.3%, and 0.2%, respectively).

Figure 24b provides an indication of the projected impacts of the 2040 medium climate scenario on median monthly flows for the current LOD. Under the 2040 medium climate scenario, median monthly flow decreases in low flow months are projected to range from 27% in December to 37% in March. Median monthly flows are also projected to decrease throughout the high flow ranging from an 11% decrease in August to a 23% decrease in June. November is projected to have a 9% increase in median monthly flows under a 2040 climate (Figure 24b).

A



B



C

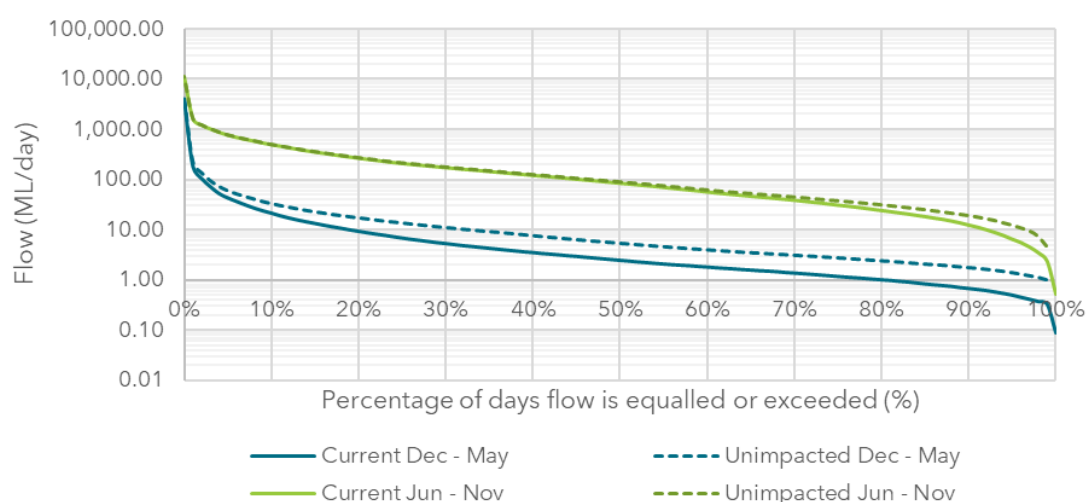


**Figure 24. Hydrologic analysis Reach 5 - Kennedys Creek - Source modelled hydrologic data**

Development is modelled to have significant impacts on flow during December to May. Clear separation of flow duration curves is observed (Figure 24c), with a 57% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows and a 44% decrease in the magnitude of 20<sup>th</sup> exceedance percentile flows during this period (Table 18). Substantial impacts of development are modelled for low flows during June - November, with minor impacts on higher magnitude flows (Table 18, Figure 24c).

**Table 18. Impacts of development on the magnitudes of 80<sup>th</sup> and 20<sup>th</sup> exceedance percentile flows in Reach 5**

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December - May  | 2.4                     | 1.0                  | -57%                                          |
|                       | June - November | 30.8                    | 23.9                 | -22%                                          |
| 20%                   | December - May  | 17.1                    | 9.5                  | -44%                                          |

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
|                       | June - November | 267.7                   | 263.0                | -2%                                           |

### 3.8.5 Groundwater connections

The Quaternary Sediments within Reach 5 are underlain by both the LTA and LMTA. To our knowledge, little is known regarding the magnitude and spatial and temporal variability of groundwater – surface water interactions in this Reach. In this case, any groundwater contribution to streamflow is captured/embedded in the streamflow data.

The BOM GDE Atlas shows high potential aquatic GDEs in Kennedys Creek, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.8.6 Water Quality

During the October 2025 site visit, water in Kennedy's Creek was highly turbid and chocolate brown in colour. A neighbouring landowner noted that during drier times, the creek is reduced to barely a trickle and is spring fed with clear water. The locations of freshwater springs in Kennedys Creek and other reaches are unknown.

Electrical conductivity is continuously monitored at the Kennedys Creek streamflow gauge 235211 (Appendix 5). Monthly spot water quality data has been recorded at gauge 235211 since January 1990. Spot water quality is variable for pH (mean 7.0, min 5.4, max 8), dissolved oxygen (mean 7.2 mg/L, min 0.8 mg/L, max 11.8 mg/L), salinity (mean 694  $\mu$ S/cm, min 0.8  $\mu$ S/cm, max 8040  $\mu$ S/cm) and turbidity (mean 2.3 NTU, min 3.2 NTU, max 143 NTU). While mean WQ parameters may be moderate, some spot measurements suggest that water quality in Kennedys Creek can, at times, be unsuitable for aquatic fauna (DO < 3 mg/L in 22 months out of 431 months). Salinity levels in Kennedys Creek are higher than those in other study reaches. Spot data may miss peak and extreme WQ events.

## 3.9 Gellibrand estuary

The EFTP consider the estuary to be the 'jewel in the crown' of the Gellibrand catchment and note the importance of the estuary in the context of the catchment, for the ecosystems and values it supports and as receiving waters for Gellibrand freshwater flows. The Gellibrand estuary is captured by the Reach 4 map in Section 3.7.

**Please note** that as the estuary flow recommendations will not generally be updated as part of the present FLOWS study, the EFTP did not undertake an additional site visit in October 2025. Consequently, descriptions of aquatic fauna, vegetation and geomorphology have been carried forward from the Site Paper (Alluvium 2025). New Gellibrand estuary low flow objectives were developed in a workshop on 17 November 2025, and described in Section 7.1. Other flow objectives from the EEFAM study (Lloyd et al 2008) will be carried forward into this FLOWS study (see Section 7.2).

### 3.9.1 Aquatic fauna

Macroinvertebrate community composition of the wetlands varied between wetlands and over time (Robson et al., 2002). A whole-of-estuary bird survey in 2010 identified 1406 individuals from 48 species and nine functional groups (Hansen 2010). Nineteen fish species are listed on the Victorian Biodiversity Atlas as from the Gellibrand estuary (Appendix 1). Australian Grayling was not identified in the Victorian Biodiversity Atlas search for the estuary but is likely to utilise the estuary with the location of the spawning location unknown.

Sherwood (2006) suggested 29 species of fish are likely to occur in the Gellibrand River estuary at some stage in their lifecycle. The high number of native fish species that occur in the Gellibrand places it among Victoria's more important rivers for the conservation of native fish. Yelloweye mullet and Black bream numbers dominate estuarine recreational fish populations (Sherwood 2006). Other fish species include Pouched lamprey, as well as Common galaxias, Smelt, Gudgeon, Estuary perch, Short-finned eel, Tupong, Estuary perch and Mulloway.

Platypus have also been identified as being present in the estuarine reach of the Gellibrand River and are known to inhabit estuaries from other waterways such as the Hopkins River (D. Iervasi personal observations). The estuarine reaches of waterways are likely to be feeding and foraging habitat for Platypus.

### 3.9.2 Vegetation

The Gellibrand estuary is one of 25 estuaries in western and central Victoria that supports an assemblage of species associated with open-coast salt-wedge estuaries and listed as a threatened ecological community under the *EPBC Act 1999* (Endangered category, DCCEEW 2018). The estuary is fringed by Nationally Important Wetlands (Prinetown Wetlands), which provide habitat for EPBC-listed migratory birds and aquatic fauna.

The vegetation of the estuary is diverse and spatially complex, with Australian Ecosystems (2010) recording 16 wetland EVCs during their survey of estuaries of the broader Corangamite region. The largest single vegetation type present in the Gellibrand estuary at the time was EVC 10 Estuarine Wetland, with 103 ha. Sea Rush, *Juncus kraussii*, is the dominant species in this EVC. Two vegetation types

dominated by Common Reed, *Phragmites australis*, were the next-most extensive: in the fresher areas, EVC 821 Tall Marsh (105 ha) and in the more saline areas, EVC 952 Estuarine Reedbed (64 ha). Other extensive vegetation types included the *Carex*-dominated Wet Verge Sedgeland (41 ha), the *Melaleuca*-dominated Swamp Scrub (31 ha), EVC 308 Aquatic Sedgeland (20 ha), a community dominated by robust sedges, and EVC 937 Swampy Woodland (12 ha), a community dominated by *Acacia* and *Eucalyptus* trees and shrubs. Note that none of the seven different types of coastal saltmarsh was recorded at the estuary (see Australian Ecosystems 2010, Table 3); similarly, Boon et al. (2015) did not report the presence of coastal saltmarsh at the site and the most recent vegetation mapping available on the NatureKit website (viewed 25 May 2026) does not indicate the presence of coastal saltmarsh anywhere in the estuary. In total, 409 ha of native estuarine vegetation was recorded by Australian Ecosystems (2010). Vegetation condition varied from high-quality, with a number of significant vegetation areas, to highly degraded, the latter often associated with grazing land. Seagrasses were not explicitly recorded, but this may have been a function of the scope of the investigation. Table 19 summarises the extent of various EVCs in the estuary as reported in Australian Ecosystems (2010).

**Table 19. Area and condition of EVCs in Gellibrand estuary (Taken from Australian Ecosystems, 2010)**

| <b>EVC</b>                             | <b>Area</b> | <b>Site score<br/>(condition)</b> |
|----------------------------------------|-------------|-----------------------------------|
| Tall Marsh                             | 105         | 45                                |
| Estuarine Wetland                      | 103         | 58                                |
| Estuarine Reedbed                      | 64          | 68                                |
| Wet Verge Sedgeland                    | 41          | 63                                |
| Swamp Scrub                            | 31          | 55                                |
| Aquatic Sedgeland                      | 20          | 71                                |
| Brackish Grassland                     | 18          | N/A                               |
| Swampy Woodland                        | 12          | 50                                |
| Estuarine Flats Grassland              | 6           | 30                                |
| Brackish Wetland (aggregate)           | 3           | 59                                |
| Estuarine Scrub                        | 3           | 51                                |
| Gahnia Sedgeland / Swamp Scrub Complex | 2           | N/A                               |
| Coastal Dune Scrub                     | 1           | 20                                |
| Coastal Dune Grassland                 | <1          | 37                                |
| Aquatic Herbland                       | <1          | 41                                |
| Coastal Headland Scrub                 | <1          | N/A                               |
| Fern Swamp                             | <1          | N/A                               |

Figure 25 shows the extant EVCs of the Gellibrand River in 2009. Estuarine Wetland (EVC 10) is common, especially in the most seaward areas of the estuary. Estuarine Reedbed (EVC 952) and Tall Marsh (EVC 821) are also common in the lower estuary. Patches of Wet Verge Sedgeland (EVC 932) are located in the central to upper estuary, while Aquatic Sedgeland (EVC 932) abuts Tall Marsh (EVC821) in the lower

estuary, and Swamp Scrub (EVC 53) adjoins Aquatic Sedgeland in the lower estuary. Descriptions of these EVCs from Australian Ecosystems 2010 are provided below.

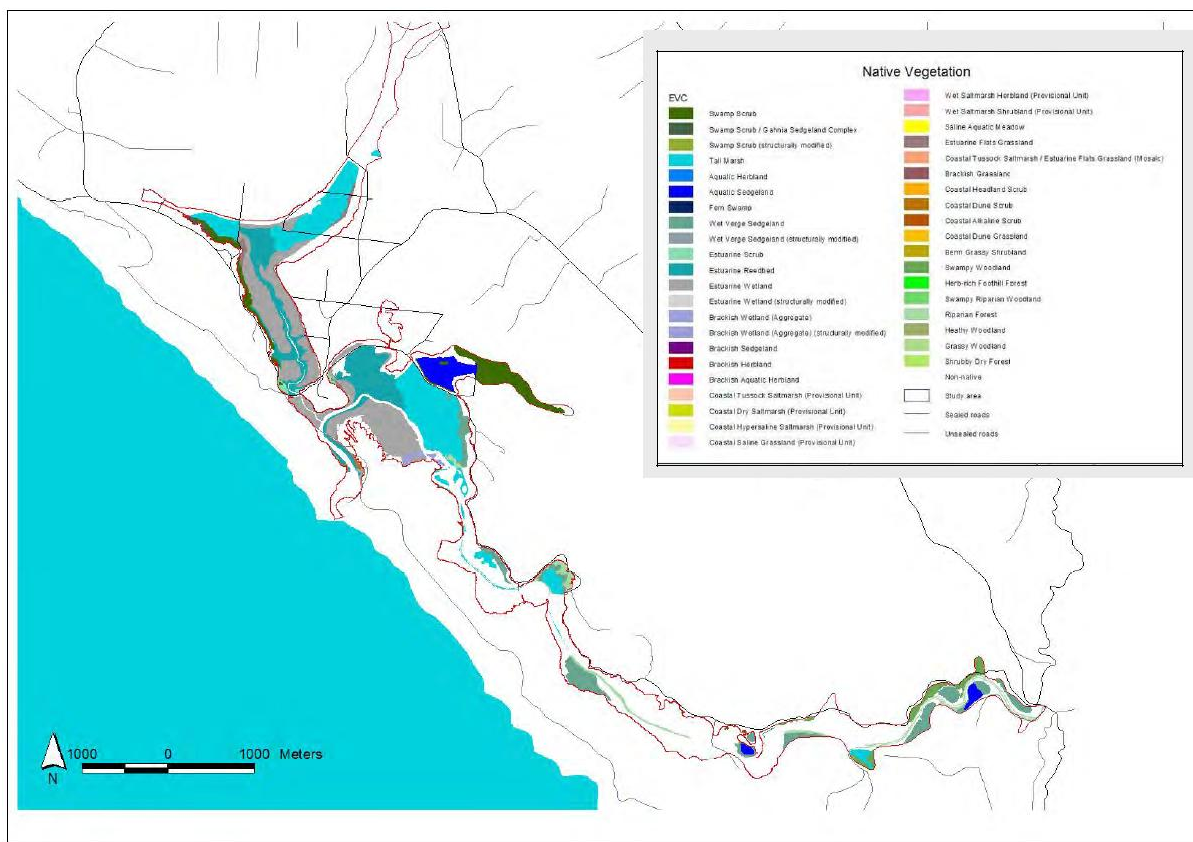


**Figure 25. Extant ecological vegetation classes of the Gellibrand estuary (Australian Ecosystems 2010, noting that the in-figure legend includes several EVCs that are not present in the Gellibrand estuary)**

It is important to note that the field work for the Australian Ecosystems' investigation was undertaken in 2009. Estuarine vegetation is widely acknowledged as being spatially complex and highly dynamic (e.g. Australian Ecosystems 2010, p. 7), and it is possible that the type and distribution of vegetation types supported by the estuary has changed over the intervening 15+ years.

The site visit undertaken in March 2025 was very brief and on-ground inspections were limited to a small part of the most seaward section of the estuary. Observations from this inspection are broadly consistent with the earlier descriptions of the vegetation being dominated by EVC10 Estuarine Wetland and vegetation types dominated by Common Reed, including EVC 952 Estuarine Reedbed and EVC 821 Tall Marsh (Figure 26). A vegetation type that corresponds to EVC 914 Estuarine Flats Grassland may also be present near the part of the estuary visited during the site inspection. Descriptions of these vegetation types, as well as some of the more common ones recorded by Australian Ecosystems (2010), are provided below.



Figure 26. Vegetation of the floodplain of the lower Gellibrand estuary. Photograph taken by PI Boon March 2025.

**Estuarine Wetland (EVC 10).** The dominant plant in EVC10 is Sea Rush, *Juncus kraussii*. Sea Rush has a high salinity tolerance and a medium-high water-logging tolerance (Sainty et al. 2012), but like most estuarine plants, it requires low-salinity conditions for seed to germinate and young plants to establish (Greenwood & MacFarlane 2006). Typically, Sea Rush is found at the fringes of estuarine wetlands (Frood & Papas 2016), often on slightly raised ground, where freshwater flows augment otherwise saline environments (e.g. see the estuarine mapping of Sinclair & Sutter 2008).

**Estuarine Reedbed (EVC 952).** The dominant plant in EVC 952 in the Gellibrand estuary is Common Reed, *Phragmites australis*. Other tall, rhizomatous taxa that may occur in EVC 952 include Sea Rush (*Juncus kraussii*), Salt Club-sedge (*Bolboschoenus caldwellii*) and Chaffy Saw-sedge (*Gahnia filum*). The plants characteristic of EVC 952 are tolerant of a wide range of salinity and water regimes (Ganf et al. 2010; Roberts & Marston 2011; Rogers 2011; Sainty et al. 2012). The main risks to the ongoing presence of EVC 952 Estuarine Reedbed in the Gellibrand estuary are (i) prolonged inundation that drowns-out adult plants and prohibits sexual reproduction and (ii) prolonged dry phases, which reduce plant vigour directly via desiccation and perhaps indirectly via causing the sediments to become too saline for these usually moderately-salt-tolerant taxa to survive.

**Estuarine Flats Grassland (EVC 914).** EVC 914 may be present in the estuary, given the present of at least some of the characteristic taxa of this vegetation type, such as Knobby Club-sedge (*Ficinia nodosa*), Prickly Spear-grass (*Austrastipa stipoides*) and, possibly, Blue Tussock-grass (*Poa poiformis*). All have only a moderate tolerance to salinity and waterlogging, with a low tolerance to inundation for *Poa* species (Sainty et al. 2012).

EVC descriptions as described by Australian Ecosystems (2010) are as follows:

**Tall Marsh (EVC 821)** is dominated by tall emergent monocots (often >1m high). It occurs in semi-permanent freshwater. It may occur as species poor stands, or consist of a number of different emergent macrophytes with a range of other species present....Tall Marsh and Estuarine Reedbed can be similar in appearance when both EVCs are characterised by stands of *Phragmites australis*. [Tall Marsh mapped in the Gellibrand estuary are species rich and] dominated by *Phragmites australis* (Common Reed), *Typha domingensis* (Narrow-leaf Cumbungi), *Baumea articulata* (Jointed Twig-sedge), with *Lycopus australis* (Gipsy Wort), *Persicaria praetermissa* (Spotted Knotweed), *Epilobium pallidiflorum* (Showy Willow-herb), *Isachne globosa* (Swamp Millet), *Cyperus gunnii* subsp. *gunnii* (Flecked Flat-sedge), *Carex appressa* (Tall Sedge) and *Juncus procerus* (Tall Rush).

**Wet Verge Sedgeland (EVC 932)** consists of dense stands of sedge species, with a range of herb and rush species which are tolerant of seasonal periods of inundation. This EVC is more often fresh, but is tolerant of slightly brackish conditions. [Species include] *Carex appressa* (Tall Sedge), *Carex fascicularis* (Tassel Sedge), *Carex gaudichaudiana* (Fen Sedge), *Cyperus lucidus* (Leafy Flat-sedge), *Cyperus gunnii* subsp. *gunnii* (Flecked Flat-sedge), with a range of additional species including *Juncus sarophorus* (Broom Rush), *Juncus gregiflorus* (Green Rush), *Triglochin procera* (Water Ribbons), *Myriophyllum crispatum* (Up-right Water-milfoil), *Ranunculus amphitrichus* (Small River Buttercup), *Eleocharis acuta* (Common Spike-sedge) and *Isachne globosa* (Swamp Millet).

**Aquatic Sedgeland (EVC 308)** often occurs as species poor vegetation dominated by one to a few robust sedges which are tolerant of extended periods of inundation. This EVC often occurs in association with Aquatic Herbland. Species recorded locally for this EVC include *Eleocharis sphacelata* (Tall Spike-rush), *Triglochin procera* (Water Ribbons), *Isolepis fluitans* (Floating Club-sedge), *Myriophyllum simulans* (Amphibious Water-milfoil) and *Ranunculus amphitrichus* (Small River Buttercup).

**Swamp Scrub (EVC 53)** occurs on poorly-drained sites, with high nutrient availability and consistent fresh water; inundation is typical during the wet winter months. Locally, *Leptospermum lanigerum* (Woolly Tea-tree) is the dominant overstorey species, with occasional *Acacia melanoxylon* (Blackwood) and *Melaleuca squarrosa* (Scented Paper-bark). The understorey of this EVC varies depending on soil type, duration of soil saturation, and water source.

### 3.9.3 Geomorphology

The Gellibrand estuary is a wave-dominated estuary. The estuary is intermittently open/closed to the sea, with opening and closing of the sand berm at the entrance controlled (under natural conditions) by coastal processes (i.e. waves, wind and tides) and freshwater inflows (Alluvium 2017).

As part of a preliminary visit in March 2025, estuarine geomorphology depth profiles were measured at four bridges that cross the estuary (See Site Paper, Alluvium 2025). The measured profiles were compared to those measured at the same sites in 1982. Based on the measured profiles and observations of the estuary over 40 years, there has been little change in the estuary geomorphology since 1982. It is unlikely that the estuarine hydrodynamics have altered since the 2008 environmental flow study.

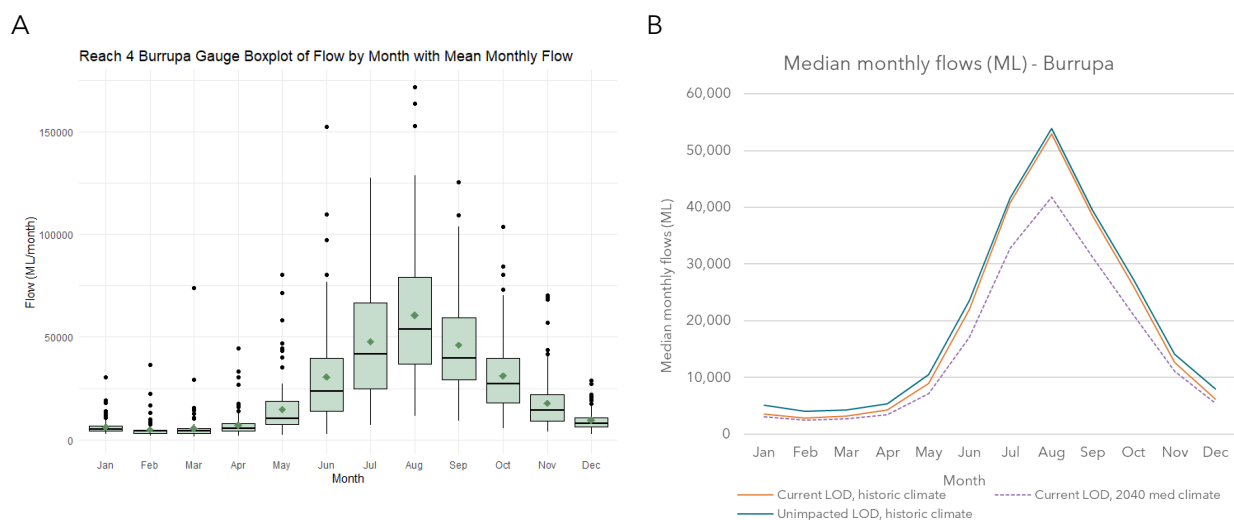
### 3.9.4 Hydrology

Freshwater inflows to the Gellibrand estuary are modelled at the Burrupa gauge (235224), the most downstream gauge in Gellibrand Reach 4. Burrupa gauge (235224) demonstrates typical flow seasonality patterns with a high flow period from June to October, a low flow period from December to April and with May and November serving as flow transition months (Figure 27a).

For the Burrupa gauge (235224), the median monthly flows for the historical climate are substantially impacted by development during the true low flow months (ranging from a 20% to 30% decrease) (Figure 27b). Relatively minor impacts of development are modelled during true high flow months (June - October), ranging from a 2% to 7% decrease in flow magnitude.

Figure 27b provides an indication of the projected impacts of the 2040 medium climate scenario on median monthly flows for the current LOD. Under the 2040 medium climate scenario, median monthly flow decreases in low flow months are projected to range from 12% in December to 21% in April. Median monthly flows are also projected to decrease throughout the high flow period ranging from an approximately 19% decrease in July and September to a 22% decrease in June (Figure 27b).

The flow duration curve (Figure 27c, Table 20) shows development is modelled to impact December - May flows across the entire flow range, with flow decreases of 32% and 17% for 80<sup>th</sup> and 20<sup>th</sup> exceedance percentile flows, respectively. Impacts in June - November affect lower magnitude flows (i.e. greater separation of curves occurs at lower flow magnitudes / higher exceedance percentiles). The magnitudes of 20<sup>th</sup> and 80<sup>th</sup> exceedance percentile flows and differences in the magnitudes of these percentile flows with development are presented in Table 20.



C

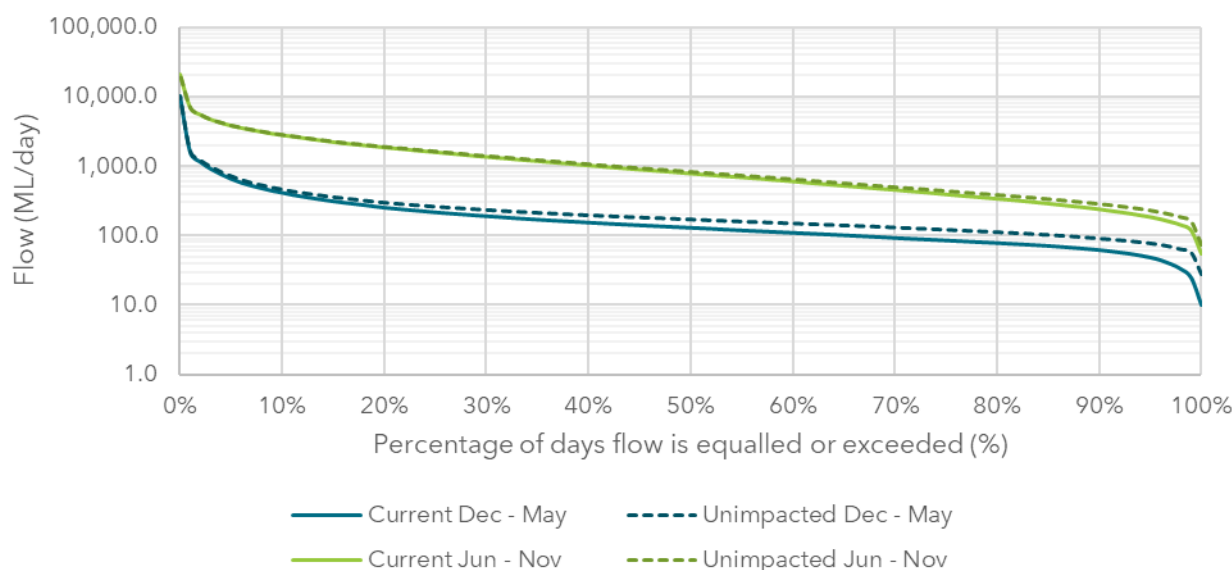


Figure 27. Hydrologic analysis for the Gellibrand estuary (Burrupa Gauge 235224) - Source modelled hydrologic data

Table 20. Impacts of development on the magnitudes of 80th and 20th exceedance percentile inflows to the Gellibrand estuary

| Exceedance percentile | Period          | Unimpacted LOD (ML/day) | Current LOD (ML/day) | Change in flow magnitude (%) with development |
|-----------------------|-----------------|-------------------------|----------------------|-----------------------------------------------|
| 80%                   | December - May  | 112.9                   | 77.2                 | -32%                                          |
|                       | June - November | 384.1                   | 339.8                | -12%                                          |
| 20%                   | December - May  | 300.8                   | 250.1                | -17%                                          |
|                       | June - November | 1878.6                  | 1841.3               | -2%                                           |

### 3.9.5 Groundwater connections

The Quaternary Sediments of the Gellibrand Estuary are primarily underlain by the LTA. The Estuary Environmental Flows Assessment (Lloyd et al. 2008) incorporated groundwater depth and salinity, and groundwater-dependent vegetation into conceptual models. However, no local groundwater data was available for the estuary and this study did not consider the hydrogeological setting, source of groundwater or specific groundwater-surface water interactions. Based on the discussions provided in the Estuary Environment Flows Assessment, reference to groundwater appears to focus on the Quaternary Aquifer. Little is known about the interactions or otherwise between the underlying aquifers.

The BOM GDE Atlas shows high potential aquatic GDEs in the Gellibrand estuary and fringing wetlands, noting that the Atlas does not distinguish the source(s) that supply groundwater to these systems.

### 3.9.6 Water quality

Four active EstuaryWatch sites are spread across the length of the Gellibrand River estuary.

Summaries of 2021-2024 assessments and long term EstuaryWatch data from these sites (adapted from CCMA 2024) are provided in Table 21. Turbidity is fair throughout the estuary, and pH is also typically fair across the estuary (good at the LaTrobe Creek Bridge). Long-term data has poor to fair dissolved oxygen at all sites, which improved to good and excellent in recent years.

**Table 21. Estuary watch water quality data (adapted from CCMA 2024)**

| Location                           | Period of Record | Dissolved Oxygen (top) | Dissolved Oxygen (bottom) | Turbidity | pH (Top) |
|------------------------------------|------------------|------------------------|---------------------------|-----------|----------|
| G2 Old Coach Road Bridge           | 2021-24 data     | Good                   | Excellent                 | Fair      | Fair     |
|                                    | Long-term data   | Fair                   | Fair                      | Fair      | Fair     |
| L1G3 bridge at Latrobe Creek mouth | 2021-24 data     | Excellent              | Excellent                 | Fair      | Good     |
|                                    | Long-term data   | Fair                   | Fair                      | Fair      | Fair     |
| G4 Rivernook Bridge                | 2021-24 data     | Good                   | Excellent                 | Fair      | Fair     |
|                                    | Long-term data   | Poor                   | Poor                      | Fair      | Fair     |
| G5 Coxons Bridge                   | 2021-24 data     | Good                   | Excellent                 | Fair      | Fair     |
|                                    | Long term-data   | Fair                   | Good                      | Fair      | Fair     |

### 3.10 Reach condition summary and management direction

This section draws together the reach descriptions in Sections 3.1 to 3.9 to provide an integrated assessment of current ecological condition for each reach across four domains – aquatic fauna, vegetation, geomorphology, and hydrology – and states the overall management direction for environmental flow objectives. The condition ratings and management directions provided here inform the environmental objectives in Section 6 and provide the basis for distinguishing between reaches where the primary objective of environmental flows is to maintain current values at low risk and reaches where there is a realistic prospect of improvement.

Condition ratings use a three-point scale: **Good** (values largely intact relative to an ecologically healthy reference condition, key threatening processes absent or minor); **Moderate** (values present but degraded, key threatening processes active but not dominant); and **Poor** (values substantially depleted, threatening processes dominant and persistent). These ratings are qualitative assessments based on EFTP field observations, existing data, and the reach descriptions in Section 3. They are not formally calibrated against the Index of Stream Condition or an equivalent index, as that data was not systematically available for all reaches at the time of this assessment.

Management direction is expressed as either **Maintain** (environmental flows are expected to sustain values at their current condition, with improvement dependent primarily on non-flow complementary actions) or **Maintain and improve** (environmental flows have a realistic prospect of directly contributing to improved condition in addition to sustaining current values). Where improvement is conditional on complementary non-flow actions being implemented concurrently, this is noted.

Table 22. Reach condition summary and management direction

| Reach                                      | Aquatic fauna condition | Vegetation condition | Geomorphic condition | Hydrologic condition       | Overall condition | Management direction                           |
|--------------------------------------------|-------------------------|----------------------|----------------------|----------------------------|-------------------|------------------------------------------------|
| <b>Reach 1 - Love Creek</b>                | Moderate                | Moderate-Poor        | Moderate             | Poor                       | Moderate-Poor     | Maintain and improve (conditional)             |
| <b>Reach 2a - Gellibrand River (upper)</b> | Moderate                | Moderate-Poor        | Moderate             | Moderate-Poor              | Moderate          | Maintain and improve (conditional)             |
| <b>Reach 2b - Gellibrand River (mid)</b>   | Moderate                | Moderate             | Good-Moderate        | Moderate                   | Moderate          | Maintain and improve (conditional)             |
| <b>Reach 2c - Lardner Creek</b>            | Moderate-Good           | Moderate-Poor        | Moderate             | Good                       | Moderate-Good     | Maintain (precautionary)                       |
| <b>Reach 3a - Arkins and First Creeks</b>  | Moderate-Good           | Good                 | Good                 | Poor (downstream of weirs) | Moderate          | Maintain upstream; Improve downstream of weirs |
| <b>Reach 3b - Carlisle River</b>           | Moderate                | Moderate-Poor        | Moderate-Poor        | Moderate-Poor              | Moderate-Poor     | Maintain and improve (conditional)             |
| <b>Reach 4 - Gellibrand River (lower)</b>  | Moderate                | Poor                 | Moderate             | Poor                       | Poor-Moderate     | Maintain and improve (conditional)             |

| Reach                               | Aquatic fauna condition | Vegetation condition | Geomorphic condition | Hydrologic condition | Overall condition | Management direction               |
|-------------------------------------|-------------------------|----------------------|----------------------|----------------------|-------------------|------------------------------------|
| <b>Reach 5 - Kennedys Creek</b>     | Moderate                | Poor                 | Moderate             | Poor                 | Poor-Moderate     | Maintain and improve (conditional) |
| <b>Reach 6 - Gellibrand estuary</b> | Good-Moderate           | Good-Moderate        | Good                 | Poor-Moderate        | Good-Moderate     | Maintain                           |

The basis for each reach rating and management direction is described below.

**Reach 1 - Love Creek.** Aquatic fauna values are moderate, with a reasonably diverse native fish assemblage (six species recorded), very high macroinvertebrate diversity (28 taxa), and Spiny crayfish present. Platypus have previously been reported in Love Creek ([Atlas of Living Australia](#)). Suitable platypus habitat exists and possible burrows were observed on the site assessment. The riparian zone is in poor to moderate condition – narrow, fragmented, largely limited to the canopy layer, highly weedy in the shrub and ground layers, and only partly fenced. Instream vegetation is sparse. Geomorphic condition is moderate: the channel is partially confined, large wood is present, but bank undercutting and slumping were observed in October 2025 and instream geomorphic complexity is limited.

Hydrologic condition is poor, with the most severe flow impacts of any freshwater reach – a 61% reduction in summer low flows and a 26% reduction in moderate flows during December-May, compounded by reductions in groundwater contributions to surface flows associated with Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield, and projected climate-driven reductions in winter flows. Water quality is periodically poor, with low dissolved oxygen in low flow periods, elevated salinity potentially due to groundwater contributions, and pesticides detected.

The overall condition is moderate-poor. The management direction is **maintain and improve**, conditional on complementary non-flow related actions to reduce stock access, extend riparian fencing and revegetation, and continue to facilitate recovery of the LTA.

**Reach 2a - Gellibrand River (upper).** Aquatic fauna condition is moderate, with a diverse native fish assemblage including Australian grayling, River blackfish, Platypus and Spiny crayfish. Stevensons Falls provides partial refuge from Brown trout predation. The riparian zone is in poor to moderate condition – narrow, revegetated but only one to two trees wide, with a depauperate shrub and ground layer and significant weed presence. Instream submerged vegetation is scarce. Geomorphic condition is moderate: the reach is partially confined with large wood and log jams present, though bank slumping was observed and sand deposition is increasing in the mainstem.

Hydrologic condition is moderate-poor, with development reducing summer low flows by 17% (80th exceedance percentile) and moderate flows by 28% (20th exceedance percentile), compounded by operation of West Gellibrand Reservoir, reductions in groundwater contributions associated with Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield and climate-driven reductions across all months. Spot water quality data is available for this reach.

Overall condition is moderate. The management direction is **maintain and improve**, conditional on complementary non-flow related actions to improve riparian fencing and weed management, and continue to facilitate recovery of the LTA.

**Reach 2b - Gellibrand River (mid).** Aquatic fauna condition is moderate: nine native fish species recorded including Australian grayling and River blackfish, Platypus and Spiny crayfish present, and the reach supports high instream habitat diversity including boulders, cobbles, rock bars, pools, and abundant large woody debris. However, macroinvertebrate data are absent, River blackfish recruitment appears low, and the conservation-listed Otway stonefly (*Eusthenia nothofagi*) has been reported but its distribution is unknown. Vegetation condition is moderate: the riparian zone in the mid-reach is the most intact in the study, with continuous native forest cover extending from the stream. Riparian vegetation is weedy in places, and fringing instream vegetation is sparse. Geomorphic condition is good-moderate: the reach appears stable with an exposed rock bar, depositional benches, and large wood intact; post-fire sedimentation from January 2026 has since delivered sand to drainage lines and represents a near-term geomorphic risk.

Hydrologic condition is moderate: development reduces summer low flows by 18% (80th exceedance percentile), and climate change is projected to reduce flows across all months by 10–28%. The reach was directly impacted by the January 2026 bushfire, which destroyed the Bunkers Hill streamflow gauge (since reinstated) and is likely to increase sediment loads and alter riparian shading in the short to medium term.

Overall condition is moderate. The management direction is **maintain and improve**. Relatively intact riparian and instream condition means this reach is best placed to respond to improved flow delivery in the study, but post-fire recovery monitoring and complementary sediment management will be important.

**Reach 2c - Lardner Creek.** Aquatic fauna condition is moderate-good: historic records include Short-finned eel, Tupong, Lamprey and Common galaxias. Australian grayling and River blackfish are predicted to be present, and the near-natural flow regime likely supports a diverse fauna community not fully captured in available records. Vegetation condition is moderate-poor: the riparian zone is narrow, revegetated with limited fencing, and the shrub and ground layers are highly depauperate and weedy; this reflects non-flow threats more than hydrological impacts. Geomorphic condition is moderate: the reach is a partially confined, meandering sand bed stream with some active bank erosion; significant recent bank slumping with revegetated trees entering the stream was observed in October 2025. Hydrologic condition is good: Lardner Creek retains a near-natural flow regime with negligible modelled impacts of current development, making it the least hydrologically impacted freshwater reach in the study. Climate change is projected to reduce flows by up to 24% in transition months.

Overall condition is moderate-good. The management direction is **maintain (precautionary)**. The near-natural hydrology is a key asset and must not be eroded through the inadvertent creation of an environmental flow 'floor'. Flow recommendations will be developed with explicit precautionary framing to protect the existing flow regime from future extraction pressure, alongside complementary fencing and bank stabilisation works.

**Reach 3a - Arkins and First Creeks.** Aquatic fauna condition upstream of the weirs is moderate-good: crayfish burrows observed, Spiny crayfish and Climbing galaxias are anticipated, and Platypus habitat is present in both Arkins Creek branches. Downstream of the weirs, aquatic fauna condition is effectively poor during periods when weirs are not overtopped and the creeks cease to flow entirely. Vegetation condition upstream of the weirs is good: the surrounding Wet Forest (EVC 30) and Cool Temperate Rainforest (EVC 31) are largely intact, the wet microclimate is maintained by continuous stream flow, and

water-dependent mosses, ferns and algal biofilms are well developed. Fringing aquatic vegetation and wetlands are absent, consistent with the steep, bedrock-confined geomorphic setting. Geomorphic condition is good: the creeks are steep, bedrock-confined systems with natural sediment throughput.

Hydrologic condition is poor downstream of the weirs: all three creeks cease to flow when weir inflows are insufficient to overtop the weir crest, effectively eliminating the natural flow regime below the diversions for periods of the year. Upstream of the weirs, modelled unimpacted flows represent an intact hydrological template.

Overall condition is moderate upstream of weirs and poor downstream. The management direction is **maintain upstream values; improve downstream of weirs**. Environmental flow recommendations for these creeks may inform any potential future review of the Bulk Entitlement (Otway System) Conversion Order 1997, including the introduction of passing flow obligations, which would be the single most consequential flow management action available for this reach.

**Reach 3b - Carlisle River.** Aquatic fauna condition is moderate: River blackfish, Australian grayling, Platypus and mussels are present, but macroinvertebrate condition assessed by the Waterbug Blitz showed a SIGNAL score of 4.2, indicating impacted conditions. Large woody debris and habitat diversity are notable positive features. Vegetation condition is moderate-poor: the riparian zone is mostly cleared in the lower sections, the narrow strips of EVC 18 Riparian Forest and EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex that remain are unfenced, and revegetation efforts are being undermined by ongoing erosion. Geomorphic condition is moderate-poor: the channel is incised with a low width-depth ratio, limited active depositional features, and active erosion including bank slumping that is taking revegetated plants into the stream.

Hydrologic condition is moderate-poor: the most substantial low flow impacts in any regulated reach, with a 38% reduction in summer 80th exceedance percentile flows and a 23% reduction in winter low flows, attributable primarily to Arkins and First Creek diversions reducing tributary contributions to the Carlisle River. Climate change is projected to reduce median monthly flows by 8-26% across all months. Water quality is generally good for most parameters but dissolved oxygen concentrations decline at low flow.

Overall condition is moderate-poor. The management direction is **maintain and improve**, conditional on fencing, weed management, and bank erosion control, as well as addressing the upstream Reach 3a weir diversions which are the primary driver of summer low flow deficits in this reach.

**Reach 4 - Gellibrand River (lower).** Aquatic fauna condition is moderate: River blackfish, Australian grayling, Short-finned eel and Platypus are present, with Platypus directly sighted by the EFTP in October 2025. However, macroinvertebrate data are absent, and the reach is heavily degraded by stock access. Vegetation condition is poor: the site is largely cleared and used for cattle grazing; the riparian zone is almost non-existent except for isolated Manna Gum; Common Reed dominates channel margins; and the reach is highly weedy and completely unfenced. Geomorphic condition is moderate: the reach is alluvial and unconfined with depositional bars and benches, a functional floodplain, and a flood runner wetland adjacent to the right bank – these are important physical assets. However, active pugging and erosion from stock access were observed, and the channel was highly turbid during the October 2025 site visit.

Hydrologic condition is poor: water system development reduces summer low flows by 36% (80th exceedance percentile) and moderate summer flows by 20%. Climate change is projected to reduce median low-flow period flows by 13–25% and high-flow period flows by 19–22% by 2040.

Overall condition is poor-moderate. The management direction is **maintain and improve**. Significant improvement is possible with flow delivery, but the near-complete absence of riparian fencing and the extent of stock degradation mean that complementary non-flow related land management actions are required in order to deliver meaningful ecological gains. The floodplain wetland and billabong adjacent to the site represent a priority inundation target.

**Reach 5 - Kennedys Creek.** Aquatic fauna condition is moderate: Platypus and Spiny crayfish are recorded, suitable fish habitat exists and there are no known fish barriers, but the species assemblage is sparser than other reaches, possibly reflecting catchment clearing and poor riparian condition rather than flow impacts alone. Macroinvertebrate data are absent. Vegetation condition is poor: the broader catchment is largely cleared for agriculture, the riparian zone is highly variable in condition with some sections entirely lacking native vegetation, Common Reed dominates channel margins, and the reach is unfenced at the FLOWS study site. Geomorphic condition is moderate: the channel is unconfined with pool-riffle morphology, instream timber, and a billabong depression present at the site – positive features.

Hydrologic condition is poor: the most severely impacted unregulated reach in the study, with a 57% reduction in summer low flows (80th exceedance percentile) and 44% reduction in moderate summer flows (20th exceedance percentile), despite Kennedys Creek not being subject to surface water Bulk Entitlement extractions. The drivers behind these reductions are not fully resolved but may include take-and-use licence pumping and potentially farm dams. Climate change is projected to reduce low-flow period flows by 27–37% and high-flow period flows by 11–23% by 2040. Water quality in October 2025 was very poor (highly turbid, chocolate-brown). Spot water quality data indicate times of poor water quality (22 months with dissolve oxygen concentrations below 3 mg/L, with a minimum reading of 0.8 mg/L which would not support fish viability).

Overall condition is poor-moderate. The management direction is **maintain and improve**, with improvement in fauna condition contingent on complementary non-flow related actions to improve riparian revegetation, fencing, and investigate the drivers behind the decline in flows. The billabong depression at the site represents a priority inundation target.

**Reach 6 - Gellibrand estuary.** Aquatic fauna condition is good-moderate: the estuary supports up to 29 fish species, is nationally important for waterbird diversity (48 species, 1,406 individuals recorded in 2010), and Platypus have been observed in the estuarine reach. The estuarine community is broadly intact but subject to periodic fish kill risk during mouth-closure events and artificial opening drawdowns. Vegetation condition is good-moderate: the estuary contains a diverse and floristically rich assemblage of estuarine EVCs, the estuarine community is listed as an endangered ecological community under the EPBC Act 1999. There is unrestricted livestock access to parts of the Gellibrand estuary and floodplain that has significant potential to impact vegetation. Geomorphic condition is good: estuarine depth profiles measured in March 2025 showed little change since 1982, and estuary hydrodynamics appear largely unaltered since the 2008 EEFA study.

Hydrologic condition is moderate: freshwater inflows from the catchment are subject to a 32% reduction in summer low flows at the Burrupa gauge and moderate climate-driven reductions across all months projected to 2040; the estuary remains an intermittently open and closed system broadly consistent with its natural behaviour. Water quality is generally fair across the estuary, with improvements in dissolved oxygen in recent years.

Overall condition is good-moderate – the best overall condition of any reach in the study, consistent with the EFTP's view of the estuary as the ecological centrepiece of the Gellibrand catchment. The management direction is **maintain**. The estuary's relatively intact condition reflects its position as a receiving water body and the protection provided by its national recognition, rather than active flow management. Protecting and, where necessary, restoring the volume, timing and seasonality of freshwater inflows from upstream reaches is the primary flow-related contribution to maintaining estuary condition.

Revised low flow magnitude recommendations for the estuary will require further dedicated investigation beyond the scope of this FLOWS study.

## 4 Catchment scale threats and issues

Catchment threats were described in the Site Paper (Alluvium) and are summarised in Table 23.

Catchment threats impact the potential to support catchment values via flow. As noted in Table 23, few catchment threats can be directly mitigated through flow themselves, and instead, broader catchment management actions are required. It is noted that many catchment threats are compounding in their negative impact on catchment values, as one impact can reduce the resilience of values to second and subsequent impacts.

### 4.1 Impacts of development

**Note:** 'development' refers to 'water system development in the catchment' - i.e. urban and rural demands (extraction under entitlements, licences, groundwater pumping, farm dams, plantation forestry etc.), and broader river operations (storage, flow routing etc.). Source modelled hydrologic data for each reach are presented in Section 3.1 – 3.8.

#### Modelled impacts on flow

The hydrology in all FLOWS study reaches, except for Lardner Creek, is significantly impacted by development, particularly during the period of December – May (see Section 3).

The most severely impacted are Love Creek (Reach 1, 61% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows, 26% decrease in the magnitude of 20<sup>th</sup> exceedance percentile flows) and Kennedys Creek (Reach 5, 57% decrease in the magnitude of 80<sup>th</sup> exceedance percentile flows, 44% decrease in the magnitude of 20<sup>th</sup> exceedance percentile flows). Note that Love Creek and Kennedys Creek are unregulated tributaries and not subject to surface water extractions under Bulk Entitlements.

Impacts of development on low flows during the December – May period are also seen in Carlisle River (Reach 3b), Gellibrand River lower (Reach 4), and the Gellibrand estuary (32-36% decrease in the magnitude of 80<sup>th</sup> percentile flows). Higher magnitude flows during December – May are impacted to a lesser extent by development in Love Creek (Reach 1), Carlisle River (Reach 3b) and all freshwater reaches of the Gellibrand River.

The modelled impacts of development during the June – November periods are less severe in all reaches (compared to December – May), with Carlisle River (Reach 3b) and Kennedys Creek (Reach 5) modelled to experience the greatest changes in the magnitude of low flows in this period (decreases of 23% and 22% respectively). Development has a minor to negligible impact on the magnitudes of higher flows (20<sup>th</sup> exceedance percentile flows) (ranging from -0.5% for Reach 1 to -5% for Reach 3b).

Lardner Creek (Reach 2c) is the only FLOWS study reach where modelled flows seem largely unaffected by development, and this is despite the reach being subject to extractions for the Gellibrand township under a Bulk Entitlement. This is because the annual extraction of 60 ML from Lardner Creek is dwarfed by the creek's average annual flows of 25 GL. The natural flow regime makes Lardner Creek particularly valuable in the context of the broader catchment for the provision of refugia.

## Impacts of extractions and diversions on ecological values

The harvesting of surface water and groundwater ultimately leads to there being less water in the environment. This can result in changes to the water availability and quality and, if not managed correctly, can put ecosystems under stress. Bulk entitlement diversions without passing flow requirements exist in Arkins and First Creeks, and flows below the weirs cease when inflows are insufficient to overtop the weirs. This most commonly occurs during low flow periods and is not reflected in the modelled data for Reach 3a. Bulk entitlements with passing flow rules that allow take of all flow in the river when flows are  $\leq 12$  ML/day (at the North and South Otway offtakes) exist in Reach 4. There are legacy issues due to other historically licensed extractions/diversions throughout the catchment that may now not be viewed as sustainable, given current knowledge and accepted best practice.

Extractions and diversions pose greater impacts in some reaches than others. While the Arkins Creek weirs are located on small streams in the upper catchment and as such likely pose minimal risk to fish (at a whole of catchment level), the lack of overtopping flows threatens reach connectivity and the stream-adjacent wet riparian microclimate. First Creek is considerably smaller than the two Arkins Creek branches, with smaller inflows and limited pool habitats (noting that the EFTP did not undertake an extended physical assessment of Arkins Creek or First Creek beyond the weir pools). The general fauna values of First Creek are likely forest and microclimate- dependent (for example, Otway black snail). Aquatic macroinvertebrates are anticipated, however fish and large aquatic fauna are less likely to be found. First Creek is a small stream, and while streamflow is important for aquatic fauna and a likely contributor to the wet microclimate, fauna are more likely to be forest-dependent, than streamflow dependent. Despite the presence of weirs, Arkins Creek catchment has records of platypus and Climbing galaxias, indicating these barriers pose minor threats, except under low flow conditions.

Management and protection of recharge areas and groundwater-surface water interaction is also important, as different sources can play different roles in helping to sustain river flows.

## Barriers to fish movement

Fish migration and movement barriers influence the achievement of flow objectives and ecological outcomes and include weirs, bridges, culverts and crossings (e.g. fords). Whilst the CCMA have removed a number of priority barriers (such as weirs associated with decommissioned gauges), some artificial barriers to fish movement remain (e.g. West Gellibrand and Olangolah Reservoirs and diversion weirs in Arkins Creek West, Arkins Creek East and First Creeks) (DCCEEW 2018). Small barriers such as Arkins Creek weirs likely impede movement at low flows, whereas major barriers, such as reservoir dams, effectively eliminate movement across all flows. Barriers negatively affect both local movement and seasonal migrations of fish.

## 4.2 Impacts of climate

The broader Corangamite catchment is predicted to experience higher temperatures, lower average rainfall and higher frequency of extreme rainfall events as a consequence of climate change (CCMA 2024a), placing increased pressure on water resources. Indeed, the HARC Source modelling suggests that under a drier climate scenario, the Otway supply system requires augmentation and system upgrades to provide for the modelled 2065 level of demand (HARC 2025).

Climate is modelled to impact the hydrology in all flows study reaches. Under the median 2040 climate projection, climate is predicted to affect median flows in all months of the year, in all reaches. It is important to note, however, that in contrast to the impacts of development (which are most evident on low magnitude flows in the low flow season), the projected climate impacts are greatest during the wettest months of the year, decreasing the magnitude of peak flow events and decreasing the total volumes of water passing through the catchment. Based on the 2020 climate guidelines (DELWP 2020) used by HARC in development of the Source model, the 2040 median projection represents a 7% reduction in runoff.

Beyond flow, climate change is also anticipated to directly impact habitat quality (e.g. moisture, temperature), fire regime, catchment land use, aquifer recharge and the frequency of estuary mouth closures and associated ecological risks. Shifting flow regimes will also directly impact on behaviour and life cycles of aquatic fauna. Protecting natural flow regimes in upstream unregulated reaches is essential for ensuring refugia over time, and the provision of flows is important to build resilience in the ecosystem and help mitigate existing threats.

Additional climate impacts are anticipated in the Gellibrand estuary, which is subject to sea level rise, storm surge events and incursion of saline water into surface and groundwater, in addition to reduced freshwater inflows from the Gellibrand River (CCMA 2017, DCCEEW 2018, HARC 2025). Reduced freshwater flows and increased sea level and storm surges are likely to allow saline water to move further into the estuary and the near-coastal groundwater. Sea level increase and storm surges are likely to alter the formation of the sandy berm at the mouth. Together, these impacts will affect vegetation communities and thereby the quality and availability of estuarine habitats.

There has been an increasing shift towards the consideration of climate change in water management and understanding impacts of climate on water resources (DELWP 2021). A 2024 review of the FLOWS method recommended increased consideration of climate change in the setting of flow recommendations (Alluvium 2024). This built on a requirement of the FLOWS method Ed. 2 (DEPI 2013) for flow recommendations to be seasonally adaptive (i.e. with different recommendations developed for dry, average and wet years).

It is not the EFTP's intention to develop a flow regime that prematurely transitions the catchment to a drier climate, nor does the EFTP intend to recommend a 'natural' (pre-development) flow regime. Instead, the EFTP endeavour to develop (minimum) flow recommendations that support and where possible improve the condition of ecological and cultural values in a current climate. The recommendations report will include performance analyses that demonstrate the extent to which the recommended flow regime might be achieved in a future climate (2040 and 2065), to inform water resource management.

## **Implications for Stage 2 - determining environmental flow recommendations**

Climate change does not alter the environmental values and objectives that flow recommendations are designed to protect – rather, it affects how frequently flow recommendations can be met under projected future conditions. Stage 2 will test flow recommendations against the 2040 medium climate scenario to provide water resource managers with an understanding of the degree to which recommended flows can be delivered as the climate dries. The seasonally adaptive approach (DEPI 2013) will be used to set priorities for environmental water delivery under drought, dry, average, and wet year conditions, recognising that not all flow components may be achievable in all years and that management priorities

will need to adapt accordingly. This approach is consistent with Action 8-9 of the Central and Gippsland Region Sustainable Water Strategy (Section 5.6), which identifies improving summer flows in the Gellibrand River as a priority even as the climate continues to shift.

### 4.3 Bushfire impacts

The Gellibrand catchment, as per the broader state of Victoria, is anticipated to experience increasingly frequent and severe bushfire activity (DEECA 2024). Rates of runoff and erosion often increase as a result of landscape disturbance. Post-fire debris flows are known to occur in fire-impacted steep upland catchments following high intensity rainfall events before vegetation cover is re-established (Nyman, 2011). Fire alters soil water repellence, which changes infiltration rates and results in greater runoff and less infiltration. Ash beds are high in particulate carbon, salts, trace metals and contaminants, and the low density of ash enables it to be readily entrained by overland flow and delivered to waterways (see Smith et al., 2011, DEECA 2023). Increases in suspended sediments impact primary producers, while turbidity and sediment deposition negatively impact aquatic fauna (through clogging fish gills and insect filtering apparatus) and the quality and availability of habitats (foraging and breeding) (Smith et al., 2011, Johnston et al., 2014).

Following bushfire, riparian vegetation no longer acts as a buffer to the delivery of runoff and sediment to waterways. The reduced canopy cover and mid-storey cover promotes increased light penetration, which may impact stream temperatures and promote algal growth (Smith et al., 2011). Furthermore, fire-affected riparian vegetation offers less protection and habitat to terrestrial species.

In January 2026, parts of the Gellibrand catchment (including Reach 2b and 4) were directly impacted by bushfires. FLOWS study Site 2b was directly impacted, with the Bunkers Hill streamflow gauge destroyed (note, the gauge has since been reinstated). Riparian vegetation was burned, with complete loss of ground storey vegetation at most cross sections. Substantial loss of foliage in canopy and mid-storey occurred through direct scorch or post-fire leaf fall (Figure 28). Bracken and blackberry were actively regrowing in March 2026. Post-fire regrowth of mid and overstorey vegetation is anticipated to reduce catchment run-off in Reach 2b and 4. A reduction of waterway shading may impact water temperature and evaporation/evapotranspiration, the extent to which is unknown. A substantial pulse of sand has also been delivered to waterways and drainage lines at Site 2b.



Figure 28. Site 2b, looking downstream from cross section 7 (A) 28 October 2025 (B) 4 March 2026, approximately six weeks after bushfire



Figure 29. Sand deposition in an inflowing creek near cross section 4 at Site 2b. Sand clogged the culvert and the creek was flowing over the bridge.

## 4.4 Artificial estuary openings

Estuary entrance modification and artificial estuary openings pose a risk to water quality and aquatic fauna in the estuary, due to the runoff of nutrient rich, low oxygen concentrations in water from fringing wetlands into the estuary channel. In the short term, single and/or repeated openings can disrupt fish populations, bird habitats and vegetation (Lloyd et al. 2025). In the longer term, repeated artificial estuary openings over many years can alter the ecological character of estuaries (Lloyd et al. 2025). Corangamite CMA has been tracking estuary openings and the occurrence of fish deaths, finding that fish death events vary in severity following estuary opening. There are up to three artificial estuary openings per year in dry years, with fewer required in wet years as increased freshwater inflows in wet years support natural estuary opening.

## 4.5 Land use and threats to water quality

Riparian areas are important for aquatic fauna by helping to regulate habitat (water temperature, shading, filtering, etc), input litter and carbonic material to support food webs, improve productivity, provision of complex habitat (large woody debris and tree roots), and bank stabilisation (Singh et al. 2021; Vincent 2025). Riparian areas in the Gellibrand River are under stress, particularly in the mid to lower catchment due to the following land use and management actions:

- Forestry – sedimentation, runoff, chemicals;
- Fire – impact to flow, sedimentation, riparian cover, fire operations;

- Stock grazing – particularly cattle access, erosion, trampling, weed introduction, vegetation impact, high nutrient/chemical runoff.

Environmental flows cannot be expected to ‘fix’ the water quality threats and other negative impacts on flow caused by land use change, catchment management and bushfires. Such threats need to be mitigated at their source. Land use and catchment management challenges have significant potential to undermine the achievement of environmental objectives in the Gellibrand catchment.

The mid to lower Gellibrand River and some of its tributaries exhibit poor water quality primarily linked to sedimentation and associated turbidity. Water in Reaches 2b, 4, and 5 was observed to be highly turbid (October 2025), noting that the site assessment followed recent high rainfall events. Bank erosion, particularly slumping and bank undercutting, was prevalent in most reaches, contributing to instream sediment loads. ARI has reported increasing sand deposition in the Gellibrand River main stem during native fish report card surveys (ARI 2024). Direct cattle access to streams and pugging of waterway banks was observed at several sites. The PAG observe additional erosion and sediment contributions from plantation forestry, logging and roads. Sedimentation poses a significant threat to water quality and the quality of instream habitats. Indeed, sedimentation (sand deposition) of deep holes, instream habitats and woody debris has been proposed as a contributor to declines in River blackfish population abundance and size structure in the Gellibrand catchment (ARI 2015). Low river flows are also thought to result in loss of access to in-stream habitat and contribute to poor water quality (ARI 2015).

Wastewater runoff to streams has been identified by the PAG as a threat to water quality in developed mid- and lower-reaches, including all reaches of the Gellibrand River, the Carlisle River and Kennedys Creek.

Cacciatori et al (2026) recently published a citizen science monitoring campaign to investigate pesticide occurrence in Gellibrand River catchment waterways (i.e. Gellibrand River, Love Creek, Charleys Creek and Boggy Creek). Fungicides were the most frequently detected class of pesticides, with other chemicals including insecticides, herbicides and intermediates, breakdown products and metabolites also detected. Identified compounds have various uses in agriculture and plantation forestry. At times, total acute toxic unit thresholds were reached or exceeded for crustaceans (*Daphnia magna*), attributed to the insecticides Deltamethrin, carbaryl, endrin aldehyde and 2,4'-Methoxychlor. This study suggests a potential pesticide threat to the condition of aquatic invertebrates (primary consumers and food source for higher organisms) from agricultural and plantation activities in the catchment.

Geomorphic changes have also resulted in a simplification of habitat and loss of complexity crucial for sustaining aquatic fauna. Loss of riparian cover also impacts on water quality through changes in temperature and shading. Whilst flows cannot treat the root cause of sedimentation, they can help to ameliorate or mitigate some of its impacts by maintaining breeding and foraging habitats. However, providing flows to attract fish into river reaches that subsequently experience poor water quality or complete drying will not benefit these species and pose a threat to the achievement of environmental objectives for aquatic fauna.

## 4.6 Introduced plant and animal species

All freshwater FLOWS study reaches, except for Arkins and First Creeks (Reach 3a), had highly weedy riparian zones, compromising riparian ecosystem diversity, productivity and function. Brown trout is widespread throughout the catchment, recorded in all reaches except 3a and 5, but likely present across all reaches. Rainbow trout also exist but have only been recorded in Reach 4. Brown trout appears to be present in low to moderate abundance, which increases in upper catchment areas (ARI 2025). Trout have been implicated in the decline of several native fish species, including small-bodied fish such as Galaxiids ([Native Fish Australia](#)). Brown trout can have a significant impact on Blackfish due to predation and competition. They prey on small fish (including Blackfish young) and compete for habitat and food resources. Predation can lead to a decline in populations and may impact on achievement of flow objectives for this species (DCCEEW 2011). Achievement of flow objectives for aquatic fauna may also benefit introduced fish species and affect population dynamics.

## 4.7 Illegal and non-compliant fishing

Illegal netting (e.g. opera house nets) has been observed in the Gellibrand River (anecdotal evidence). Illegal netting directly impacts aquatic fauna and can be lethal for non-target bycatch. Whilst acknowledged as a risk, it is considered a low risk to the achievement of environmental objectives.

Table 23. Catchment threats (G = geomorphology, V = vegetation, AF = aquatic fauna: fish and aquatic macroinvertebrates)

| Threat                                                                                                                    | Values affected | Can the threat be influenced by flow?                                                                                                                                                                                                                       | 1 | 2a | 2b | 2c | 3a | 3b | 4 | 5 | E            |
|---------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|----|----|----|----|----|---|---|--------------|
| <b>Development</b> - Water extraction (surface or groundwater). Note, water demand expected to increase in future         | G, V, AF        | <b>Partly</b> - reduced extraction will retain flows in the system.                                                                                                                                                                                         | X | X  | X  |    | X  | X  | X | X | X            |
| <b>Development</b> - Removal of billabong soaks due to development and land use change                                    | G, V, AF        | <b>Partly</b> - while flows can support billabongs and wetlands via inundation, development and land use change will not be mitigated through flows.                                                                                                        |   | X  | X  |    |    |    |   |   |              |
| <b>Development</b> - Farm dams affecting catchment hydrology                                                              | G, V, AF        | <b>No</b>                                                                                                                                                                                                                                                   |   |    |    |    |    | X  |   |   |              |
| <b>Plantation forestry</b> - altered yield and sediment inputs                                                            | G, V, AF        | <b>No</b>                                                                                                                                                                                                                                                   |   |    |    | X  |    | X  | X | X |              |
| <b>Invasive and exotic plant species</b> (e.g., willows and blackberries).                                                | V, AF           | <b>No</b> - riparian pest species management required.                                                                                                                                                                                                      | X | X  | X  | X  |    | X  | X | X | Not assessed |
| <b>Water quality</b> - High litter input from surrounding non-flow dependent riparian vegetation affecting nutrient loads | V, AF           | <b>Yes</b> - entrainment of carbon from riparian zones and the maintenance of food webs is a key function of overbank flows. Land management approaches in freshwater reaches to reduce litter loads, e.g. as Cultural burning, may reduce blackwater risk. | X | X  | X  |    |    |    |   |   |              |
| <b>Water quality</b> - nutrient loads, salinity and dissolved oxygen due to prolonged inundation of fringing wetlands     | AF              | <b>Partly</b> - higher flows are required to manage water quality and fish kill risk upon estuary opening.<br><br>Freshwater inflows will help to maintain the estuarine salt wedge and an oxygenated freshwater lens on the surface of the estuary.        |   |    |    |    |    |    |   |   | X            |
| <b>Water quality</b> - chemical / pesticide concentrations                                                                | AF              | <b>No</b> - reduced usage of chemicals / pesticides or bans of high-risk chemicals would be required.                                                                                                                                                       | X | X  | X  |    |    |    |   |   |              |
| <b>Water quality</b> - wastewater runoff, nutrient enrichment from agricultural operations                                | V, AF           | <b>No</b> - on-farm wastewater management required. Stock exclusion from riparian zone (fencing) required.                                                                                                                                                  |   | X  | X  |    |    | X  | X | X |              |

| Threat                                                                                                                                        | Values affected | Can the threat be influenced by flow?                                                                                                                                                                                                                             | 1 | 2a | 2b | 2c | 3a | 3b | 4 | 5 | E |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|----|----|----|----|----|---|---|---|
| <b>Water quality</b> - excessive algal and macrophyte growth (encroachment)                                                                   | V, AF           | <b>Partly</b> - higher magnitude flows scour algae. Freshes are thought ineffective at preventing stream encroachment by Phragmites.                                                                                                                              |   |    |    | X  |    |    | X | X |   |
| <b>Water quality</b> - wastewater from residential development, septic systems                                                                | V, AF           | <b>No</b> - threat should be mitigated at the source, not via dilution by flows.                                                                                                                                                                                  |   |    | X  |    |    | X  | X |   |   |
| <b>Water quality - erosion, turbidity and sedimentation</b> - affecting instream vegetation and quality of breeding habitat for aquatic fauna | V, AF           | <b>Partly</b> - while a key role of larger magnitude flows is to move sediment, excess erosion and sediment inputs from land clearing, agriculture, cattle access to streams, recreational vehicles and plantation forestry is unlikely to be mitigated by flows. |   | X  | X  | X  |    | X  | X | X | X |
| <b>Climate change</b> - altered hydrology, bushfire risk                                                                                      | G, V, AF        | <b>No</b>                                                                                                                                                                                                                                                         | X | X  | X  | X  | X  | X  | X | X | X |
| <b>Climate change</b> - sea level rise, storm surge                                                                                           | G, V, AF        | <b>No</b>                                                                                                                                                                                                                                                         |   |    |    |    |    |    |   |   | X |
| <b>Potential for salinity impacts</b>                                                                                                         | AF              | <b>Partly</b> - While improving freshwater flows can reduce salinity, the salinity will continue to reflect the quality of the different water sources.                                                                                                           | X |    |    |    |    |    |   | X |   |
| <b>Invasive fauna</b> - brown trout                                                                                                           | AF              | <b>No</b>                                                                                                                                                                                                                                                         | X | X  | X  | X  |    |    | X |   |   |
| <b>Instream barriers</b> - natural and built                                                                                                  | AF              | <b>No</b>                                                                                                                                                                                                                                                         |   | X  |    |    |    |    |   |   |   |
| <b>Artificial estuary openings</b>                                                                                                            | V, AF           | <b>Partly</b> - Timing of artificial estuary openings with high magnitude freshwater inflow to the estuary may help to reduce poor water quality and fish kill risks.                                                                                             |   |    |    |    |    |    |   |   | X |

## 5 Policy and strategic objectives

Policies and strategies that apply to the Gellibrand catchment and are relevant to the setting of flow recommendations are described below.

### 5.1 Water is Life

*Water is Life* (DELWP 2022) is a Victorian Government roadmap for increasing Traditional Owner roles in, and resources for, water management in Victoria. The strategy was developed by the Victorian Government and Traditional Owners, with Nations providing standalone statements in Section B.

The roadmap (Section A) has twelve targeted outcomes, including the recognition of waterways and surrounding lands as living, integrated, natural and cultural entities in law, with Traditional Owners recognised as a unique 'voice' of the living entities. *Water is Life* implies that while not yet legislated, for the purpose of the FLOWS study the Gellibrand River (from the headwaters of the river and its tributaries through to the river mouth) should be regarded as a living and integrated natural entity, with Gulidjan, Gadubanud and Kirrae Whurrong Traditional Owners providing a voice for the entity.

*Water is Life* establishes outcomes for Traditional Owners to become formal partners in the water sector; to determine how environmental water is used to heal Country; to be involved in public land management; to be recognised as waterway managers for specific locations; and to be recognised as environmental water holders. Outcomes also relate to Traditional Owner access to water entitlements for self-determined use.

Through enactment of *Water is Life* and future policies, Traditional Owners will be significant future water managers and entitlement holders in the Gellibrand catchment.

### 5.2 Water is Life Eastern Maar Nation Statement

Eastern Maar Aboriginal Corporation prepared a Nation Statement for *Water is Life* (Eastern Maar 2022), in its roles as both a Registered Aboriginal Party and a Prescribed Body Corporate. In the statement, Eastern Maar assert an inherent obligation to safeguard Ancestral Territory, including water. To Eastern Maar, *Water is Life* presents an opportunity for all parties in the water sector to step towards depoliticising Parreeyt (water). Parreeyt is described as 'bio-cultural in its entirety' and must be both protected and managed. All flows are bio-cultural.

Eastern Maar assert Cultural obligations, rights and unceded authority to speak for Parreeyt and to make decisions for Parreeyt. The Nation Statement recognises that the current water system dispossesses, alienates and marginalises Eastern Maar as contributors to, and beneficiaries of, Parreeyt. Eastern Maar seek to be reinstated as managers and decision makers for water.

The statement's proposed management approach focusses on bio-cultural regions and landscapes, with fresh, brackish and saline systems holding equal value to Eastern Maar people. A primary objective is to "restore waterways to a healthy condition as determined by its bio-cultural value within the broader landscape" with a key outcome being to provide a "stable foundation that supports a rich and abundant biodiversity".

## 5.3 Eastern Maar Meerreengeeye ngakeepoorryeeyt (Our Country, Far Seeing) Eastern Maar Country Plan

**Interpretation of the Country Plan in the context of the FLOWS study:** Eastern Maar take a holistic approach to Country - everything is connected. While the FLOWS study tends to break complex and integrated systems down into parts (reaches, sites, environmental objectives), Traditional Owners consider water across the whole landscape, not just the water in the river or floodplain. The whole landscape is affected by surface flows, for example by the creation of microclimates, groundwater connections, soil moisture, refugia during extremes, plants, (which provide food, shade and habitats and are values in and of themselves), fungi, and fauna, which live in habitats and rely on the river for drinking water. The shape and form of the land, the soils and rocks, and the air are also connected, as are Eastern Maar citizens.

To align with the Country plan, the EFTP will take an integrated approach to the development of flow objectives, considering life histories, connections between values and connections across the landscape and with people.

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*Meerreengeeye ngakeepoorryeeyt* documents Eastern Maar's vision for healing Country, strengthening culture and supporting future generations. Central to the plan is the deep, enduring connection between Eastern Maar people and Country.

***"Everything on, under and above our Country is connected; and needs to be managed as a system" (p.33).***

The plan has six goals that focus Eastern Maar's efforts to achieve the vision, each of which is founded on Eastern Maar Law/Lore. Caring for Country is both a cultural obligation and a pathway to community strength, spirituality and connection. Eastern Maar people have cared for Country for millennia, using Traditional Ecological Knowledge as a foundation for maintaining ecosystems and managing natural resources responsibly and sustainably. The Country Plan highlights the need for Eastern Maar leadership to manage waterways and for Eastern Maar people to be reinstated as primary knowledge holders for water. This reflects the understanding that water is a bio-cultural entity connected to Ancestors, identity and wellbeing. Eastern Maar asserts and seeks legal recognition as sovereign rights-holders to land, water and other resources, including the right to access, use and manage these resources for economic and social benefit.

Consistent with a holistic approach to Country, Cultural burning, the revitalisation of traditional practices, connecting to Country, working on Country and using cultural knowledge are all integral to Eastern Maar's approach to caring for Country and water management. Cultural connections to bio-cultural values are all-encompassing and include the many aquatic and riparian species, as well as to the water, land, and air.

The Eastern Maar six seasonal calendar reflects ecological rhythms and landscape cues of Country, and so is fundamentally different from the conventional western calendar (Figure 30). The six seasons of the Eastern Maar calendar shift from year to year reflecting changes on Country.

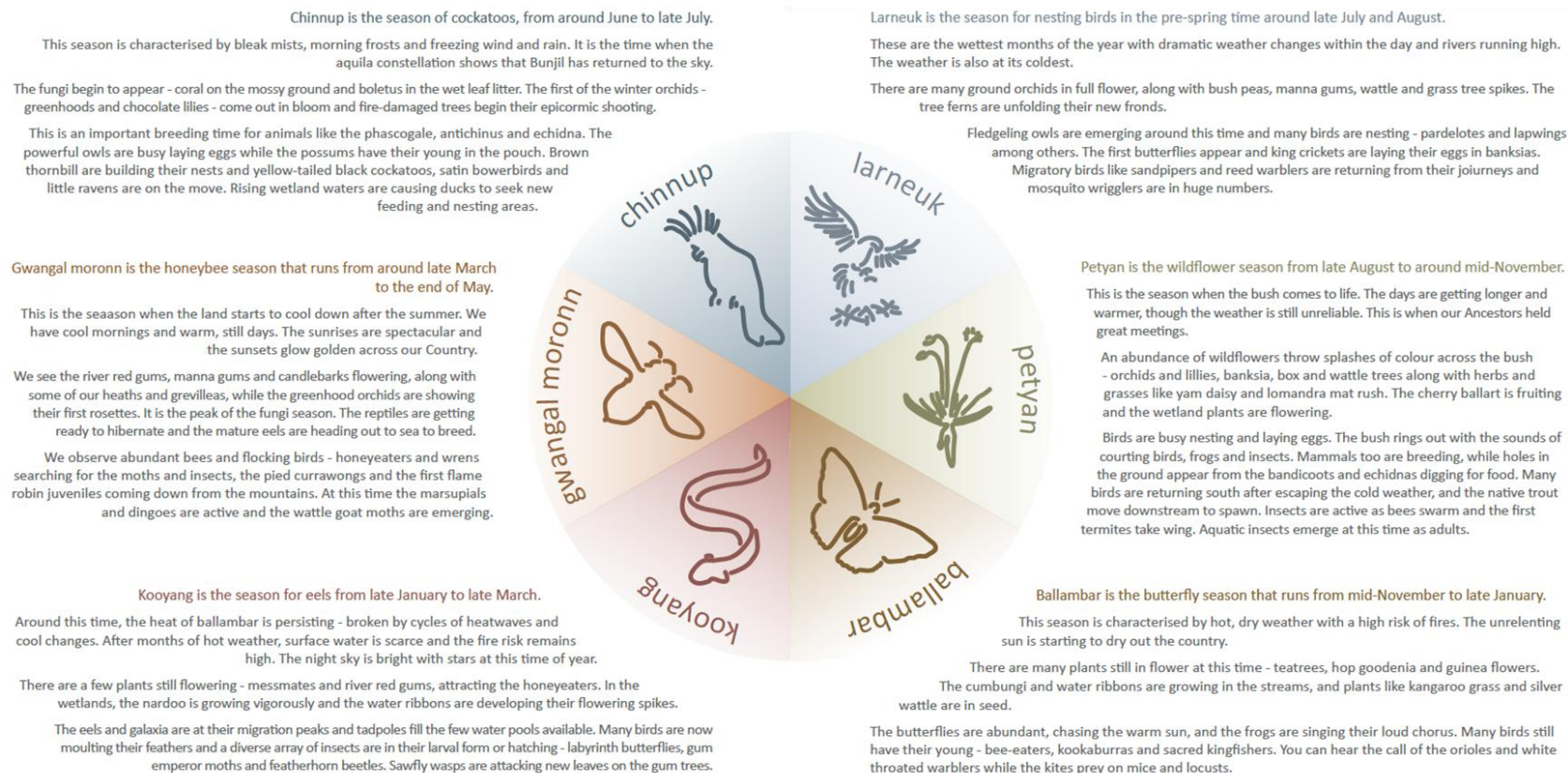


**Figure 30. Six seasons of Eastern Maar Country (reproduced from Eastern Maar Country Plan with permission)**

The seasonal calendar in the Country Plan is generic for all of Eastern Maar Country, and highlights some aspects of rivers, wetland hydrology, and life histories of flora and fauna (Figure 30). Eastern Maar Aboriginal Corporation recognise that climate change is already affecting the seasonal calendar, and that these effects will vary across the breadth of Country (J. Britton, Pers. Comm March 2026). It is important to understand that while broad month ranges are shown for each season, in a given year the timing of the seasonal changes vary because the whole of Country is connected (J. Britton, J. Honan Pers Comm March 2026).

The seasons have been presented here with permission from Eastern Maar Aboriginal Corporation. There is an expectation that agencies will partner with Eastern Maar Aboriginal Corporation and Traditional Owners when interpreting the seasons and using landscape cues to inform timing of flow delivery and on-Country works.

## 5.4 Pang-ngooteekeeya weeng malangeepa ngeeye (Remembering our future: bringing old ideas to the new) Bio-cultural Landscape Strategy

Pascoe et al. (2024) propose a bio-cultural values-centred approach to caring for Maar Country (Meereeng). This approach recognises Eastern Maar obligations to Kin and Country, including the role of Eastern Maar people as stewards of Country and custodians of ancestral knowledge. The Strategy describes six principles for the biocultural landscape restoration approach, founded in Customary Lore, knowledge and practice:

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Six principles for biocultural landscape restoration:

**Holistic understanding** – of ecosystems, recognising the cultural dimensions and diverse skills, knowledge and experience that are required to address challenges to the health of Country.

**Traditional knowledge and practices** – valuing and incorporating the Traditional Ecological Knowledge held by Aboriginal communities such that restoration efforts are informed by local wisdom, knowledge, experience and research.

**Cultural resilience** – recognising the importance of cultural resilience alongside environmental resilience, enabling the Eastern Maar community to adapt, maintain its identity and to sustain relationship with (and as) Country.

**Community engagement and ownership** – recognising the importance of involvement and empowerment of local communities in ecological restoration (in decision making, planning and implementation) to ensure alignment with community needs, values and obligations.

**Ethical considerations** – prioritising and respecting Aboriginal peoples' and communities' rights, knowledge systems and cultural practices.

**Benefits for nature and society (Country)** – delivering shared benefits for ecosystems and communities (ecosystem health, community resilience and enhanced quality of life) by integrating cultural values, livelihood systems and social equity.

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The paper uses the term 'culturally significant entity' (CSE) (after Goolmeer et al., 2022) to identify significant features of Country. CSEs are associated with regions of the Maar landscape through language, dreaming stories and ceremonies and can refer to culturally significant species, seascapes and landscapes. Carlisle Heath is explicitly identified as habitat for the Eastern Ground Parrot, a CSE. While Carlisle Heath and the Eastern Ground Parrot are not directly flow-dependent, the paper implies the need to recognise the connectedness of landscapes and habitats across the Gellibrand catchment and to manage the catchment as a living and integrated natural entity.

The paper further highlights the importance of removing policy and regulatory barriers that limit access of Eastern Maar people to their lands and waters.

## 5.5 The Western Region Sustainable Water Strategy

The Western Region Sustainable Water Strategy (WRSWS) (DSE 2011) identifies potential challenges for water management and opportunities to secure water resources by outlining policies and actions to ensure sustainable water supply and management. It contains two actions associated with flows in the Gellibrand River.

Action 7.1 placed caps on the amount of unallocated surface water that remains available for new winter diversions from unregulated waterways to balance the needs of existing users with environmental

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WRSWS:

"Revise caps on the amount of unallocated surface water available for winter-fill diversions in Otways catchments". **Action 7.1**

"Improve summer flows in the Gellibrand River". **Action 7.3**

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values, while leaving options open for potential new allocations in the future; Action 7.1 aims to improve critical flows in the Gellibrand River through the summer low flow period.

In July 2025, the Victorian Premier announced the development of a new WRSWS, which will take place during 2026 - 2027.

## 5.6 Central and Gippsland Region Sustainable Water Strategy

The Central and Gippsland Region Sustainable Water Strategy (CGRSWS) (DELWP 2022a) carries forward the WRSWS Action 7.3 to 'improve summer flows in the Gellibrand River' (CGRSWS Action 8-9). Action 8-9 is an ongoing action led by Wannon Water in partnership with DEECA, Eastern Maar Aboriginal Corporation and Corangamite CMA. This will be achieved through a combination of assessing the expected environmental outcomes for each option to reduce water extraction from the Gellibrand River (based on an independent expert report) and undertaking a holistic assessment of preferred water supply augmentation options to improve flows in the Gellibrand River particularly within the summer period. Low flows are a key management priority in the catchment. Action 8-9 is a driver for the inclusion of lower Gellibrand reaches (Reaches 3a, 3b, 4, 5 and the estuary) in this FLOWS study.

WRSWS Action 7.1 is reframed in the CGRSWS, 'to support [Eastern Maar Aboriginal Corporation] applications for unallocated water in the Otway Basin' (Action 6-15), consistent

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CGRSWS:

"Support applications for unallocated water in the Otway Basin, including in the Gellibrand River". **Action 6-15**

"Improve summer flows in the Gellibrand River". **Action 8-9**

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with the Victorian Government's commitment to support Traditional Owner access to water. Action 6-15 is one of three included in the CGRSWS that supports the provision of water access to the Eastern Maar Aboriginal Corporation. The target for this action is that by 2022, the Eastern Maar Aboriginal Corporation should be able to apply for unallocated surface water and groundwater on and under Maar Country.

The FLOWS study is a technical study and does not make management decisions on water ownership or allocation. It is noted, however, that current policy direction supports both the transfer of water to

Traditional Owners and the self-determined involvement of Traditional Owners in water management and decision-making. Indeed, this is the purpose of Water is Life: Traditional Owner Access to Water Roadmap (DELWP 2022b) – to acknowledge injustices and establish a framework to increase Traditional Owner roles and resources in water management.

## 5.7 Corangamite Regional Catchment Strategy 2021-2027

The Corangamite Regional Catchment Strategy (CCMA 2021) provides a framework and program of works for the management of rivers, estuaries and wetlands in the Corangamite region. The strategy sets a vision of:

***“Healthy and productive lands and waters cared for and enjoyed by thriving communities”.***

The CRCS contains four key regional water outcomes (WO) particularly relevant to flows.

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Corangamite Regional Catchment Strategy regional water outcomes:

“By 2027 there is an improvement in riparian extent and condition, hydrological regime and water quality compared to 2022 baselines in priority waterways defined in the Corangamite Waterway Strategy”. **WO1**

“By 2027, the condition of Ramsar listed wetlands and other priority wetlands identified in the Corangamite Waterway Strategy will be maintained and improved compared to 2021 baseline”. **WO4**

“By 2027, the water quality of priority estuaries are (sic) maintained or improved, compared to index of estuary condition 2019 baseline”. **WO5**

“By 2027 there will have been an increase in the extent of in-stream habitat compared to 2021 baseline in priority waterways for resilience of threatened native fish and waterway dependent species”. **WO9**

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The Corangamite Regional Catchment Strategy also specifies water and biodiversity outcomes specific to the **Otway Coast local area** that are relevant to the FLOWS study.

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Corangamite Regional Catchment Strategy Otway Coast *water* outcomes (by 2027, compared to 2022 baselines):

"The efficiency of consumptive water use in the Otway Coast Landscape System will be improved through the use of cost effective alternate water sources and demand management strategies that results in less take from source water". **OtwWO1**

"There is an improvement in riparian extent and condition, hydrological regime and water quality in Otway Coast priority waterways as defined in the Corangamite Waterway Strategy". **OtwWO2**

"Urban areas will have identified waterway amenity values to enhance user experience and connection to the natural landscape". **OtwWO3**

"Drinking water supply catchments are protected to provide quality water for urban water supplies". **OtwWO4**

"Increase the community understanding and awareness of water values and management for the Otway Coast". **OtwWO5**

"Understand and enhance Eastern Maar values of the main waterways and ensure Eastern Maar People have a strong voice in their management". **OtwWO6**

"Water quality in the Gellibrand River, Aire River and Anglesea River are maintained or improved, compared to index of estuary condition 2010". **OtwWO7**

Corangamite Regional Catchment Strategy Otway Coast *biodiversity* outcomes (by 2027, compared to 2022 baselines):

"Achieve a net gain in the overall extent, connectivity and condition of Otway Coast habitats across land and waterway environments through effective climate change adaptation strategies". **OtwBO1**

"Increase understanding and awareness of biodiversity values of the Otway Coast Landscape System". **OtwBO5**

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The CRCS further contains 2027 regional water outcomes to have a strong Traditional Owner voice on the timing and quantum of all environmental water releases and minimum environmental flows required for a healthy river system (WO6). Otway Coast local area water outcomes include that by 2027, compared to baselines, [agencies] understand and enhance Eastern Maar values of the main waterways and ensure Eastern Maar People have a strong voice in their management. (OtwWO6)

## 5.8 Corangamite Waterway Strategy 2014-2022

The Corangamite Waterway Strategy 2014 - 2022 (CCMA 2014) is a central instrument of the Corangamite Regional Catchment Strategy 2021-2027 (CCMA 2021). The Corangamite Waterway Strategy provides a vision, framework, overarching goals and objectives and program of works for the management of rivers, estuaries and wetlands in the Corangamite region. The waterway strategy vision for the Corangamite region is for:

***“A healthy Corangamite catchment valued by engaged communities”.***

Regional goals outlined in the strategy are ambitious and work towards targets that apply to a 20-year timeframe. The *‘[management] of water for the environment to improve waterway condition (ENV3)’* is specified as a regional goal with a long-term target of managing environmental water entitlements for priority waterways to maximise environmental outcomes. However, it is noted that this goal did not explicitly apply to the Gellibrand reaches, as the catchment does not have an environmental water entitlement. Regional goals and long-term resource condition targets (limited to species known to be in the Gellibrand catchment) are summarised in Table 24.

**Table 24. Regional goals and long-term resource condition targets (Corangamite Waterway Strategy 2014-2022)**

| Type | Regional Goal                                                                         | Long-term Resource Condition Targets                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| S1   | Maintain or improve waterway condition where it supports high social values.          | High value social attributes of waterways are maintained.                                                                                                                                                                                                                                                                                                                                                                                                                       |
| EC1  | Secure and manage waterways that provide significant economic benefits to the region. | Waterways within special water supply catchments are managed to provide quality water for urban water supplies.<br>Waterways that support licensed diversions for irrigated agriculture are managed to maintain or improve the quality and viability of the resource.                                                                                                                                                                                                           |
| ENV1 | Maintain the viability of populations of threatened native fish species.              | Known populations and habitat of Australian mudfish are maintained or improved.<br>The condition of sites where Yarra pygmy perch currently occur show no further decline.<br>The probability that important Dwarf galaxias populations become self-sustaining is increased.<br>The probability that important Australian grayling populations become self-sustaining is increased.                                                                                             |
| ENV2 | Maintain or improve the resilience of other threatened waterway dependent species.    | Known habitat and breeding sites for populations of threatened wetland dependent bird species are secured from further environmental degradation.<br>All extant populations of the Corangamite water skink are maintained in systems of reserves and/or areas managed specifically for their conservation.<br>Populations of Growling grass frog are secured, particularly those occurring in known breeding habitats.<br>All extant populations of Otway crayfish are secured. |
| ENV3 | Manage water for the environment to improve waterway condition.                       | Environmental water entitlements for priority waterways are managed to maximise environmental outcomes.                                                                                                                                                                                                                                                                                                                                                                         |

| Type | Regional Goal                                                              | Long-term Resource Condition Targets                                                                                                                                                                                                     |
|------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ENV4 | Maintain or improve waterways with formally recognised significance.       | The ecological character of Ramsar wetlands is maintained or improved.<br>The condition of values of nationally important wetlands are (sic) maintained or improved.<br>The listed values of heritage rivers are maintained or improved. |
| ENV5 | Maintain the extent and condition of other significant wetlands (by type). | The condition of freshwater marshes and meadows supporting the seasonal herbaceous wetlands ecological community are maintained or improved.                                                                                             |
| ENV6 | Maintain waterways in near natural condition.                              | All environmental values of near natural rivers and estuaries are maintained.                                                                                                                                                            |

All existing FLOWS study reaches, besides Reach 3a Arkins and First Creeks, are listed as priority waterways in the Corangamite Waterway Strategy, mostly for economic reasons (EC1) and water-dependent species (ENV2) (Table 25).

**Table 25. Regional goals for Gellibrand catchment priority waterways listed in the Corangamite Waterway Strategy (2014 - 2022) (CCMA 2014). Note: Reach 3a Arkins and First Creeks is not listed as a priority waterway in the strategy.**

| Reach number | Name             | Waterway strategy reach ID | S1 Social | EC1. Economic | ENV1. Native fish | ENV2. Waterway dependent Sp. | ENV3. Environmental water | ENV4. Formally recognised | ENV5. Significant wetlands | ENV6. Excellent condition |
|--------------|------------------|----------------------------|-----------|---------------|-------------------|------------------------------|---------------------------|---------------------------|----------------------------|---------------------------|
| 1            | Love Creek       | 35-24                      |           | ●             |                   | ●                            |                           |                           |                            |                           |
| 2a           | Gellibrand River | 35-15, 35-16               | ●         | ●             |                   |                              |                           |                           |                            |                           |
| 2b           | Gellibrand River | 35-14                      |           | ●             | ●                 |                              |                           |                           |                            |                           |
| 2c           | Lardner Creek    | 35 - 23                    |           | ●             |                   |                              |                           |                           |                            |                           |
| 3b           | Carlisle River   | 35-21                      |           | ●             |                   |                              |                           |                           |                            |                           |
| 4            | Gellibrand River | 35-13                      |           | ●             | ●                 |                              |                           |                           |                            |                           |
| 5            | Kennedys Creek   | 35-17                      |           | ●             |                   | ●                            |                           |                           |                            |                           |
| 6            | Estuary          | 35-212                     | ●         |               |                   | ●                            |                           | ●                         |                            |                           |

A range of management activities funded by Corangamite CMA focus on waterways within the Gellibrand Catchment. Management activities differ based location within the Gellibrand River system, including re-vegetation of native, riparian and wetland habitats, fencing, weed and pest control, establishment of management agreements, assessment of recreational native fish habitat, maintenance of citizen science groups and monitoring of existing conditions. Specific actions associated with the delivery of environmental flows include monitoring compliance with bulk entitlements, assessing sediment sources and sinks, investigating options to improve environmental water management, which include an

assessment of options to address summer low flow shortfalls (as identified in the WRSWS) and the impacts to environmental flows throughout the broader Otway Coast catchment basin.

## 5.9 Gellibrand River estuary management plan

A Gellibrand River estuary management plan (EMP) (CCMA 2017) was developed by the Corangamite CMA and the Victorian Government in 2017, with the following goal *"the management condition of the Gellibrand River estuary is maintained or improved, promoting a healthy, rich and diverse wetland and estuarine ecosystem and supporting long-term sustainable use"*. Two EMP objectives are particularly relevant for the FLOWS study:

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Gellibrand River estuary management plan objectives:

1. The diverse native vegetation communities and wildlife of the estuary are protected and enhanced.
  2. Water flows support estuary values and the quality of water entering the estuary improves over time.
- 

Key ongoing management actions in the EMP include work to investigate options to improve summer low flows and to protect and enhance stands of remnant Ecological Vegetation Classes (EVCs) on private and public land at the estuary, with a particular focus on those that are threatened. It is noted too that in 2018, the estuary itself was listed as an endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999 (Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria)*, with conservation advice for protection, conservation and recovery actions. A key flow-related 'restore' action under the listing is to:

***"restore natural or typical river flows with seasonal high and low flow cycles"*** (DCCEEW 2018).

## 5.10 Dedicated Gellibrand low flow investigations

As noted above, the WRSWS, CGRSWS and EMP have actions to improve summer / low flows in the Gellibrand River, particularly in lower reaches (Reach 4 and estuary). The improvement of low flows is therefore a management priority and has been the focus of several dedicated studies. A 2010 options assessment by GHD evaluated several options to improve flows downstream of the North Otway and South Otway pump stations, including groundwater substitution and storage augmentation. The study was followed by an Alluvium investigation (Alluvium 2012) to improve supply security and address summer flow stress in the Gellibrand River. The investigation found that the lower Gellibrand River's minimum summer low flow requirements are mainly driven by the estuary which, based on the 2008 EEFA study (Lloyd et al. 2008), requires flows of around 100 ML/d to maintain mouth openings and control the salt wedge.

A Gellibrand estuary low flow investigation by Alluvium 2017 examined relationships between summer / autumn low flows, estuary mouth status and water quality (dissolved oxygen) to guide decision-making

around the artificial opening of the estuary and to inform understanding of risks to aquatic life. Key findings related to low flows is that flow below 100 ML/day would lead to rapid estuary mouth closure, while flows > 150 ML/day are predicted to prolong the duration of open mouth status (> 1 month). This study cast doubt on the whether the current 100 ML/day summer/autumn low flows recommendation (based on the 2008 Estuary Environmental Flows Assessment) can achieve the environmental objective to 'keep the estuary mouth open'.

The summer / autumn low flow recommendation was intended to *prolong* an open mouth state. The recommendation was not intended to keep the mouth open in perpetuity, nor was it intended to open a closed mouth, although neither is explicitly stated in the recommendations of the 2008 EEFAM study or the 2006 FLOWS study. Agency representatives and the EFTP note that ambiguous wording of the 2008 EEFAM low flow objective sets unrealistic expectations (within the community and agencies) as to what low flows in the estuary could achieve with respect to estuary mouth state and dynamics.

## 5.11 Project Advisory Group expectations and preferences

On 24 November 2025, the Project Advisory Group (PAG) for the Gellibrand River FLOWS study met at Echidna House, Kawarren to discuss the development of environmental flow objectives. This workshop followed earlier meetings to introduce the project (6 March 2025), discuss Gellibrand catchment values and threats (19 June 2025) and discuss the hydrologic model developed to inform the FLOWS Study (24 September 2025). PAG representatives have noted a decline in flow and ecological condition across the catchment and were consistent in their desire to see 'improvements' in environmental condition as opposed to 'maintenance' of current condition through environmental flows. The PAG vision is for catchment values to 'be the best they can be', with the condition of values continually improving into the future. The EFTP has taken this vision on board in the development and refinement of environmental objectives.

The PAG has expressed concerns about the quality of some of the streamflow data used to build the hydrologic model and a lack of confidence in the ability for hydrologic modelling to reflect reality. Specific concerns raised regarding the hydrologic model are addressed in Appendix A.3.2.

The PAG has also expressed concerns about the scope of the FLOWS study and that this method focuses on developing minimum rather than optimum flow targets. To help with this, the assumptions and limitations of applying the FLOWS method are discussed in Appendix 4. Broader assumptions and limitations will be fully addressed in the recommendations report.

## 6 Environmental flow objectives

### 6.1 Aquatic fauna

The Gellibrand catchment supports particular groups of aquatic species which are dependent on river flows including freshwater fish (e.g. River blackfish), estuarine-dependent fish (e.g. Short-finned eels and Australian grayling), and estuarine residents (e.g. Black bream) (Lloyd 2008), along with aquatic invertebrates. The catchment is also known to support a state significant population of River blackfish, for which recruitment over the past 20 years appears to be declining and is not well understood (Earth Tech 2006a; ARI 2025). Australian grayling are threatened at the state and national level (endangered and vulnerable, respectively). They are known to occur in the Gellibrand River mainstem and are catadromous, with juveniles migrating upstream to freshwater environments for growth and adults migrating downstream to spawn. This species has been captured consistently, with some evidence of increased distribution, through long-term fish monitoring programs (ARI 2025).

Platypus are listed as vulnerable in Victoria and are an icon species for the region, and although population dynamics are largely unknown, they are an important value to consider for environmental flows (CCMA 2024). Rakali whilst widespread, are also an important cultural species to consider. Freshwater crayfish species (*Euastacus*, *Engaeus*, and *Geocharax*) are also widespread throughout the catchment with population dynamics largely unknown (Eastern Maar Aboriginal Corporation Pers Comm. April 2026).

Environmental objectives for aquatic fauna focused on both particular and generic values associated with the Gellibrand catchment. Generic values, such as broad fish groups and macroinvertebrates, and then specific values, such as River blackfish, Short-finned eels, Australian grayling, Crayfish and Platypus. The latter are values important to the community or ecosystem, threatened, widespread and/or for which information on population dynamics and flow requirements are better understood. Flow objectives focus on the flow components (magnitudes, timing, frequency and duration) that are required to support habitat, food web and life cycle requirements for aquatic fauna species.

#### 6.1.1 Environmental objectives to support aquatic fauna

|     |                                                                                                                    |
|-----|--------------------------------------------------------------------------------------------------------------------|
| F1  | Maintain abundance and diversity of native fish assemblage                                                         |
| F2  | Improve abundance of River blackfish                                                                               |
| F3  | Maintain self-sustaining populations of freshwater fish (Galaxias, Gudgeon, Pygmy perch, Blackfish)                |
| F4  | Maintain self-sustaining populations of migratory species (Australian grayling, Short-finned eel, Lamprey, Tupong) |
| F5  | Maintain self-sustaining populations of estuarine residents (Estuary perch, Black bream)                           |
| F6  | Maintain connection to the estuary and marine environment                                                          |
| F7  | Maintain estuary habitat                                                                                           |
| FC1 | Maintain self-sustaining populations of freshwater crayfish                                                        |
| P1  | Improve condition and extent of Platypus population                                                                |

|    |                                                                    |
|----|--------------------------------------------------------------------|
| R1 | Maintain self-sustaining populations of Rakali                     |
| M1 | Maintain self-sustaining populations of aquatic macroinvertebrates |

Alignment of aquatic fauna objectives with catchment policy and strategy is detailed in Table 26.

**Table 26. Alignment of aquatic fauna objectives with policy and strategy**

| Objective | Policy / strategy                     | Detail                                                                                                                                                                                                                                                                                 |
|-----------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| F1        | ENV1                                  | Maintains the viability of populations of threatened native fish species.                                                                                                                                                                                                              |
| F2        | ENV1                                  | Maintains the viability of populations of threatened native fish species.                                                                                                                                                                                                              |
| F3        | S1                                    | Maintains waterway condition to support social values.                                                                                                                                                                                                                                 |
| F4        | EPBC 1999<br>ENV1                     | Supports EPBC-listed fish species (Australian grayling).                                                                                                                                                                                                                               |
| F5        | EPBC 1999<br>ENV1                     | Supports EPBC-listed ecological community and species.<br>Maintains the viability of populations of threatened native fish species.                                                                                                                                                    |
| F6        | EPBC 1999<br>RCS OtW07<br>RCS W04     | Supports the Gellibrand estuary threatened ecological community and threatened species.<br>Supports water quality in Gellibrand estuary.                                                                                                                                               |
| F7        | RCS W05<br>OtW07<br>EPBC 1999<br>ENV4 | Contributes to the maintenance of water quality in the Gellibrand estuary (a priority).<br>Objective aligns with protection of the estuary, which is a threatened ecological community under the EPBC Act 1999.<br>Supports waterways (estuary) with formally recognised significance. |
| FC1       | RCS W09                               | Objective contributes to the extent of in-stream habitat for resilience of waterway dependent species.                                                                                                                                                                                 |
| P1        | FFG Act 1988<br>ENV2                  | Supports the resilience of threatened waterway dependent species.<br>Aligns with Vic FFG Act 1988, supporting vulnerable species.                                                                                                                                                      |
| R1        | RCS W09                               | Objective contributes to the extent of in-stream habitat for resilience of waterway dependent species.                                                                                                                                                                                 |
| M1        | RCS OtW02<br>RCS W01, W04<br>ENV5     | Supports improvement of water quality in Otway Coast priority waterways.<br>Supports connection of waterways, riparian zones, floodplains, wetlands and billabongs.                                                                                                                    |

## 6.1.2 Rationale for the development of flow objectives to support aquatic fauna

### Freshwater fish

Flow objectives for freshwater fish are designed to support the diverse species in the catchment, and target maintenance of habitats (refuge/pools, runs/riffles). Water depths of 20cm have been used for small-bodied fish, 40cm for large-bodied fish and 50cm for Blackfish (Earth Tech 2006b). Freshes are required to maintain or improve water quality within the pool habitats, and allow for fish movement and the redistribution of fish post low flow periods. Flows for the latter are typically set by determining required depth of water over critical shallow areas (12 to 20cm for small and large fish species, respectively) (Earth Tech 2006b). The main spawning period for non-migratory fish species in the

Gellibrand River is between spring and summer (Koehn and O'Connor, 1990). Most smaller species lay eggs either on the riverbed substrate or on vegetation, so regular flushes of water are required in the lead up to the breeding season to prevent excessive sedimentation of spawning substrates (Earth Tech 2006b).

Objectives targeting Blackfish are designed to improve the abundance and distribution of this species in the Gellibrand River, as recent surveys have consistently reported a lack of juveniles and hence recruitment within the main stream (ARI 2015; 2025). This decline appears to have occurred since 1990. Whilst tributaries largely maintain habitat for Blackfish (plentiful instream woody debris, variety of water depths/velocities and minimal siltation), the mainstem has high sedimentation, which infills holes and smothers instream habitat (ARI 2015). River blackfish lay eggs in hollow logs or between boulders. Freshes during spring and summer are important for maintaining adequate water quality for larval, juvenile and adult survival and to prevent sedimentation of larval and juvenile habitats (Earth Tech 2006b). The presence and maintenance of woody debris and boulder habitat is critical for survival and abundance of Blackfish in the Gellibrand River.

## **Migratory fish**

Many migratory species require rises in flows during the breeding season to initiate spawning and migration. Flows that provide a spawning cue and adequate depths for migration of spawning adult fish are required during the autumn spawning/migration period (Earth Tech 2006b). Provision of environmental flows (freshes) in summer and autumn has been shown to significantly improve the upstream migration of juvenile Short-finned eels, as well as young of year Common galaxias in nearby Moorabool and Glenelg catchments (Amtstaetter et al. 2021a). Upstream migration of juvenile life stages is a critical process governing the populations of these diadromous fish. Ecological benefits of increased upstream movement include: reduced density-dependent mortality in lower stream reaches; increased abundance and resilience; increased spawning stock and typically recruitment; improved access to habitat important for survival and growth.

Likewise, freshes delivered in spring have been linked to similar results in other parts of Victoria (Amtstaetter et al. 2021b). Both catadromous and anadromous fishes in temperate southern Victoria have evolved to detect spring freshwater flows to initiate their upstream migration into rivers (Mallen-Cooper & Zampatti 2018). Individual discharge events may also impact the number of juveniles migrating. Amtstaetter et al. (2021b) found relatively strong support for a positive relationship between catch rates and discharge 22-30 days prior to sampling in the Werribee River.

Anguillid eels (including Short-finned eels) are long lived (10-25 years, varying with species and location), with sexually mature adults migrating out to the Coral Sea to spawn at depths >300 m (Gooley et al 1999). Larval eels (leptocephali) are carried on ocean currents back to the Continental Shelf where they metamorphose into 'glass eels' (12-18 months of age). The glass eels are carried by tides into estuaries where they undergo development into Elvers (one to three years of age), which then migrate into freshwater reaches where they grow and sexually mature. Adult Short-finned Eels are known to have a relatively small home range (400 m) for 10-20 years while growing (VFA 2026). The maintenance of habitats over an extended period is therefore essential.

River water temperature is important for adult Short-finned eel migration into freshwater from the sea, with August and Hicks (2008) showing that eels prefer water temperatures between 12°C and 20°C, with

water <12 °C and >22 °C almost completely inhibiting migration. Some studies have shown links to moon phase, with the new moon corresponding to peak migration of glass eels (Jellyman and Lambert 2003). August and Hicks (2008) state that it is unclear whether it is the moon phase itself or a correlated environmental factor, such as tides, that is the cue for migration. Crook et. al. (2014) reported that Short-finned eel movement from freshwater to estuaries primarily occurs at night, with increased frequency over summer and following high freshwater inflows (Crook et. al. 2014). Short-finned eel movement from estuaries to the sea was influenced primarily by lunar phase and to a lesser degree by water temperature, taking place from late summer to early autumn (Crook et. al. 2014). As lunar cycle influences on Short-finned eel migration are not consistent across waterways, specific studies in the Gellibrand catchment would be required to inform development flow objectives for lunar cycles.

The Australian grayling (*Prototroctes maraena*) is a nationally threatened diadromous fish that inhabits coastal rivers in south-eastern Australia. Adult fish mature and spawn in freshwater, and the eggs and larvae drift downstream to the sea, with juveniles migrating back into freshwater (Koster et al. 2013). Recent research has indicated that increased flows (within channel flow pulses) in autumn (March to May) are a key determinant of downstream migration and spawning of Australian grayling (Koster et al. 2013). Koster et al. (2017) found that for Australian grayling, it is not necessarily the volume of water released that is important, but how the flow is delivered. Peak spawning occurred in late autumn and was positively related to flow duration (longer-duration flow events (rising limb 5 days) were associated with greater spawning activity. Longer flow events are likely to allow for long-distance adult migration to spawning areas in downstream river reaches. High flow pulses in spring are also critical to support other life stages of this species (e.g. trigger upstream migration of young of year) (Koster et al 2017).

Tupong are diadromous fish found in freshwater and estuaries. Mature female tupong undertake a downstream migration from the freshwater reaches into the estuary during the spawning period of late May to late July. Crook et. al. (2010) found fish undertook rapid downstream migration then moved through the estuary and out to sea between May and August, suggesting spawning occurs at sea. Migration cue was associated with high river discharge (fresh) during the winter period and movement from the estuary to the sea tended to occur most frequently during intermediate moon phases. Outside the spawning season (September to April) tupong exhibited low rates of movement and inhabited restricted home ranges. Crook et. al. (2010) supports the provision of winter freshes as migration cues and maintenance of passage through estuarine entrances as important considerations for the conservation of tupong in flow-managed rivers.

## Estuarine fish

Fish interact with a wide variety of habitats in the estuary and respond to a wide variety of flow-related cues such as river discharge, velocity, temperature, salinity and water level. The Gellibrand estuary supports estuarine residents, estuarine dependents (typically migratory species) and estuarine opportunist fish species, with the first two groups the focus of flow recommendations. Black bream and estuary perch represent estuarine residents who complete their life cycle in the estuary but may move upstream to freshwater reaches for short periods. Black bream have wide salinity tolerances (Kailola et al 1993). Spawning is from August to December and likely occurs in the upper reaches of the estuary at the fresh/salt interface (Ramm, 1986), however the flow and water quality requirements for successful spawning and survival of eggs/larvae are not well understood (Lloyd et al 2008). Shallow seagrass and macrophyte beds are important nursery areas for juvenile bream. Maintenance of the salt wedge is likely

to be critical for the species in providing appropriate salinities and habitat for spawning (salinity between 15 and 20).

Flow objectives for estuarine residents are adapted from Lloyd et al. (2008), and focus on maintaining appropriate estuarine salinity ranges, the salt wedge and dissolved oxygen concentrations to support eggs and larval development (also see objectives for Black Bream, Table 33).

### **Freshwater crayfish**

Spiny crayfish thrive in areas with abundant instream debris and vegetation, essential for survival. The species provides an important food source for other aquatic fauna and are important processors of organic matter (NSW DPI 2013). A genome skimming study by Austin et al. (2026), revealed divergent lineages Southern Victorian spiny crayfish (*Euastacus yarraensis*) populations, such that western populations found in Love Creek and the Gellibrand River are sufficiently different to eastern populations (Barwon River basin) to warrant recognition as different species. They are long-lived and slow-growing, breeding in late winter-early spring, and building burrows on the water's edge. Spiny crayfish require cool, clear flowing water, and the maintenance of water quality and flushing of habitat to prevent siltation and support for riparian vegetation are important (Whiterod et al., 2022).

Burrowing crayfish (i.e. *Geocharax* and *Engaeus*) typically have surface entrances on stream banks or in swampy areas, often with minimal surface water. Burrows can be 0.35 – 2 m into the water table (Australian crayfish project 2015). Whilst not directly flow dependent, they are reliant upon the retention of soil moisture and swampy conditions, and good water quality. These species are impacted mainly by local agricultural practices (NRE, undated).

### **Aquatic Macroinvertebrates**

The Gellibrand catchment has a high diversity of aquatic macroinvertebrates which typically declines in a longitudinal fashion (Vertessy and Cameron 1998). Major impacts on macroinvertebrate fauna include loss of instream habitat, removal of native vegetation and turbidity in high flows. Maintenance of the macroinvertebrate communities requires maintenance of suitable low flow in all reaches at all times (Earth Tech 2006b). The low flow should be sufficient to inundate the major habitats including bed (keep damp, inundate leaf packs and woody debris), edge (inundate fringing vegetation) and riffles/runs (flowing water).

In addition to low flows, freshes are required to prevent the build-up of fine sediment on the bed of riffle habitats, to improve pool water quality during summer (through pool turnover and preventing stratification), and to disturb biofilms on rocks, woody debris in winter to maintain habitat and diversity of food sources (Earth Tech 2006b). High flows that inundate benches and overbank flows are also required to entrain organic material from outside the channel.

### **Platypus**

Platypus environmental objectives aim to improve the abundance and distribution of the platypus population. However, population improvements may well be dependent on catchment-scale processes. Environmental flows may therefore only support, rather than improve current populations.

Platypus are aquatic predators that establish territories, and construct burrows in the banks. Platypus consume a variety of invertebrate prey from the sediments in a range of habitats including lakes, rivers

and streams. They forage, primarily at dawn and dusk, in water between 15 cm and 200 cm deep. Platypus may forage for up to half the day, spending the remaining time in their burrows. In Victoria, platypus breed in September, at which time the females construct a nesting burrow that is plugged with earth to provide protection from flooding and predators (Alluvium 2024b).

Flow requirements for Platypus have been determined by Jacobs et al. (2016) and include:

- Limiting spring freshes to one-day duration and eliminating high or overbank flows in summer to protect nesting burrows and juveniles.
- Suitable habitat extent and availability to food resources is critical at all times.
- Riffles are important foraging sites due to prey abundance, and a minimum depth over riffles should be maintained. Scouring lows are also required to maintain these habitats.
- Runs are also likely important foraging habitats.
- Platypus will also benefit from the flow requirements proposed for macroinvertebrates by providing a diverse and abundant food resource.

## **Rakali**

Rakali are widely distributed and inhabit permanent water bodies including rivers, creeks, wetlands, lakes and estuaries (Alluvium 2024b). Its diet consists of insects, with some crustaceans, molluscs, fish, frogs and turtles. They live in burrows on the edge of waterways. Flow requirements for this species revolve around maintenance of pool and riffle habitat (water depth to support movement and habitat availability for territory establishment) and maintenance of food resources. Rakali also need healthy riparian vegetation and solid river banks, with minimal erosion (McKenna and Lovett, Undated).

### 6.1.3 Flow objectives to support aquatic fauna values

Table 27. Flow objectives for aquatic fauna

| Value     | Environmental objective                                                                             | Reach                                                     | Flow process /function                                       | Flow component     | Timing                           | Hydraulic criterion                                                                             | Reference(s)                           |
|-----------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------|--------------------|----------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------|
| Fish (F1) | Maintain abundance and diversity of native fish assemblage                                          | All                                                       | Habitat availability for all life stages (run/glide habitat) | Low flow           | All year                         |                                                                                                 |                                        |
|           |                                                                                                     |                                                           | Habitat availability for all life stages (riffle habitat)    | Low flow           | Summer - autumn                  | 10 cm depth over riffles                                                                        | Earth Tech (2006b)<br>Alluvium (2024b) |
|           |                                                                                                     |                                                           | Maintain water quality                                       | Low flow and Fresh | Summer - autumn                  | Velocity and pool turnover adequate to prevent water quality decline                            | See Geomorphic objectives              |
| Fish (F2) | Improve abundance of River blackfish                                                                | 1-5                                                       | As above for objective F1                                    |                    |                                  |                                                                                                 |                                        |
| Fish (F3) | Maintain self-sustaining populations of freshwater fish (galaxias, gudgeon, pygmy perch, blackfish) | 1-5                                                       | Habitat availability for small-bodied fish                   | Low flow           | All year                         | % wetted area                                                                                   |                                        |
|           |                                                                                                     |                                                           | Habitat maintenance - water quality                          | Low flow           | Summer - autumn                  | See above                                                                                       |                                        |
|           |                                                                                                     |                                                           | Refresh water quality and flush habitat                      | Fresh              | Summer - autumn                  | See above                                                                                       | Alluvium (2024)                        |
|           |                                                                                                     |                                                           | Facilitate local movement                                    |                    |                                  | 10 cm depth above low flow                                                                      |                                        |
|           |                                                                                                     |                                                           | Flush/disturb habitat<br>Facilitate local movement           | Fresh              | Winter -spring                   | Velocity and shear stress adequate to remove deposited fine sediments (critical values unknown) | See geomorphic objectives              |
|           |                                                                                                     | Gellibrand mainstem where billabongs and floodplain exist | Inundate floodplain and billabong/wetland habitats           | Overbank           | Winter- spring, Chinnup, Larneuk | Bankfull / Overbank<br>Inundate floodplain and billabong habitats                               |                                        |
| Fish (F4) | Maintain self-sustaining populations of migratory species (Australian grayling,                     | 1-6                                                       | Habitat availability                                         | Low flow           | All year                         | Pools remain full (min 30 cm depth for Grayling)                                                | Earth Tech (2006b)                     |
|           |                                                                                                     |                                                           | Prevent water quality decline (mixing and destratification)  | Low flow and Fresh | Summer - autumn                  | Velocity and pool turnover adequate to prevent water quality decline                            | See geomorphic objectives              |

| Value                     | Environmental objective                                                                  | Reach | Flow process /function                                                                                                | Flow component | Timing                                  | Hydraulic criterion                                                                                                              | Reference(s)                                                               |
|---------------------------|------------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------|----------------|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
|                           | Short-finned eel, Lamprey, Tupong)                                                       |       | Facilitate upstream migration of juvenile eels, facilitate downstream migration of mature eels for spawning migration | Fresh          | Late summer - autumn, Kooyang           |                                                                                                                                  | Crook et al (2014)<br>Amtstaetter et al (2021a)                            |
|                           |                                                                                          |       | Facilitate migratory movement (galaxias and grayling)                                                                 | Fresh          | Early winter                            | Riffles at flow of 2-4 m/s, sustained swimming 0.6 m/s<br>Prefer 0.2 to 0.35 m/sec<br>15 cm depth above winter - spring low flow | Mallen-Cooper & Zampatti (2018)<br>Alluvium (2024b)<br>Amtstaetter (2021b) |
|                           |                                                                                          |       | Stimuli for spawning (grayling)                                                                                       | Fresh          | Late autumn to winter                   | No criterion. Median seasonal flow may be used as surrogate. Flows to maintain estuary mouth open conditions.                    | Amtstaetter (2021b)<br><br>Koster et al (2017)                             |
| Fish (F5)                 | Maintain self-sustaining populations of estuarine residents (Estuary Perch, Black Bream) | 6     | Maintain salinity range for estuarine fish                                                                            | Low flow       | All year                                | Salinity range of 5 ppt to 30 ppt present over at least 50% of longitudinal section 80% of the time based on current conditions  | Lloyd et al (2008)                                                         |
|                           |                                                                                          |       | Salt wedge (& DO) for eggs/larval development                                                                         | Low flow       | Summer - autumn                         | Halocline between 15-25 ppt with in the estuary (Top waters <10, bottom waters >25)<br>DO >3.5 mg/L in waters of 25 ppt          | Lloyd et al (2008)                                                         |
| Fish (F6)                 | Maintain connection to the estuary and marine environment                                | 6     | Migratory movement / predominantly open mouth                                                                         | Low flow       | Winter -spring, Gwangal moronn, Kooyang |                                                                                                                                  | Lloyd et al (2008)                                                         |
| Fish (F7)                 | Maintain estuary habitat                                                                 | 6     | Maintain water quality                                                                                                | Low flow       | Summer - autumn                         |                                                                                                                                  | Lloyd et al (2008)                                                         |
|                           |                                                                                          |       | Refresh water quality and flush habitat                                                                               | Fresh          | Summer - autumn                         |                                                                                                                                  | Lloyd et al (2008)                                                         |
|                           |                                                                                          |       | Flush/disturb habitat                                                                                                 | Fresh          | Winter -spring                          |                                                                                                                                  | Lloyd et al (2008)                                                         |
| Freshwater crayfish (FC1) | Maintain self-sustaining                                                                 | All   | Maintain water quality                                                                                                | Low and Fresh  | Summer - autumn                         | Velocity and pool turnover adequate to prevent water quality decline                                                             | See geomorphic objectives                                                  |

| Value                   | Environmental objective                                    | Reach | Flow process /function                                                 | Flow component | Timing                                                         | Hydraulic criterion                                                                                                      | Reference(s)                          |
|-------------------------|------------------------------------------------------------|-------|------------------------------------------------------------------------|----------------|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
|                         | populations of freshwater crayfish                         |       | Maintain wet/moist habitat (including groundwater connectivity)        | Low flow       | All year                                                       | Maintain wet bed                                                                                                         |                                       |
| Platypus (P1)           | Improve condition and extent of Platypus population        | 1 - 6 | Habitat connectivity - pools                                           | Low flow       | All Year                                                       | No fixed criteria - riffle and run flows will maintain pool depths                                                       | Alluvium (2024b); Jacobs et al (2016) |
|                         |                                                            |       | Maintain riffle habitat                                                | Low flow       | All Year                                                       | 10 - 30 cm depth over riffles                                                                                            |                                       |
|                         |                                                            |       | Habitat maintenance and longitudinal connectivity                      | Low flow       | Summer - autumn                                                | Velocity and shear stress adequate to remove deposited fine sediments (critical values unknown)                          |                                       |
|                         |                                                            |       | Maintain gravel beds and flush silt                                    | Fresh          | Spring                                                         |                                                                                                                          | Alluvium (2024b)                      |
| Rakali (R1)             | Maintaining self-sustaining populations of Rakali          |       | As for Platypus                                                        |                |                                                                |                                                                                                                          |                                       |
| Macroinvertebrates (M1) | Maintain self-sustaining populations of macroinvertebrates | All   | Maintain habitat availability (pool, riffle, slackwater)               | Low flow       | All year                                                       | 10 cm depth over riffles, inundate leaf packs and CWD<br>Maintain wet bed<br>Connectivity between habitat (edge to edge) | Earth Tech (2006b)                    |
|                         |                                                            |       | Maintain habitat condition (Water quality / sediment)                  | Low flow       | Summer - autumn                                                | Maintain water quality                                                                                                   | Earth Tech (2006b)                    |
|                         |                                                            |       |                                                                        | Fresh          | Summer - autumn                                                | Mobilise silt/sediment from surfaces<br>Maintain water quality<br>Inundate fringing veg/CWD                              | Earth Tech (2006b)                    |
|                         |                                                            |       | Disturb biofilm and LWD/flush habitat to prevent sediment accumulation | Fresh          | Winter -spring                                                 | Mobilise silt/sediment from surfaces<br>Maintain WQ in pools                                                             | Earth Tech (2006b)                    |
|                         |                                                            |       | Entrain terrestrial carbon                                             | Overbank       | Anytime (typically occur winter -spring) - Chinnup and Larneuk | Bankfull/overbank                                                                                                        | Earth Tech (2006b)                    |

## 6.2 Vegetation

### 6.2.1 Environmental objectives to support vegetation

|    |                                                                                                                           |
|----|---------------------------------------------------------------------------------------------------------------------------|
| V1 | Maintain, and where possible improve, algal biofilms on submerged rocks and coarse woody debris (CWD).                    |
| V2 | Maintain, and where possible improve, submerged and floating-leafed plants in stream channel.                             |
| V3 | Maintain, and where possible improve, water-dependent mosses and small ferns growing on exposed CWD and along lower bank. |
| V4 | Maintain, and where possible improve, damp microclimates in riparian zone.                                                |
| V5 | Maintain, and where possible improve, emergent aquatic plants on lower benches and banks.                                 |
| V6 | Maintain, and where possible with complementary actions improve, condition and extent of vegetation in the riparian zone. |
| V7 | Inundate wetland depressions on the floodplain on a seasonal basis.                                                       |

The environmental objectives are designed to support the major functional types of Indigenous flow-dependent vegetation described for each reach. Alignment with catchment policy and strategy is detailed in Table 28. The rationale for the development of flow objectives to achieve environmental objectives for vegetation is provided in the following section.

**Table 28. Alignment of vegetation objectives with policy and strategy**

| Objective | Policy / strategy                       | Detail                                                                                                                                                                                                                                                    |
|-----------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| V1        | RCS WO9                                 | Recognises the supporting role played by algal biofilms in habitats, food webs and aquatic fauna. Aims to increase the extent of in-stream habitat.                                                                                                       |
| V2        | RCS WO9                                 | Aims to increase the extent of in-stream habitat for resilience of threatened native fish and waterway dependent species                                                                                                                                  |
| V3        | RCS WO9                                 | Aims to increase the extent of in-stream habitat for resilience of threatened native fish and waterway dependent species.<br>Recognises the importance of flows for maintaining damp soils and microclimates on bank and riparian zones.                  |
| V4        | EPBC 1999                               | Objective recognises the connectedness of water across the landscape, providing for damp microclimates and terrestrial species dependent upon damp microclimates and soils.                                                                               |
| V5        | RCS WO9                                 | Aims to increase the extent of in-stream habitat for resilience of threatened native fish and waterway dependent species.                                                                                                                                 |
| V6        | RCS WO1 and<br>OtwWO2                   | Improves riparian extent and condition.                                                                                                                                                                                                                   |
| V7        | RCSWO1<br>RCS WO4<br>OtwWO2<br>CWS ENV5 | Maintains and improves the condition of wetlands and riparian extent and condition.<br>Support seasonal herbaceous wetland ecological communities in the reach.<br>Recognises the connectedness between channels and floodplains and off-stream habitats. |

Many threats to flow-dependent vegetation are a function of non-flow factors (riparian land use, weed infestation, poor water quality, climate change and bushfires) which limit the ability to achieve improvements through flows alone. Where the provision of flows is not supported by non-flow complementary actions, flow recommendations are not anticipated to lead to improvements of vegetation condition. In recognition of the PAG's vision for catchment values 'to be the best they can be', wording is to 'maintain, and where possible improve'.

## 6.2.2 Rationale for the development of flow objectives to support vegetation

Water-dependent vegetation typically requires a suite of flow components in order to maintain adult plants, facilitate sexual recruitment, and facilitate the distribution of seed or stem fragments for asexual reproduction, and thus continuity of the population. Plants in different parts of the waterway typically have different flow requirements, and in this context, it is customary to differentiate between different plant functional groups and settings (Brock & Casanova 1997, 2000; Casanova 2011; Roberts & Marston 2011; Tonkin et al. 2020):

- Submerged and floating-leaved species growing in the stream, adults of which typically do not tolerate desiccation (e.g. Water Ribbons, *Cycnogeton procerum*).
- Semi-aquatic fringing species that are often amphibious and can tolerate alternating flooding and drying cycles (e.g. knot-weeds, *Persicaria* spp.).
- Fringing emergent plants that are often tall and rhizomatous and like the semi-aquatic fringing species, can tolerate alternating flooding and drying cycles (e.g. reeds such as Common Reed, *Phragmites australis*; rushes Giant Rush, *Juncus ingens*; and sedges such as Tall Sedge, *Carex appressa*).
- Riparian plants growing along the river bank and including a wide range of ground-layer species (e.g. grasses), shrubs (e.g. bottle-brushes, *Callistemon* spp.; paperbarks, *Melaleuca* spp.; and tea-trees, *Leptospermum* spp.) and trees (e.g. River Red Gum, *Eucalyptus camaldulensis*).
- Wetland plants growing in floodplain depressions and other types of wetlands.

These different functional groups and settings generally have contrasting wetting and drying requirements, in keeping with their position in the landscape. Submerged plants, such as Eelweed, generally require near-constant inundation for two reasons: (i) their vegetative organs (e.g. leaves) are intolerant of desiccation and quickly die if exposed to the air, and (ii) these organs lack supportive tissue, being suspended in the water at most times, and thus cannot remain erect and functional in the absence of water. Many submerged plants, however, possess long-lived rhizomes or roots in the sediments that withstand prolonged dry periods and resprout when re-flooded (e.g. the turions of Water ribbons, *Cycnogeton procerum*).

In contrast, the fringing emergent rushes, reeds and sedges are all rigid to some extent and so can remain in an upright aerial position in the absence of water and thus continue to photosynthesize. Differences in the tolerance to inundation and desiccation explain the positioning of different species up the elevational gradient from the waterway. For example, Common reed (*Phragmites australis*) has a very wide hydrological niche and is found in a wide range of contrasting riparian conditions, but Giant rush (*Juncus ingens*) almost always requires near-constant inundation and so is found mostly growing in the wetter regions of the streamside zone.

Woody riparian plants growing in the riparian zone generally have the least requirement for inundation, as they are to variable degrees tolerant of dry conditions and of episodic or shallow flooding (e.g. see Roberts and Marston 2011). None, however, can tolerate constant inundation or prolonged dryness. Sexual reproduction is often enhanced by flooding, and many riparian trees (e.g. River red gum, *Eucalyptus camaldulensis*) show cohorts of sexual recruitment, visible as young seedlings, coinciding with flooding high-water marks.

Terrestrial plants, which are typically intolerant of flooding or frequent inundation, are located higher up the banks or adjacent to the waterway (Brock and Casanova, 1997). This vegetation is not considered in environmental water studies, as it is reliant on soil moisture, rather than on direct surface water flows. Note that some genera of plants that are commonly considered "water-dependent" can include large numbers of terrestrial species (e.g. *Juncus spp.*).

Different flow components play different functions in maintaining water availability and quality. Tonkin et al. (2020) developed a simple but effective summary of functions of these various flow components (Figure 31).

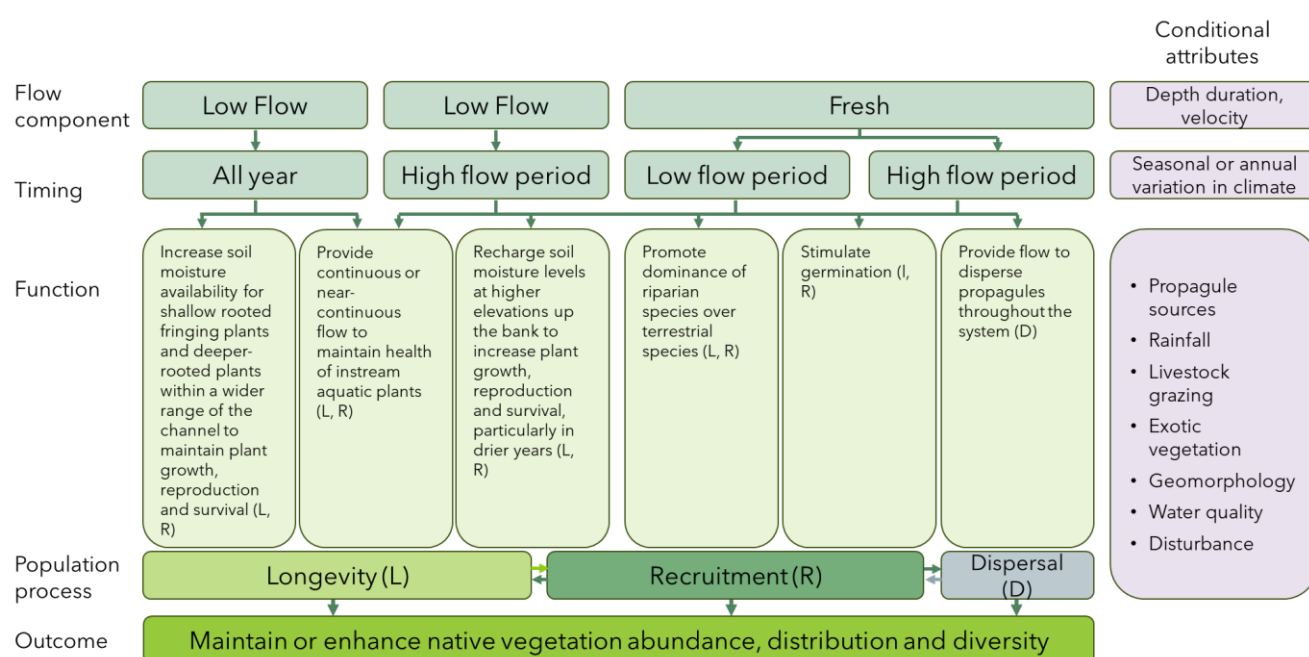


**Figure 31. Conceptual model outlining the function of various flow components in maintaining water-dependent vegetation. Adapted from Tonkin et al. (2020, Figure 3.2.10).**

In the headwaters particularly of the Gellibrand system, two additional vegetation types have to be considered:

- Algal biofilms growing on submerged surfaces such as rocks and trees (Vannote et al. 1980).
- Mosses and ferns growing alongside the waterway and kept wet by water splashing off rocks and other exposed features and further facilitated by the cool, shaded and constantly humid conditions in this special and unusual microclimate.

These two vegetation types are rarely considered in environmental water studies, probably because they are characteristic of upland or headwater streams, and most flows studies are concerned with the mid-level or lowland reaches of a river. The role of headwater streams in the Gellibrand River system in maintaining humid microclimates in which plants such as tree-ferns can grow is also an aspect of environmental water studies that is not addressed in studies of lowland river systems (Jacobs 2020). The health of terrestrial plants in wet forest, such as Arkins and First Creeks, does rely on soil and atmospheric moisture which will be influenced by local waterways.

The algal biofilms attached to hard surfaces such as submerged rocks and dead plant material play a critical role in maintaining aquatic food webs in shaded upland streams such as Arkins and First Creeks and upstream parts of Reach 2a of the Gellibrand River. They provide an easily digested form of organic matter: the leaves and bark from riparian trees that fall into the stream are, in comparison, far harder to digest, and in these cases it is the microbial films developing on the leaves that provides aquatic invertebrates such as mayflies and caddis flies with much of their food supply (e.g. Lock 1983; Lock et al. 1984). These biofilms require almost constantly wet conditions, as the algae and fungi that they are composed of are killed by desiccation. They also often require short periods of high shear stress provided by periodically rapid water flow in order to turn over the exposed surfaces and scour away existing biofilms, thus creating new surfaces for colonisation. Similarly, the maintenance of cool, humid conditions needed for the fringing mosses and ferns requires constant water availability and episodic freshes (to inundate previously exposed surfaces).

The freshwater reaches of the Gellibrand River system are slightly unusual from two other perspectives: (i) they possess few values directly associated with water-dependent vegetation, and (ii) in many cases the critical threats are not flow-related. About the first matter, in-stream submerged or floating-leaved vegetation, for example, is scarce and often restricted to a few specimens of Water ribbons. Similarly, the structurally and floristically diverse suite of reeds, rushes and sedges that typically occur along the shallow fringes of a waterway are largely absent, and a range of weeds (e.g. blackberry) have taken their place. A wide and well-vegetated riparian zone is also largely absent, and many non-hydrological factors (for example, land clearing, grazing / cattle damage, plantation forestry) have probably contributed to its current poor ecological condition (e.g. Jones 2023).

Moreover, many of the vegetation threatening processes are not directly flow-related. Grazing of the riparian zone, for example, is usually highly detrimental to wetland and riparian vegetation (Morris & Reich 2013). Infestation of the riparian zone with exotic weeds (e.g. blackberries, willows, flag irises, etc.) further contributes to a degraded riparian zone, but hardly ever is this due to an inappropriate water regime. Similarly, poor water quality (e.g. high turbidity, high nutrient concentrations) adversely affects submerged plants but in few cases is this a flow-related issue; poor water quality is a problem related to land use change and catchment management more than inappropriate hydrological conditions.

For these reasons, only a minimal set of flow components have been invoked in the vegetation objectives-flow components table. The critical flows have been identified as low flows, to maintain the vegetation, and periodic freshes or high flows, to provide ecological disturbance and maintain whatever vertical zonation there is in the fringing vegetation. It is anticipated that flow components required for other values of the waterway (e.g. fish, geomorphology) will "fill in the gaps" for the specific components not identified as being essential to maintain the current vegetation values (e.g. freshes to move plant propagules downstream).

### 6.2.3 Flow objectives to support vegetation condition and values

Table 29. Flow objectives for water dependent vegetation values

| Environmental objective                                                                                                  | Reach                                                                                                                      | Flow process /function                                                                                                                                                  | Flow component       | Timing                                      | Hydraulic criterion                                              | Reference(s)                                                        |
|--------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------------|
| Maintain, and where possible improve algal biofilms on submerged rocks and CWD                                           | All (plus Arkins Creek & associated headwaters)                                                                            | Keep biofilms inundated                                                                                                                                                 | Low flow             | All year                                    | In-stream rocks and CWD submerged by low flow                    | Vannote et al. (1980)                                               |
|                                                                                                                          |                                                                                                                            | Provide ecological disturbance: remove mature / senescent biofilms and turn-over cobbles etc, in order to create fresh habitat for new biofilms to colonise and develop | Freshes / high flows | Any time                                    | High-flow scour sufficient to remove attached biofilms           | Francoeur & Biggs (2006)                                            |
| Maintain, and where possible improve submerged and floating-leaved plants in stream channel                              | 1, 2a, 2c, 4<br><b>Note:</b> owing to the scarcity of in-stream plants across all the reaches, this is secondary objective | Keep submerged plants inundated                                                                                                                                         | Low flow             | All year (short-term desiccation allowable) | > 0.5 m but < 2 m depth                                          | Casanova (2011)<br>Greet et al. (2011a)<br>Roberts & Marston (2011) |
|                                                                                                                          |                                                                                                                            | Provide ecological disturbance: remove or disturb mature/senescent plants, in order to create fresh habitat for new plants to colonise and develop                      | Freshes / high flows | Any time                                    | High-flow scour sufficient to remove or disturb submerged plants | Rogers & Ralph (2011)<br>Webb et al. (2013)                         |
| Maintain, and where possible improve water-dependent mosses and small ferns growing on exposed CWD and along lower banks | 1, 2a, 2b, 2c, 3a, 3b                                                                                                      | Keep fringing ferns and mosses wet (see also flow objective for maintaining damp microclimates, below)                                                                  | Low flow             | All year                                    | Unknown: assume >0.5 m depth is sufficient                       | Jacobs (2020)                                                       |
| Maintain, and where possible improve damp microclimates in riparian zone                                                 | Arkins Creek & associated headwaters                                                                                       | Prevent fringing ferns and mosses from experiencing desiccation                                                                                                         | Low flow             | All year                                    | Unknown: assume >0.5 m depth is sufficient                       | Ryan & McAlpine (2005)<br>Davis et al. (2019)<br>Jacobs (2020)      |

| Environmental objective                                                                                                  | Reach                                                                                                                                                                                                                                                                                            | Flow process /function                                                                                                    | Flow component       | Timing                                                                      | Hydraulic criterion                                                                                  | Reference(s)                                                                                                                                                                   |
|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Maintain, and where possible improve emergent aquatic plants on lower benches and banks                                  | 2a, 2b, 4, 5<br><b>Note 1:</b> owing to the scarcity of fringing plants across all the reaches except for Reaches 4 & 5, this is secondary objective<br><b>Note 2:</b> Control of extensive swards of Common Reed may be required in Reaches 4 & 5, but this is mostly a non-hydrological matter | Maintain damp soils on lower benches and banks<br>Maintain vertical zonation of plants on benches and lower banks         | Low flow<br>Freshes  | All year<br>All year                                                        | Unknown: assume >0.5 m depth is sufficient<br>Freshes sufficient to inundate benches and lower banks | Brock & Casanova (1997, 2000)<br>Casanova (2011)<br>Greet et al. (2011b)<br>Roberts & Marston (2011)<br>Rogers & Ralph (2011)<br>Webb et al. (2013)<br>Poff & Zimmerman (2014) |
| Maintain, and where possible with complementary actions, improve condition and extent of vegetation in the riparian zone | All<br>Note: owing to the narrowness and generally poor condition of the riparian zone across all the reaches except for Reach 2b, this is secondary objective; see Hansen et al. 2010; Jones 2023                                                                                               | Maintain damp sub-soils in riparian zone                                                                                  | Low flow             | All year                                                                    | Unknown: assume >0.5 m depth is sufficient                                                           | Hansen et al. (2010)<br>Casanova (2011)<br>Roberts & Marston (2011)<br>Rogers & Ralph (2011)<br>Webb et al. (2013)<br>Poff & Zimmerman (2014)<br>Gawne et al. (2020)           |
| Inundate wetland depressions on the floodplain on a seasonal basis                                                       | 4, 5                                                                                                                                                                                                                                                                                             | Inundate wetland depressions to provide still-water biological habitat on the floodplain, support food-web structure etc. | Freshes / high flows | Anytime (as we have no control over high flows) but typically winter-spring | Sufficient to exceed 'Commence to Flow' for inlet channels to wetlands                               | Brock & Casanova (1997, 2000)<br>Casanova (2011)<br>Roberts & Marston (2011)<br>Rogers & Ralph (2011)<br>Webb et al. (2012)<br>Gawne et al. (2020)                             |

## 6.3 Geomorphology

### 6.3.1 Environmental objectives to support geomorphic processes

|      |                                                                                                                                      |
|------|--------------------------------------------------------------------------------------------------------------------------------------|
| Geo1 | Maintain area / volume of channel habitat for instream fauna by preventing gross sediment accumulation and or gross channel erosion. |
| Geo2 | Maintain condition and depth of pool habitat.                                                                                        |
| Geo3 | Maintain the condition of gravel bar habitat.                                                                                        |
| Geo4 | Contribute to floodplain development and evolution.                                                                                  |

Alignment with catchment policy and strategy is detailed in Table 30.

**Table 30. Alignment of geomorphic objectives with strategy and policy**

| Objective | Policy / strategy | Detail                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Geo1      | ENV1              | Instream habitat is required to maintain the viability of populations of threatened native fish.<br><br>Provides habitat to maintain or improve the resilience of other threatened waterway dependent species, such as Platypus.<br><br>Supports water quality in the Gellibrand River and Gellibrand estuary.                                                                                                                                                                                          |
|           | ENV2              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|           | RCS OtW07         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|           | RCS WO5           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Geo2      | ENV1              | Pool habitat is required to maintain the viability of populations of threatened native fish.                                                                                                                                                                                                                                                                                                                                                                                                            |
|           | ENV2              | Pool habitat to maintain or improve the resilience of other threatened waterway dependent species, such as Platypus.                                                                                                                                                                                                                                                                                                                                                                                    |
|           | RCS WO9           | Objective helps to maintain/improve the extent of instream habitat for resilience of native threatened fish and waterway dependent species.                                                                                                                                                                                                                                                                                                                                                             |
| Geo3      | ENV1              | Instream habitat is required to maintain the viability of populations of threatened native fish, through the provision of breeding and foraging habitats (biofilms and macroinvertebrates, which are integral to food webs).<br><br>Provides habitat to maintain or improve the resilience of other threatened waterway dependent species, such as Platypus.<br><br>Objective helps to maintain the extent of instream habitat for resilience of native threatened fish and waterway dependent species. |
|           | ENV2              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|           | RCS WO9           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Geo4      | ENV4              | Maintains the extent and condition of connected wetlands and billabongs.                                                                                                                                                                                                                                                                                                                                                                                                                                |
|           | S1                | Maintains or improves waterway condition in locations of high societal value (Gellibrand River and estuary).                                                                                                                                                                                                                                                                                                                                                                                            |
|           | RCS WO1           | Objective supports riparian extent and condition.                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|           | RCS WO4           | Supports the condition of wetlands in the Gellibrand system, including the estuary.                                                                                                                                                                                                                                                                                                                                                                                                                     |

The rationale for the development of flow objectives to achieve environmental objectives for geomorphic condition and values is provided in the following section.

### 6.3.2 Rationale for the development of flow objectives to support geomorphic condition and values

Geomorphic condition and processes rarely have inherent value. For the most part, the geomorphic conditions and processes in waterways support other waterway attributes and values of interest. This is the case for the Gellibrand River system. The geomorphic objectives set out in this paper have been developed to support the vegetation condition and the fauna values of the system.

As such the geomorphic objectives for the Gellibrand River system have been developed to:

- **Maintain the volume and extent of instream habitat** for macroinvertebrates, fish, Platypus and Rakali. The volume of instream habitat can be attained and maintained by providing levels of sediment transport that match supply with transport capacity, preventing gross channel aggradation.
- **Maintain pool depth.** Provision of suitable pool depth is necessary to prevent vegetation encroachment (and hence habitat loss) and is essential for fish, Platypus and Rakali. Pool depth can be maintained through the provision of flow events that regularly scour and mobilise sediment from the bed of the waterway.
- **Maintain the condition of gravel bars for algae production.** Algae is a primary food source for macroinvertebrates, which are in turn a primary food source for fish and Platypus. Algae production can be maintained by regularly scouring it from substrate material, including large wood and gravel bars.
- **Floodplain development.** Waterways operate in concert with their adjoining floodplain. Overbank inundation is essential for the movement of sediment from the stream channel to the floodplain, contributing to the maintenance of the stream channel (for instream values) and the ongoing development of the floodplain for riparian values, including riparian vegetation.

### 6.3.3 Flow objectives to support geomorphic condition and values

Flow objectives to support geomorphic condition and objectives are provided in Table 31.

**Table 31. Flow objectives to support geomorphic condition and processes (Note: The geomorphology objectives have been developed in support of vegetation and aquatic fauna objectives)**

| <b>Environmental objective</b>                                                                                                      | <b>Reach</b>                                     | <b>Flow process /function</b>                                                                                                                                                         | <b>Flow component</b>                                                                                                                  | <b>Timing</b>   | <b>Hydraulic criterion</b>                                  | <b>Reference(s)</b>                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Maintain area / volume of channel habitat for instream fauna by preventing gross sediment accumulation and or gross channel erosion | All alluvial reaches                             | Maintain both the effective discharge and the total effective work i.e. the work applied by the parts of the flow regime that exceed the threshold of motion of bed and bank material | All flow components that contribute to the effective work applied to the stream channel (typically winter / spring freshes and higher) | All year        | Total effective work                                        | FISRWG 1998<br>Tilleard J. W (2001)                                                                                                         |
| Maintain gravel bar habitat                                                                                                         | All alluvial reaches                             | Scouring biofilms from gravel bars with aid of fine sediment movement                                                                                                                 | Fresh                                                                                                                                  | Summer - autumn | Threshold of motion for silts and on in-channel gravel bars | Watts et al., 2006<br>Informed by threshold of motion studies by Shields 1937, and more recently reviewed by Buffington and Montgomery 1997 |
| Maintain gravel bar habitat                                                                                                         | All alluvial reaches                             | Mobilising fine sediment from gravel bars                                                                                                                                             | Fresh                                                                                                                                  | Winter - spring | Threshold of motion for sands on in-channel gravel bars     | Threshold of motion studies e.g. Shields 1937                                                                                               |
| Maintain condition of pool habitat                                                                                                  | All alluvial reaches                             | Mobilising fine sediment in the bed of pools                                                                                                                                          | Fresh                                                                                                                                  | Winter - spring | Threshold of motion for silts on the bed of pools           | Threshold of motion studies e.g. Shields 1937                                                                                               |
| Contribute to floodplain development and evolution                                                                                  | Alluvial reaches i.e. with adjoining floodplains | Mobilise sediment from bed and banks onto the floodplain                                                                                                                              | Overbank events                                                                                                                        | anytime         | Threshold of motion for sands on point bars                 | Threshold of motion studies e.g. Shields 1937.                                                                                              |

## 7 Estuary environmental flow objectives

As stated in the Site Paper (Alluvium 2025), an EFTP review of the 2008 EEFA-based estuary recommendations found that estuary values and objectives have not substantially changed, and the 2008 ecological objectives and environmental flow recommendations therefore remain generally applicable and are carried into the FLOWS study.

The EFTP noted uncertainty and ambiguity regarding the stated low flow objective and whether the nominated low flow magnitude was suitable. A workshop was held to revise the estuary low flow objectives, as described below.

### 7.1 Gellibrand estuary low flow objectives workshop

On Monday 17 November 2025, a two-hour online workshop was held to discuss the function and objectives for summer-autumn low flows in the Gellibrand estuary, with a view to refining the objective for the FLOWS study and explore pathways to determine the low flow magnitude for the Gellibrand estuary. The meeting was attended by the Gellibrand environmental flows technical panel (EFTP), representatives from the Project Steering Committee, the Alluvium project team, Associate Professor John Sherwood (Gellibrand FLOWS study technical advisor on the Gellibrand estuary), and Dr Sarah McSweeney, who was invited to provide specialist advice on estuary opening dynamics.

The proposed revised Gellibrand estuary summer autumn low-flow objective agreed at the workshop is:

***“To contribute to sustaining critical habitats and processes typical of a healthy Intermittently Open and Closed Estuary (IOCE)”***

EFTP representatives developed specific low-flow objectives for each estuary mouth state, in accordance with the needs of estuarine ecological values.

#### **Revised Gellibrand estuary low flow objectives:**

1. When the **estuary mouth is open**, low flows should support ecological and hydrological processes that are essential for an IOCE, including:
  - a. The ‘natural’ scale, occurrence and duration of mouth opening.
  - b. The provision of tidal exchange at the entrance – egress of surface water in an ebb tide and ingress of seawater on a flood tide – to create a dynamic salt wedge in the estuary and support fish passage to/from the sea. Maximising the extent of the salt wedge is important for estuarine and marine fish species to recruit and to accommodate the typically wide salinity tolerances of estuary plant species.
  - c. Provision of water quality (dissolved oxygen >5 mg/L in the surface mixed layer, acknowledging that there will be stratifications and possibly low dissolved oxygen in the bottom waters).
2. When the **estuary mouth is closed**, low flows should not adversely affect the depth of the freshwater lens nor reduce the water quality required to maintain the ecological character of an IOCE. In turn, this means there is a need to:

- a. Contribute to an oxygenated (>5 mg/L dissolved oxygen concentration) freshwater surface layer (freshwater lens), which supports the aerobic estuarine community as the bottom salt wedge and fringing wetlands become anoxic. The depth of this layer has not yet been determined.
- b. Generate both freshwater and brackish water fringes and inundation to support sexual reproduction by estuary plant species, including saltmarsh taxa.
- c. Maintain estuary water levels that enable natural breaching when seasonal inflows occur.
- d. Offset freshwater losses via evaporation, infiltration to groundwater and potential seepage through the berm to support objectives 1a and 1b.
- e. Facilitate sediment ingress and retention within the entrance and lower basin.
- f. Provide relatively stable conditions in order to support recruitment of estuarine fauna, such as birds and fish.
  1. Under **opening conditions**, freshwater flows should not increase the risk of fish kills during drawdown of the estuary, over that under natural (pre-development) conditions. This includes no adverse material change to the occurrence, duration and frequency of obtaining 5mg/L of oxygen in surface water from that under natural (pre-development) conditions when the estuary is opening.

There is insufficient information to revise the magnitude of the low flow recommendations at this time and further work would be required (outside of the FLOWS study) to inform the setting of the revised low flow recommendations. Therefore, while the revised estuary low flow objectives will be included in this FLOWS study, revised low flow recommendations (magnitude) will not be set. The revised estuary low flow objectives are presented in Table 32.

Table 32. Revised Gellibrand estuary low flow objectives

| Value                                    | Environmental flow objective                                                    | Flow process /function                                                                                                                                                          | Flow component       | Timing                 |
|------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------------------|
| <b>When the estuary mouth is open</b>    |                                                                                 |                                                                                                                                                                                 |                      |                        |
| Geomorphology mouth dynamics             | Support the 'natural' scale, occurrence and duration of mouth opening.          | Support the 'natural' scale, occurrence and duration of mouth opening, when the estuary mouth is open                                                                           | All flow components  | All year               |
| Geomorphology, vegetation, aquatic fauna | Provide for tidal exchange at the entrance                                      | Support egress of surface water in an ebb tide and ingress of seawater on a flood tide                                                                                          | Low flow             | All year               |
|                                          |                                                                                 | Create a dynamic salt wedge in the estuary and support fish passage to/from the sea                                                                                             | Low flow             | All year               |
| Aquatic fauna                            | Provision of water quality                                                      | Support dissolved oxygen >5 mg/L in the surface mixed layer                                                                                                                     | Low flow             | All year               |
| <b>When the estuary mouth is closed</b>  |                                                                                 |                                                                                                                                                                                 |                      |                        |
| Aquatic fauna                            | Support, and maintain good water quality in the freshwater lens                 | Contribute to an oxygenated (>5 mg/L dissolved oxygen concentration) freshwater surface layer (freshwater lens)                                                                 | Low flow             | All year               |
|                                          |                                                                                 | Offset freshwater lens losses via evaporation, infiltration to groundwater and potential seepage through the berm                                                               | Low flow             | All year               |
| Vegetation and aquatic fauna             | Maintain the estuarine salt wedge / halocline                                   | Maintain maximum extent of the salt wedge to support estuarine vegetation and aquatic fauna                                                                                     | Low flow             | All year               |
| Vegetation                               | Support sexual reproduction by estuary plant species, including saltmarsh taxa. | Generate both freshwater and brackish water fringes and inundation                                                                                                              | Low flow             | All year               |
| Geomorphology - mouth dynamics           | Maintain estuary water levels                                                   | Enable natural breaching of sand berm when seasonal inflows occur                                                                                                               | Low flow             | All year               |
|                                          | Maintain estuary water levels                                                   | Offset freshwater losses via evaporation, infiltration to groundwater and potential seepage through the berm                                                                    | Low flow             | All year               |
|                                          | Support sediment transport to support 'natural' estuary dynamics                | Facilitate sediment ingress and retention within the entrance and lower basin.                                                                                                  | Low flow             | All year               |
| Aquatic fauna                            | Support estuarine stability                                                     | Provide relatively stable conditions in order to support recruitment of estuarine fauna such as birds and fish                                                                  | Low flow             | All year               |
| <b>Under estuary opening conditions</b>  |                                                                                 |                                                                                                                                                                                 |                      |                        |
| Aquatic fauna                            | Not increase the risk of fish kills during draw down of the estuary             | Support no adverse material change to the occurrence, duration and frequency of obtaining 5mg/L of oxygen in surface water from that under natural (pre-development) conditions | Low flow and freshes | During estuary opening |

## 7.2 Estuary environmental objectives

Environmental objectives carried forward from the EEFAM study (Lloyd et.al. 2008) are listed in Table 33.

**Table 33. Estuary environmental flow objectives from Lloyd et al., 2008**

| ID                                                                   | Ecological objectives for <i>Phragmites australis</i> Grassland                                                    |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| 1a.1                                                                 | Promote salt-tolerant charophytes, herbs, grasses and forbs                                                        |
| 1a.2                                                                 | Exclude emergent macrophytes                                                                                       |
| 1b                                                                   | Maintain plant growth between inundation events.                                                                   |
| 1b.2                                                                 | Provide a source of low salinity water if inundated by saline water                                                |
| 1c, 1d                                                               | Maintain dominance of <i>Phragmites australis</i> in dense, closed stands                                          |
| Ecological objectives for Coastal Salt Marsh                         |                                                                                                                    |
| 2a                                                                   | Retain water from high estuary levels, local rainfall.                                                             |
| 2b                                                                   | Promote salt-tolerant charophytes, herbs, grasses and forbs                                                        |
| 2b.2                                                                 | Exclude emergent macrophytes                                                                                       |
| 2c                                                                   | Promote salt-tolerant charophytes and submerged vascular macrophytes                                               |
| 2d, 2e                                                               | Provide habitat for salt-tolerant grasses, sedges, herbs and forbs, exclude emergent macrophytes                   |
| 2f, 2g                                                               | Maintain <i>Sarcocornia quinqueflora</i>                                                                           |
| Ecological objectives for Estuarine Scrub                            |                                                                                                                    |
| 3a                                                                   | Maintain <i>Gahnia</i> tussock sedgeland and <i>Leptospermum lanigerum</i>                                         |
| 3b                                                                   | Maintain growth and health of <i>L. lanigerum</i> and <i>Gahnia</i> tussock sedgeland                              |
| 3c                                                                   | Maintain <i>Gahnia</i> tussock sedgeland and <i>Leptospermum lanigerum</i> .                                       |
| 3c.2                                                                 | Prevent invasion by <i>Phragmites australis</i> .                                                                  |
| 3d                                                                   | Prevent invasion by <i>Bolboschoenus caldwelli</i> and <i>Juncus kraussii</i> .                                    |
| Ecological objectives for Swamp Scrub                                |                                                                                                                    |
| 4a                                                                   | Maintain dense <i>L. lanigerum</i> canopy                                                                          |
| 4b                                                                   | Maintain growth and health of <i>L. lanigerum</i> , <i>P. tenuissima</i>                                           |
| 4c                                                                   | Exclude aquatic macrophytes from understorey. Prevent flood stress to <i>L. lanigerum</i> , <i>P. tenuissima</i> . |
| Ecological and Hydrological Objectives for Herb-rich Foothill Forest |                                                                                                                    |
| 5a, 5b                                                               | Maintain <i>Acacia melanoxylon</i> and <i>Eucalyptus ovata</i> overstorey                                          |
| Ecological and Hydrological Objectives for Sea-grass Meadow          |                                                                                                                    |
| 6a                                                                   | Seagrass meadows tolerate salinities above and below sea water                                                     |
| 6b                                                                   | <i>Zostera muelleri</i> – stable water levels but mostly inundated                                                 |
| 6c                                                                   | Light penetration required to support seagrass photosynthesis and growth                                           |
| 6d                                                                   | Prevent excessive sedimentation, which smothers seagrasses                                                         |
| Ecological and hydrological objectives for Black Bream               |                                                                                                                    |
| 7a                                                                   | Maintain estuarine salinities                                                                                      |
| 7b                                                                   | Spawning/egg survival                                                                                              |

|                                                                                                |                                                             |
|------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| 7c                                                                                             | Refuge/feeding for settlement and post settlement juveniles |
| <b>Ecological and hydrological objectives for King George Whiting</b>                          |                                                             |
| 8a                                                                                             | Allow migration to estuary from the sea                     |
| 8b                                                                                             | Provide habitat for larvae to survive and grow              |
| <b>Ecological and hydrological objectives for Australian Grayling</b>                          |                                                             |
| 9a                                                                                             | Adult spawning                                              |
| 9b                                                                                             | Egg development                                             |
| 9c                                                                                             | Marine Migration by larvae                                  |
| 9d                                                                                             | <i>Migratory cue to return to estuary</i>                   |
| 9e                                                                                             | Freshwater Migration to estuary from sea by juveniles       |
| 9f                                                                                             | Migration from estuary to freshwater reaches by juveniles   |
| <b>Ecological and hydrological objectives for Common Jollytail (<i>Galaxias maculatus</i>)</b> |                                                             |
| 10a                                                                                            | Migration to estuary in autumn before spring tides          |
| 10b                                                                                            | Adults spawning                                             |
| 10c                                                                                            | Marine Migration by larvae                                  |
| 10d                                                                                            | <i>Migratory cue to return to estuary</i>                   |
| 10e                                                                                            | Freshwater Migration to estuary from sea by juveniles       |
| 10f                                                                                            | Migration from estuary to freshwater reaches by juveniles   |

Ecological and hydrological objectives (carried forward) from the 2008 EEFAM study are presented in Table 34.

Table 34. Ecological and hydrological objectives for the Gellibrand estuary (carried from 2008 EEFA study, Lloyd et al. 2008)

Please note that 1000 EC = 0.64 ppt

| ID                                                                                      | Habitat component                                    | Role of habitat component                                                                                            | General conditions required                                                                                                                                                         | Flow component (Magnitudes from Lloyd et al. 2008)                                  | Timing          | Hydraulic criterion (specific physical factors)                                                                                                                                                           |
|-----------------------------------------------------------------------------------------|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Ecological and Hydrological Objectives for <i>Phragmites australis</i> Grassland</b> |                                                      |                                                                                                                      |                                                                                                                                                                                     |                                                                                     |                 |                                                                                                                                                                                                           |
| 1a                                                                                      | Brackish flood water (1a)                            | Promote salt-tolerant charophytes, herbs, grasses and forbs                                                          | Flooding by brackish water in summer and autumn for sufficient durations to exclude emergent macrophytes and to provide reliable growing conditions for salt-tolerant aquatic herbs | Low flow (100 ML/day)                                                               | Summer / autumn | Median salinities of 5 parts per thousand (ppt) to 10 ppt in shallow (<1 m deep) estuary water downstream of cross section 10 in summer and autumn                                                        |
|                                                                                         |                                                      | Exclude emergent macrophytes                                                                                         | Flooding by fresher water in spring to support growth of <i>Phragmites</i> and less salt-tolerant species.                                                                          | Low flow fresh (220 ML/day)                                                         | Winter / spring | Median salinities 2 ppt to 5 ppt in shallow (<1 m deep) estuary water downstream of cross section 10 in winter and spring                                                                                 |
| 1b                                                                                      | Shallow low salinity groundwater                     | Maintain plant growth between inundation events. Provide a source of low salinity water if inundated by saline water | Groundwater salinity predicted to be less than 3 ppt<br>Depth to water table predicted to be less than 0.2 m deep at all times                                                      | N/A                                                                                 | N/A             | No assessment possible                                                                                                                                                                                    |
| 1c                                                                                      | Frequent and prolonged flooding in winter and spring | Maintain dominance of <i>Phragmites australis</i> in dense, closed stands                                            | <i>Phragmites</i> habitat inundated to a depth of 0.25 to 0.5 m for a quarter of the time in winter and spring.                                                                     | Fresh (1800 ML/day when estuary is open)<br>200 ML/day when estuary mouth is closed | Winter / spring | River level must exceed 1.25 to 1.5 m AHD at cross section 10 25% of the time between June and December with a maximum interval between events of 4 weeks.                                                |
| 1d                                                                                      | Intermittent flooding in summer and autumn           | Maintain dominance of <i>Phragmites australis</i> in dense, closed stands                                            | <i>Phragmites</i> habitat intermittently inundated to a depth of 0.25 and 0.5 m during summer.<br>Years with no events may occur 1 year in 3                                        | Fresh (1800 ML/day when estuary is open)<br>200 ML/day when estuary mouth is closed |                 | River level must exceed 1.25 to 1.5 m AHD at cross section 10 25% of the time between June and December with a maximum interval between events of 4 weeks.<br>Years with no events may occur 1 year in 3. |
| <b>Ecological and Hydrological Objectives for Coastal Salt Marsh</b>                    |                                                      |                                                                                                                      |                                                                                                                                                                                     |                                                                                     |                 |                                                                                                                                                                                                           |

| ID                                                                | Habitat component                                                  | Role of habitat component                                                                            | General conditions required                                                                                                     | Flow component (Magnitudes from Lloyd et al. 2008) | Timing          | Hydraulic criterion (specific physical factors)                                                                           |
|-------------------------------------------------------------------|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------|
| 2a                                                                | Depth and extent of floodplain depressions                         | Retain water from high estuary levels, local rainfall.                                               | Geomorphic processes to maintain depression depth of approximately 0.5 m and current extent                                     | N/A                                                | N/A             | Not required                                                                                                              |
| 2b                                                                | Flooding by saline water in summer and autumn                      | Promote salt-tolerant charaphytes, herbs, grasses and forbs<br>Exclude emergent macrophytes          | Peak salinity (between refreshing events) of 7.5 ppt to 20 ppt in summer and autumn in depressions                              | Low flow                                           | Summer / autumn | Median salinities in shallow (<1 m deep) estuary water downstream of cross section 10 exceeds 5 ppt in summer and autumn. |
| 2c                                                                | Flooding by brackish water in winter and spring                    | Promote salt-tolerant charaphytes, herbs, grasses and forbs<br>Exclude emergent macrophytes          | Peak salinity (between refreshing events) of 5 ppt in winter and spring in depressions                                          | Low flow (maximum inflow 240 ML/day)               | Winter / spring | Median salinities in shallow (<1 m deep) estuary water downstream of cross section 10 exceeds 3 ppt in winter and spring  |
| 2d                                                                | Persistent flooding in winter and spring by fresh / brackish water | Promote salt-tolerant charaphytes and submerged vascular macrophytes<br>Exclude emergent macrophytes | Persistent flooding to depth of 0.25 to 1.0 0.5 m (predominantly 0.5 m) from May to October                                     | As per 2c                                          | May - October   | Median interval between events where water level at cross section 10 exceeds 1.5 1.0 m AHD is 2 weeks in May to October.  |
| 2e                                                                | Shallow flooding in late spring / early summer                     | Provide habitat for salt-tolerant grasses, sedges, herbs and forbs                                   | Average water level from November to December is 50% of average water level from August to September                            | Low flow                                           | Summer / autumn | Median interval between events where water level at cross section 10 exceeds 1 m AHD is 3 weeks in summer and autumn      |
| 2f                                                                | Intermittent flooding in summer and autumn                         | Maintain <i>Sarcocornia quinqueflora</i>                                                             | Depressions less than 20% of maximum depth 80% of the time over summer autumn                                                   | Low flow                                           | Summer / autumn | Median interval between events where water level at cross section 10 exceeds 1 m AHD is 8 weeks in summer and autumn      |
| 2g                                                                | Waterlogging by saline groundwater in summer and autumn            | Maintain <i>Sarcocornia quinqueflora</i>                                                             | Groundwater depth less than 0.4 m to maintain evaporative concentration of salts in surface soil. Groundwater salinity 10 to 60 | N/A                                                | N/A             | No assessment possible                                                                                                    |
| <b>Ecological and Hydrological Objectives for Estuarine Scrub</b> |                                                                    |                                                                                                      |                                                                                                                                 |                                                    |                 |                                                                                                                           |
| 3a                                                                | Seasonal waterlogging                                              | Maintain <i>Gahnia</i> tussock sedgeland and <i>Leptospermum lanigerum</i>                           | Groundwater less than 0.2 m deep for 4 to 8 months of the year                                                                  | N/A                                                | N/A             | No assessment possible                                                                                                    |

| ID                                                                          | Habitat component                             | Role of habitat component                                                                                                                                    | General conditions required                                                                      | Flow component (Magnitudes from Lloyd et al. 2008)              | Timing                                  | Hydraulic criterion (specific physical factors)                                                                                                                                                                                             |
|-----------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3b                                                                          | Low salinity groundwater                      | Maintain growth and health of <i>L. lanigerum</i> and <i>Gahnia</i> tussock sedgeland                                                                        | Groundwater salinity less than 3000 EC                                                           | N/A                                                             | N/A                                     | No assessment possible                                                                                                                                                                                                                      |
| 3c                                                                          | Infrequent inundation                         | Maintain <i>Gahnia</i> tussock sedgeland and <i>Leptospermum lanigerum</i> . Prevent invasion by <i>Phragmites australis</i> .                               | Less than 10 inundation events per year. No single inundation event longer than 10 days duration | High flow fresh 3900 ML/day mouth open, 200 ML/day mouth closed | Any month                               | Median duration of events where water level exceeds 1.5 m AHD at cross section 9 is 1 to 2 weeks. Frequency of events where water level exceeds 1.5 m at cross section 9 is 5 per year.                                                     |
| 3d                                                                          | Inundation by brackish to fresh surface water | Maintain <i>Gahnia</i> tussock sedgeland and <i>Leptospermum lanigerum</i> . Prevent invasion by <i>Bolboschoenus caldwelli</i> and <i>Juncus kraussii</i> . | None listed                                                                                      | Fresh (600 ML/day)<br>Fresh (300 ML/day)                        | Autumn (March - May)<br>Winter / spring | Median salinities in shallow (<1 m deep) estuary water downstream of cross section 9 is less than 3 ppt in summer and autumn. Winter and spring salinities may this salinity or fresher.                                                    |
| <b>Ecological and Hydrological Objectives for Swamp Scrub</b>               |                                               |                                                                                                                                                              |                                                                                                  |                                                                 |                                         |                                                                                                                                                                                                                                             |
| 4a                                                                          | Perennial waterlogging                        | Maintain dense <i>L. lanigerum</i> canopy                                                                                                                    | Groundwater less than 0.2 m deep at all times                                                    | N/A                                                             | N/A                                     | No assessment possible                                                                                                                                                                                                                      |
| 4b                                                                          | Low salinity groundwater                      | Maintain growth and health of <i>L. lanigerum</i> , <i>P. tenuissima</i>                                                                                     | Groundwater salinity less than 1000 EC                                                           | N/A                                                             | N/A                                     | No assessment possible                                                                                                                                                                                                                      |
| 4c                                                                          | Brief and infrequent inundation               | Exclude aquatic macrophytes from understorey. Prevent flood stress to <i>L. lanigerum</i> , <i>P. tenuissima</i> .                                           | Less than 5 inundation events per year. No single inundation event longer than 5 days duration   | Moderate overbank (7000 ML/day)                                 | Any time                                | Median duration of events where water level exceeds 2.0 m AHD at cross section 10 is less than 1 week. Frequency of events where water level exceeds 2.0 m at cross section 10 is less than 5 per year. Zero events per year is acceptable. |
| <b>Ecological and Hydrological Objectives for Herb-rich Foothill Forest</b> |                                               |                                                                                                                                                              |                                                                                                  |                                                                 |                                         |                                                                                                                                                                                                                                             |
| 5a                                                                          | Shallow low-salinity groundwater              | Maintain <i>Acacia melanoxydon</i> and <i>Eucalyptus ovata</i> overstorey                                                                                    | Groundwater depth less than 2 m at all times<br>Groundwater salinity less than 1000 EC           | N/A                                                             | N/A                                     | No assessment possible                                                                                                                                                                                                                      |
| 5b                                                                          | Rare, brief flooding                          | Maintain <i>Acacia melanoxydon</i> and                                                                                                                       | Flooded to a maximum of 10 days per year.                                                        | Moderate overbank (6000 ML/day)                                 | Any time                                | Water level exceeds 3.0 m AHD at cross section 2 for a total of less than 10 days per year (median).                                                                                                                                        |

| ID                                                                 | Habitat component            | Role of habitat component                                                | General conditions required                                                                                                                                                         | Flow component (Magnitudes from Lloyd et al. 2008)                           | Timing          | Hydraulic criterion (specific physical factors)                                                                                                                                                                          |
|--------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Eucalyptus ovata</i> overstorey                                 |                              |                                                                          |                                                                                                                                                                                     |                                                                              |                 |                                                                                                                                                                                                                          |
| <b>Ecological and Hydrological Objectives for Sea-grass Meadow</b> |                              |                                                                          |                                                                                                                                                                                     |                                                                              |                 |                                                                                                                                                                                                                          |
| 6a                                                                 | Salinities                   | Seagrass meadows tolerate salinities above and below sea water           | Salinity which varies with tide and flow but has a median salinity of 0.5 to 1.0 times sea water. (15 - 35 Salinity) - will tolerate down to salinities 6) in the lowest kilometre. | Low flow (salt will penetrate the estuary at freshwater inflows <300 ML/day) | Winter / spring | Flows required to extend salt upstream                                                                                                                                                                                   |
|                                                                    |                              |                                                                          | Freshwater pulses may be trigger for germination. Prolonged fresh conditions will remove <i>Heterozostera</i> .                                                                     | Fresh (900 ML/day to trigger breeding)                                       | May - July      | Sufficient flows to transition to a fresh regime                                                                                                                                                                         |
| 6b                                                                 | Water level                  | <i>Zostera muelleri</i>                                                  | Stable water levels but mostly inundated                                                                                                                                            | N/A                                                                          | N/A             | Water level monitoring (within normal tidal range)                                                                                                                                                                       |
| 6c                                                                 | Turbidity                    | Light penetration required to support seagrass photosynthesis and growth | Maintain euphotic conditions within 1 km of estuary entrance.                                                                                                                       | Fresh (300 ML/day)                                                           | Winter / spring | Flows required to extend salt upstream                                                                                                                                                                                   |
| 6d                                                                 | Sedimentation                | Excessive sedimentation smothers seagrasses                              | Provide regular flushing flows to prevent excessive accumulation of sediment within 1 km of estuary entrance.                                                                       | N/A                                                                          |                 | River flow [shear stress to move silt but not large enough to shift/disturb the seagrass (uproot the bed)]<br>Seagrass is located in a depositional environment. Do not set a flow recommendation for flushing silt      |
| <b>Ecological and hydrological objectives for Black Bream</b>      |                              |                                                                          |                                                                                                                                                                                     |                                                                              |                 |                                                                                                                                                                                                                          |
| 7a                                                                 | Adult fish habitat           | Maintain estuarine salinities                                            | Salinity range of 5 ppt to 30 ppt present over at least 50% of longitudinal section 80% of the time                                                                                 | Low flow                                                                     | Summer / autumn | Freshwater inflows to create estuarine conditions (5 ppt to 30 ppt salinity)                                                                                                                                             |
| 7b                                                                 | Salt wedge                   | Spawning/egg survival                                                    | Salinity between 15 ppt and 20 ppt in middle reaches, where <i>Phragmites</i> stands largest. DO >5 mg/L in bottom water during spawning season Sep to Dec                          | Low flow                                                                     | Summer / autumn | Presence of halocline between 15 ppt and 20 ppt. Top (0.1 m) water salinity less than 10 ppt AND bottom (0.5 m above bottom) salinity greater than 25 ppt. DO/residence time of 2 days anywhere in water below halocline |
| 7c                                                                 | <i>Phragmites</i> / seagrass | Refuge/feeding for settlement and post settlement juveniles              | Inundated vegetation near salinity 15 ppt to 20 ppt                                                                                                                                 | Low flow                                                                     | Summer / autumn | Specify flow band which positions the (former) halocline near the required                                                                                                                                               |

| ID                                                                    | Habitat component              | Role of habitat component                      | General conditions required                                                                                                                                                                                                                                              | Flow component (Magnitudes from Lloyd et al. 2008)             | Timing                             | Hydraulic criterion (specific physical factors)                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------|--------------------------------|------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                       |                                |                                                |                                                                                                                                                                                                                                                                          |                                                                |                                    | vegetation type (seagrass or Phragmites)                                                                                                                                                                                                                                    |
| <b>Ecological and hydrological objectives for King George Whiting</b> |                                |                                                |                                                                                                                                                                                                                                                                          |                                                                |                                    |                                                                                                                                                                                                                                                                             |
| 8a                                                                    | Entrance of larvae to estuary  | Allow migration to estuary from the sea        | Open Mouth August to late October                                                                                                                                                                                                                                        | High flow fresh 1500ML/day mouth open, 500 ML/day mouth closed | August - October (Winter - spring) | Mouth 30-50cm deep during period August to October (inclusive)                                                                                                                                                                                                              |
| 8b                                                                    | Larval fish habitat in estuary | Provide habitat for larvae to survive and grow | Up to 5 months (settlement in spring summer Jenkins and May 1994, Jenkins, Wheatley and Poore 1996) shallow sea grass and macroalgae.<br>Salinities greater than 25 ppt in bottom water.<br>DO greater than 5 mg/L in bottom water during this period.                   | Low flow (100 ML/day)                                          | Spring and summer                  | Steady state conditions which create salinity greater than 25 ppt in bottom 1 m more than 80% of the time below cross section 12 (lowest Bridge) during spring and summer.<br>Set maximum DO residence time of 2 days below cross section 12 (lowest Bridge) in bottom 1 m. |
| <b>Ecological and hydrological objectives for Australian Grayling</b> |                                |                                                |                                                                                                                                                                                                                                                                          |                                                                |                                    |                                                                                                                                                                                                                                                                             |
| 9a                                                                    | Flow fresh                     | Adult spawning                                 | Low salinity pulse                                                                                                                                                                                                                                                       | Low flow Fresh                                                 | Late autumn                        | Flow event that creates max salinity of 2 ppt at 9,600 m (third bridge) (top section of estuary or just upstream) - throughout water column in autumn.                                                                                                                      |
| 9b                                                                    | Freshwater in upper estuary    | Egg development                                | Larvae take 14 + days to develop, they require Flow Fresh, required for a few days to develop in <5 salinity.<br>High O <sub>2</sub> in pools to allow survival                                                                                                          | Fresh (900 ML/day)                                             | May - July                         | Flow event which creates salinity of less than 5 ppt at 9,600m (third bridge) in autumn or winter.<br>Residence time of <= 2 days                                                                                                                                           |
| 9c                                                                    | Estuary Mouth State            | Marine Migration by larvae                     | Mouth open during May to July (downstream movement)<br>Velocity create flow after the mouth open (flow sufficient to move silt downstream)<br>Velocity sufficient to take larvae 4 days to get down to an already open mouth (from GOR Bridge - with a small mouth open) | High flow fresh 1500ML/day mouth open, 500 ML/day mouth closed | May - July                         | Require open mouth during May to July. Salinity is not critical - up to 35 is OK for periods of up to a 7 days with 2-3 events during the season                                                                                                                            |

| ID                                                                                             | Habitat component                                   | Role of habitat component                                 | General conditions required                                                                                                                                                                                                                                                              | Flow component (Magnitudes from Lloyd et al. 2008)                | Timing               | Hydraulic criterion (specific physical factors)                                                                                                                                                                                                                        |
|------------------------------------------------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 9d                                                                                             | Estuary Mouth State                                 | <i>Migratory cue to return to estuary</i>                 | Uncertain. Presumed met by flows required to provide passage.                                                                                                                                                                                                                            | N/A                                                               | N/A                  | No assessment required                                                                                                                                                                                                                                                 |
| 9e                                                                                             | Estuary Mouth State                                 | Freshwater Migration to estuary from sea by juveniles     | 30 – 50 cm deep river mouth<br>Mouth open during Oct – Dec (upstream migration)                                                                                                                                                                                                          | High flow fresh 1500ML/day<br>mouth open, 500 ML/day mouth closed | Oct - Dec            | Require open mouth, 30 – 50 cm deep, during Oct-Dec, salinity not material, duration should be for up to 7 days with 2 – 3 events during the season                                                                                                                    |
| 9f                                                                                             | Low Flow fresh                                      | Migration from estuary to freshwater reaches by juveniles | Flow cue to migrate upstream                                                                                                                                                                                                                                                             | Fresh (240 ML/day)                                                | Spring<br>Dec - May  | Require access to upstream reaches over riffles - Upstream riffle depth at least 0.3 m min. (Thalweg depth a bar/riffle 0.3 m)<br>At least 2 events in spring (to provide 2 opportunities).<br>Dec – May, min 4 events                                                 |
| <b>Ecological and hydrological objectives for Common Jollytail (<i>Galaxias maculatus</i>)</b> |                                                     |                                                           |                                                                                                                                                                                                                                                                                          |                                                                   |                      |                                                                                                                                                                                                                                                                        |
| 10a                                                                                            | High Flow Fresh                                     | Migration to estuary in autumn before spring tides        | Flow cue to migrate downstream                                                                                                                                                                                                                                                           | Fresh (240 ML/day)                                                | Autumn               | Require access to estuary over riffles - Upstream riffle depth at least 0.3 m min.<br>At least 2 events in autumn (to provide 2 opportunities)                                                                                                                         |
| 10b                                                                                            | Flooded samphire or estuarine floodplain vegetation | Adults spawning                                           | Spring tide in autumn following migration event                                                                                                                                                                                                                                          | Fresh (600 ML/day)                                                | Autumn (March – May) | Inundation of emergent vegetation or samphire at the upper extent of the intertidal zone (once every two weeks based on the tidal regime).<br>Requires mouth to be open with mean daily tidal range equal to or greater than 0.2 m at lower bridge (cross section 10). |
| 10c                                                                                            | Estuary Mouth State                                 | Marine Migration by larvae                                | 30 – 50 cm deep mouth open during May to July (downstream movement)<br>Velocity create flow after the mouth open (flow sufficient to move silt downstream)<br>Velocity sufficient to take larvae 4 days to get down to an already open mouth (from GOR Bridge – with a small mouth open) | High flow fresh 1500ML/day<br>mouth open, 500 ML/day mouth closed | May - July           | Require open mouth during May to July, salinity is not critical so up to 35 ppt is OK for periods of up to a 7 days with 2 – 3 events during the season (as per 9c)                                                                                                    |

| ID  | Habitat component                  | Role of habitat component                                 | General conditions required                                                            | Flow component (Magnitudes from Lloyd et al. 2008)                | Timing          | Hydraulic criterion (specific physical factors)                                                                                                                                                    |
|-----|------------------------------------|-----------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10d | Estuary Mouth State                | <i>Migratory cue to return to estuary</i>                 | <i>Uncertain. Presumed met by flows to provide passage</i>                             | N/A                                                               | N/A             | No assessment required                                                                                                                                                                             |
| 10e | Estuary Mouth State                | Freshwater Migration to estuary from sea by juveniles     | 30 - 50 cm deep river mouth<br>Mouth open during July to December (upstream migration) | High flow fresh 1500ML/day<br>mouth open, 500 ML/day mouth closed | Oct - Dec       | Require open mouth, 30 - 50 cm deep, during Oct-Dec, salinity not material, duration should be for up to 7 days with 2 - 3 events during the season                                                |
| 10f | Riffles, stream bars, flow freshes | Migration from estuary to freshwater reaches by juveniles | flow cue to migrate upstream - probably flow freshes                                   | Fresh (300 ML/day)                                                | Winter - Spring | Require access to upstream reaches over riffles - Upstream riffle depth at least 0.3 m min (0/3 m thalweg depth at rock bar / riffle).<br>At least 2 events in spring (to provide 2 opportunities) |

## 8 References

- ACHRIS (2025). Aboriginal Cultural Heritage Register and Information System website – available at <https://achris.vic.gov.au/#/onlinemap>
- Alluvium (2017). Gellibrand River estuary low flow investigation. Report by Alluvium Consulting Australia for Corangamite Catchment Management Authority, Colac.
- Alluvium (2024a). Review of the Victorian FLOWS method, Report by Alluvium Consulting Australia for Victorian Government Department of Energy, Environment and Climate Action, Melbourne.
- Alluvium (2024b). St George River FLOWS study. Recommendations paper. Report prepared by Alluvium Consulting for Barwon Water, Geelong, Victoria.
- Alluvium (2025). Site Paper: Gellibrand River FLOWS study. Report prepared by Alluvium Consulting Australia for Barwon Water, Geelong, Victoria
- Amtstaetter, F., Tonkin, Z., O'Connor, J., Stuart, I. and Koster, W.M. (2021a). Environmental flows stimulate the upstream movement of juvenile diadromous fishes. *Marine and Freshwater Research* 72(7):1019-1026.
- Amtstaetter, F., Yen, J.D.L., Hale, R., Koster, W.M., O'Connor, J., Stuart, I. and Tonkin, Z. (2021b). Elevated river discharge enhances the immigration of juvenile catadromous and amphidromous fishes into temperate coastal rivers. *Journal of Fish Biology* 99:61-72.
- ARI (2015). Gellibrand Catchment River blackfish population assessment. J. O'Connor, J. Lieschke and R. Ayres. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning Unpublished Client Report for Corangamite Catchment Management Authority
- ARI (2024). Native Fish Report Card. Gellibrand River 2024. Corangamite Region.
- ARI (2025). Gellibrand River native fish report card survey. Field survey update. Arthur Rylah Institute for Environmental Research.
- Atkinson, A. P., Cartwright, I., Gilfedder, B. S., Hofmann, H., Unland, N. P., Cendon, D. I., & Chisari, R. (2015). A multi-tracer approach to quantifying groundwater inflows to an upland river; assessing the influence of variable groundwater chemistry. *Hydrological Processes*, 29(1), 1-12. <https://doi.org/10.1002/hyp.10122>
- Austin, C. M., S. T. Ahyong, A. Miller, et al. (2026). "A Prickly Problem: Genome Skimming Reveals Varying Levels of Phylogenetic Diversity in the Freshwater Crayfish *Euastacus armatus* Complex (Parastacidae) With Implications for Taxonomy and Conservation." *Ecology and Evolution* 16, no. 4: e73428. <https://doi.org/10.1002/ece3.73428>.
- Australian crayfish project (2015). The Otway's Cray, *Geocharax gracilis*. Available at: <https://austcray.com/the-otways-cray-geocharax-gracilis/>
- BlueSphere Environmental (2024). Hydrogeological Investigation of the Kawarren Subbasin, Surrounding Environment Investigation. Report by BlueSphere Environmental Pty Ltd for Barwon Water

Boon PI, Allen T, Carr G, Frood D, Harty C, McMahon A, Mathews S, Rosengren N, Sinclair S, White M & Yugovic J (2015). Coastal wetlands of Victoria, south-eastern Australia: Providing the inventory and condition information needed for their effective management and conservation. *Aquatic Conservation: Marine & Freshwater Ecosystems* 25: 454–479.

Brock, M. A. & Casanova, M. T. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. In: Klomp, N. & Lunt, I. (eds). *Frontiers in ecology: building the links*. Elsevier, Oxford (UK). Pages 181–192.

Brock, M.A. & Casanova, M.T. (2000). Are there plants in your wetland? Land & Water R&D Corporation, Canberra.

Buffington, J.M. & Montgomery, D.R. (1997). A systematic analysis of eight decades of incipient motion studies. *Water Resources Research*, 33(8), 1993–2029.

Cacciatori C, Myers J, Mariani G, Gawlik BM and Pettigrove V (2026). Community engagement and screening of 447 pesticides in the Gellibrand River catchment, Victoria, Australia. *Front. Environ. Sci.* 14:1765617. doi: 10.3389/fenvs.2026.1765617

Casanova, M.T. (2011). Using water plant functional groups to investigate environmental water requirements. *Freshwater Biology* 56: 2637–2652.

CCMA Undated. Corangamite Natural Resource Management Plan for Climate Change.

CCMA (2014). Corangamite Waterway Strategy 2014-2022

CCMA (2017). Gellibrand River 2017 Estuary Management Plan.

CCMA (2020). Data Interpretation and Analysis of Citizen Science Data from the Gellibrand Landscape Zone

CCMA (2021). Corangamite Regional Catchment Strategy 2021-2027.

CCMA (2024a). Gellibrand Citizen Science Report 2021.24 Corangamite Catchment Management Authority Regional Citizen Science Program.

Clark, I.D (1990). Aboriginal Languages and Clans: An Historical Atlas of Western and Central Victoria, 1800–1900, Monash Publications, in *Geography* No 37, 1990, Monash University, Melbourne. (p189)

Crook, David & Koster, Wayne & Macdonald, Jed & Nicol, Simon & Belcher, Chris & Dawson, David & O'Mahony, Damien & Lovett, Danny & Walker, Adam & Bannam, Lucas. (2010). Catadromous migrations by female tupong (*Pseudaphritis urvillii*) in coastal streams in Victoria, Australia. *Marine and Freshwater Research*. 61. 474-483. 10.1071/MF09170.

Crook, D.A., Macdonald, J.I., Morrongiello, J.R., Belcher, C.A., Lovett, D., Walker, A. and Nicol, S.J. (2014), Environmental cues and extended estuarine residence in seaward migrating eels (*Anguilla australis*). *Freshw Biol*, 59: 1710-1720. <https://doi.org/10.1111/fwb.12376>

Davis, K.T., Dobrowski, S.Z., Holden, Z.A., Higuera, P.E. & Abatzoglou, J.T. (2019). Microclimatic buffering in forests of the future: the role of local water balance. *Ecohydrology* 42: 1–11.

DCCEE (2011). Advice to the Minister for Sustainability, Environment, Water, Population and Communities from the Threatened Species Scientific Committee (the Committee) on an Amendment to

the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

DCCEEW (2018). Approved Conservation Advice (including Listing Advice) for the Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria ecological community

DEECA (2023). Victorian Water Quality Analysis 2022 Summary Report. Report produced by the Department of Energy, Environment and Climate Action.

DEECA (2024). Victoria's Bushfire Management Strategy. Department of Energy, Environment and Climate Action.

DELWP (2020). Guidelines for assessing the impact of climate change on water availability in Victoria (Final)

DELWP (2022a). *Central Gippsland Region Sustainable Water Strategy*. Victorian Department of Environment, Land, Water and Planning.

DELWP and Traditional Owners (2022b). *Water is Life. Traditional Owner Access to Water Roadmap*

DEPI (2013). *FLOWS - a method for determining environmental water requirements in Victoria*. Edition 2. The state of Victoria. Department of Environment and Primary Industries.

DSE (2011). *Western Region Sustainable Water Strategy*. Victorian Government Department of Sustainability and Environment

Dwyer GK & Lester RE (2021). *Gellibrand River catchment: State of knowledge review*. Report to Corangamite CMA by Deakin University, Waurin Ponds.

Earth Tech (2006a). *Environmental flow determination for the Gellibrand River. Site paper*.

Earth Tech (2006b). *Environmental flow determination for the Gellibrand River. Issues paper*.

Earth Tech (2006c). *Environmental flow determination for the Gellibrand River. Recommendations*.

Eastern Maar Aboriginal Corporation (2022). *Water is Life Eastern Maar Nation Statement. Water is Life: Traditional Owner Access to Water Roadmap*. (Section B: Traditional Owner Nation Statements).

Eastern Maar Aboriginal Corporation (2015). *Eastern Maar Meerreengeeye ngakeepoorryeeyt (Our Country, Far Seeing)*. Eastern Maar Country Plan.

Federal Interagency Stream Restoration Working Group (FISRWG) (1998). *Stream corridor restoration: Principles, processes, and practices*. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, DC.

Flowers TJ, Hajibagheri MA & Clipson NJ (1986). Halophytes. *Quarterly Review of Biology* 61: 313–337.

Francoeur, S.N. & Biggs, B.J.F. (2006). Short-term effects of elevated velocity and sediment abrasion on benthic algal communities. *Hydrobiologia* 561: 59–69.

Flood D & Papas P (2016). *A guide to water regime, salinity ranges and bioregional conservation status of Victorian wetland Ecological Vegetation Classes*. Technical Report № 226. Arthur Rylah Institute for Environmental Research, Melbourne

- Ganf G, White S & Oliver R (2010). Allocating water to the wetlands of the Murray Valley to maximise aquatic plant species diversity. In *Ecosystem response modelling in the Murray-Darling Basin*. Edited by Saintilan N & Overton I. Pages 279–299. CSIRO Publishing, Collingwood
- Gawne, B. *et al.* (2020). Monitoring of environmental flow outcomes in a large river basin: The Commonwealth Environmental Water Holder's long-term intervention in the Murray-Darling Basin, Australia. *River Research and Applications* 36: 630–644.
- GHD (2013). Groundwater Assessment Baseflow Dependent Rivers. Report prepared for Department of Environment and Primary Industries, September 2013.
- Goolmeier T, Skroblin A, Grant C, van Leeuwen C, Archer R, Gore-Birch C, Wintle BA (2022). Recognizing culturally significant species and indigenous-led management is key to meeting international biodiversity obligations. *Conservation Letters* 15, e12899. doi:10.1111/conl.12899
- Greenwood ME & MacFarlane GR (2006). Effects of salinity and temperature on the germination of *Phragmites australis*, *Juncus kraussii*, and *Juncus acutus*: implications for estuarine restoration initiatives. *Wetlands* 26: 854–861.
- Greet, J., Webb, A.J. & Downes, B.J. (2011a). Flow variability maintains the structure and composition of in-channel riparian vegetation. *Freshwater Biology* 56: 2514–2528.
- Greet, J., Webb, A.J. & Cousens, R.D. (2011b). The importance of seasonal flow timing for riparian vegetation dynamics: a systematic review using causal criteria analysis. *Freshwater Biology* 56: 1231–1247.
- Hansen, B., Reich, P., Lake, P. S., & Cavagnaro, T. (2010). *Minimum width requirement for riparian zones to protect flowing waters and to conserve biodiversity: a review and recommendations with application to the state of Victoria*. Department of Sustainability and Environment, Melbourne.
- HARC (2025). Gellibrand Source Model Development. Technical Report. Final. Produced by HARC Services Pty Ltd (HARC) for Barwon Water.
- Jacobs (2020). *Cement Creek environmental flows study*. Report to Melbourne Water, Melbourne.
- Johnston K., Matthews, T.G., Robson, B.J., and Chester, E.T (2014). Impacts of Extreme Events on Southeastern Australian Freshwater Crayfish. *Freshwater Crayfish* 20(1):61–71  
<http://dx.doi.org/10.5869/fc.2014.v20-1.61>
- Jones, C. (2023). *Comparing flow and non-flow drivers of riparian vegetation communities and their interactions*. VEFMAP Stage 7 report, Arthur Rylah Institute, Melbourne.
- Kailola, P.J., Williams, M.J., Stewart, P.C., Reichelt, R.E., McNee, A. and Grieve, C. (1993). Australian Fisheries Resources. (Bureau of Resource Sciences, Department of Primary Industries and Energy, and Fisheries Research and Development Corporation: Canberra, Australia.)
- Koster, W. M., Dawson, D. R., and Crook, D. A. (2013). Downstream spawning migration by the amphidromous Australian grayling (*Prototroctes maraena*) in a coastal river in south-eastern Australia. *Marine and Freshwater Research* 64, 31–41. doi:10.1071/MF12196.
- Koster, W.M., Amtstaetter, F., Dawson, D.R., Reich, P. and Morrongiello, J.R. (2017). Provision of environmental flows promotes spawning of a nationally threatened diadromous fish. *Marine and Freshwater Research*, 68:159–166.

Lawson, J.R., Fryirs, K.A., Lenz, T. & Leishman, M.R. (2015). Heterogeneous flows foster heterogeneous assemblages: relationships between functional diversity and hydrological heterogeneity in riparian plant communities. *Freshwater Biology* 60: 2208–2225.

Lloyd, L.N., Anderson, B.G., Cooling, M., Gippel, C.J., Pope, A.J. and Sherwood, J.E. (2008). Environmental water requirements of the Gellibrand estuary: Final estuary environmental flows assessment report

Lloyd L. (2025). Literature review and factsheet on the known adverse environmental impacts of artificial estuary openings. Report prepared by Lance Lloyd (Lloyd Environmental) for Corangamite Catchment Management Authority (CCMA project number COR-230)

Lock, M.A. (1993). Attached microbial communities in rivers. In Ford, T.E. (ed). *Aquatic Microbiology*. Pages 113–38. Blackwell Scientific, Oxford.

Lock, M.A., Wallace, R.R., Costerton J.W. & Charlton, S.E. (1984). River epilithon (biofilm): Toward a structural functional model. *Oikos* 42: 10–22.

Mallen-Cooper, M., & Zampatti, B. P. (2018). History, hydrology and hydraulics: Rethinking the ecological management of large rivers. *Ecohydrology*, 11, e1965.

McKenna K and Lovett, S. Guide: Rakali. Recognising and caring for our Australian water rat. Rivers of Carbon guide. Available at: <https://riversofcarbon.org.au/guide-recognising-and-caring-for-rakali-our-australian-water-rat/>

Morris, K. & Reich, P. (2013). Understanding the Relationship Between Livestock Grazing and Wetland Condition. Technical Report Series No. 252. Arthur Rylah Institute, Melbourne.

Moss and Clifton (2018). Catchment carbon offsets trial: Gellibrand River case study. Report prepared by Jacobs Group (Australia) Pty Ltd for Goulburn Broken Catchment Management Authority.

NRE (undated). Tasmania's freshwater burrowing crayfish brochure. Available at: <https://nre.tas.gov.au/Documents/Burrowing-Crayfish-brochure.pdf>

NSW DPI Freshwater Spiny Crayfish in North East NSW. NSW Department of Primary Industries, Primefact 1327, First Edition. Fisheries Ecosystems Uni, Port Stephens Fisheries Institute

Park G. and Roberts A (2023). Gellibrand River Integrated Catchment Management Plan. Report prepared by Geoff Park and Anna Roberts (Natural Decisions).

Pascoe, J., Clarke, M., Hickey, E., Prentice, L., Couzens, V., & Clarke, J. (2024). Pang-ngooteekeeeya weeng malangeepa ngeeye (remembering our future: bringing old ideas to the new). *Wildlife Research*, 51(10). <https://doi.org/10.1071/WR24068>

Poff, N.L. & Zimmerman, J.K.H. (2014). Ecological responses to altered flow regimes: A literature review to inform the science and management of environmental flows. *Freshwater Biology* 55: 194–205.

Riis, T & Biggs, B.J.F (2003). Hydrologic and hydraulic control of macrophyte establishment and performance in streams. *Limnology and Oceanography* 48: 1488–1497.

Ramm, D.C. (1986). An ecological study of the ichthyoplankton and juvenile fish of the Gippsland Lakes, Victoria. (University of Melbourne: Melbourne).

Roberts, J. & Marston, F. (2011). *Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin*. National Water Commission, Canberra.

Robson, B.J., Sherwood, J., McKay, S.F. and Kelly, L.M. (2002). Floodplain wetlands of the Gellibrand estuary: What type of invertebrate community? *Ecological Management and Restoration* 3: 139-141

Rogers K (2011). Vegetation. In *Floodplain wetland biota in the Murray-Darling Basin*. Edited by Rogers K & Ralph T.J. Pages 17–82. CSIRO Publishing, Collingwood

Rogers, K. & Ralph, T.J. (2011). *Floodplain wetland biota in the Murray-Darling Basin: water and habitat requirements*. CSIRO Publishing, Collingwood.

Rozema J (1975). The influence of salinity, inundation and temperature on the germination of some halophytes and non-halophytes. *Oecologia Plantarum* 10: 317–329.

Ryan, J.G. & McAlpine, C.A. (2005). Simulating the feedback between land cover configuration and ecohydrological functioning in complex adaptive landscapes. In: Zenger, A. & Argent, R.M. (eds). *International Congress on Modelling and Simulation (MODSIM05)*, December 12-15, Melbourne (Australia). Pages 758–764.

Sainty G, Hoskin J, Carr G & Adam P (2012). *Estuary plants and what's happening to them in south-east Australia*. Sainty & Associates, Sydney.

Sherwood, J.E. (2006). Environmental flow needs of the Gellibrand Estuary. Appendix A in *Earth Tech, Environmental flow determination for the Gellibrand River: Recommendations*. Corangamite Catchment Management Authority, Colac, July.

Shields, A. (1937). Application of similarity principles and turbulence research to bed-load movement. (English translation of 1936 dissertation; various reprints and summaries exist)

Sinclair SJ & Sutter GR (2008). Estuarine wetland vegetation mapping, Glenelg Hopkins CMA. Technical Report Series No. 178. Arthur Rylah Institute for Environmental Research, Melbourne.

Singh, R., Tiwari, A.K. and Singh, G.S. (2021). Managing riparian zones for river health improvement: an integrated approach. *Landscape and Ecological Engineering* 17:195-223.

Smith, H., Cawson, J., Sheridan, G., and Lane, P (2011). Desktop review - Impact of bushfires on water quality. Report prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Forests and Water Group, Department of Forest and Ecosystem Science Melbourne School of Land and Environment, The University of Melbourne.

SWIFFT (2025). State Wide Integrated Flora and Fauna Teams website for the Otway black snail. Available at: [https://www.swifft.net.au/cb\\_pages/sp\\_otway\\_black\\_snail.php#:~:text=The%20Otway%20Black%20Snail%20inhabits%20wet%20forest%2C%20cool,between%20these%20forest%20types%20%28Burrell%20et%20al.%202007%29](https://www.swifft.net.au/cb_pages/sp_otway_black_snail.php#:~:text=The%20Otway%20Black%20Snail%20inhabits%20wet%20forest%2C%20cool,between%20these%20forest%20types%20%28Burrell%20et%20al.%202007%29)

Tilleard, J. W. (2001). River channel adjustment to hydrologic change. PhD thesis, Department of Civil and Environmental Engineering, The University of Melbourne.

Tonkin, Z., Jones, C., Clunie, P., Vivian, L., Amtstaetter, F., Jones, M., Koster, W., Mole, B., O'Connor, J., Brooks, J., Caffrey, L. & Lyon, J. (2020). Victorian Environmental Flows Monitoring and Assessment Program. Stage 6 Synthesis Report 2016-2020. Technical Report Series No. 316, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Ungar IA (1962). Influence of salinity on seed germination in succulent halophytes. *Ecology* 43: 763–764.

Vannote, R.L., Minshall, W.G., Cummins, K.W., Sedell, J.R. & Cushing, C.E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 130–137.

Vertessy, D. and Cameron A (1998). Biological Monitoring in the Gellibrand River Catchment, WATER ECOscience (T/as AWT Victoria).

VFA (2026). Short-finned eel webpage. Victorian Fisheries Authority. Available at <https://vfa.vic.gov.au/education/fish-species/short-finned-eel>

Vincent, T.J. (2025). Influence of riparian vegetation type on fish assemblages in the Gellibrand catchment, Victoria. Thesis submitted in partial fulfilment of the degree of Bachelor of Environmental Science, Honours. School of Life and Environmental Sciences, Deakin University.

Waisel Y (1972). The biology of halophytes. Academic Press, New York.

Watts, R.J., Ryder, D.S., Burns, A., Wilson, A.L., Nye, E.R., Zander, A., & Dehaan, R. (2006). Responses of biofilms to cyclic releases during a low flow period in the Mitta Mitta River, Victoria, Australia Institute for Land, Water and Society Report No. 24, Charles Sturt University.

Webb, J.A., Wallis, E.M. & Stewardson, M.J. (2012). A systematic review of published evidence linking wetland plants to water regime components. *Aquatic Botany* 103: 1–14.

Webb, J.A., Miller, K.A., King, E.L., de Little, S.C, Stewardson, M.J., Zimmerman, J.K.H. & Poff, N.L. (2013). Squeezing the most out of existing literature: a systematic re-analysis of published evidence on ecological responses to altered flows. *Freshwater Biology* 58: 2439–2451.

Whiterod, N. S., Furse, J. M., Lutz, M., Lintermans, M., McCormack, R., Zukowski, S., Thompson, R., Raadik, T. A., Marshall, J., Miller, A. D., Austin, C., Ahyong, S. T. (2022). The 2022 Action Plan for priority 2019–20 bushfire impacted species from Australia's endemic freshwater crayfish genus *Euastacus* (Parastacidae). A report to the Department of Agriculture, Water and the Environment. Aquasave-Nature Glenelg Trust, Victor Harbor.

## A.1 Appendix 1 - Aquatic fauna recorded in the Gellibrand catchment

Aquatic fauna values in the Gellibrand catchment were described in the Site Paper (Alluvium 2025), and the summary table reproduced below in Table 35.

**Table 35. Aquatic fauna in the Gellibrand catchment**

(ALA = Atlas of living Australia, IEC = Index of estuary condition, PMST = protected matters search tool, EPBC = Environment Protection and Biodiversity Conservation, FFG = Flora and Fauna Guarantee. V = listed as vulnerable. E = listed as endangered; ● indicates species observed in reach. \* indicates introduced species)

| Common Name            | Taxonomic Name                 | ALA | IEC | PMST | EPBC Act | FFG Act | Life history                | Timing of higher flows                           | Presence of species by Reach (VBA/Nature Kit) |    |    |    |    |    |   |   |   |  |
|------------------------|--------------------------------|-----|-----|------|----------|---------|-----------------------------|--------------------------------------------------|-----------------------------------------------|----|----|----|----|----|---|---|---|--|
|                        |                                |     |     |      |          |         |                             |                                                  | 1                                             | 2a | 2b | 2c | 3a | 3b | 4 | 5 | E |  |
| Flathead Gudgeon       | <i>Philypnodon grandiceps</i>  | +   | -   | -    | -        | -       | Freshwater                  |                                                  |                                               |    |    |    |    |    |   |   | ● |  |
| Brown Trout*           | <i>Salmo trutta</i>            | +   | +   | -    | -        | -       | Freshwater                  |                                                  | ●                                             | ●  | ●  | ●  |    | ●  | ● |   | ● |  |
| Rainbow Trout*         | <i>Oncorhynchus mykiss</i>     | +   | -   | -    | -        | -       | Freshwater                  |                                                  |                                               |    |    |    |    |    | ● |   |   |  |
| Southern Pygmy perch   | <i>Nannoperca australis</i>    | +   | +   | -    | -        | -       | Freshwater                  |                                                  | ●                                             | ●  | ●  |    |    |    | ● | ● | ● |  |
| Australian Smelt       | <i>Retropinna semoni</i>       | +   | +   | -    | -        | -       | Freshwater/estuarine        |                                                  |                                               | ●  | ●  |    |    |    | ● |   |   |  |
| Common Galaxias        | <i>Galaxias maculatus</i>      | +   | +   | -    | -        | -       | Catadromous                 | Downstream migration in autumn. Spawn in spring. | ●                                             | ●  | ●  | ●  |    | ●  | ● | ● | ● |  |
| River Blackfish        | <i>Gadopsis marmoratus</i>     | +   | +   | -    | -        | -       | Freshwater                  |                                                  | ●                                             | ●  | ●  | ●  |    | ●  | ● |   |   |  |
| Ornate Galaxias        | <i>Galaxias ornatus</i>        | +   | +   | -    | -        | -       | Freshwater                  |                                                  | ●                                             | ●  | ●  | ●  |    |    |   |   |   |  |
| Southern Shortfin Eel  | <i>Anguilla australis</i>      | +   | +   | -    | -        | -       | Catadromous                 | Summer to early autumn                           | ●                                             | ●  | ●  | ●  |    | ●  | ● | ● | ● |  |
| Pouched lamprey        | <i>Geotria australis</i>       | +   | +   | -    | -        | -       | Anadromous                  | Late winter to early summer                      |                                               | ●  |    | ●  |    | ●  | ● |   |   |  |
| Spotted Galaxias       | <i>Galaxias truttaceus</i>     | +   | +   | -    | -        | -       | Catadromous                 | Autumn to winter                                 | ●                                             |    |    |    |    | ●  | ● | ● | ● |  |
| Tupong                 | <i>Pseudaphritis urvillii</i>  | +   | +   | -    | -        | -       | Catadromous                 | Autumn to winter                                 | ●                                             | ●  | ●  |    |    |    | ● |   | ● |  |
| Australian Grayling    | <i>Prototroctes maraena</i>    | +   | +   | +    | V        | E       | Catadromous                 | Late summer to winter                            |                                               | ●  | ●  |    |    |    | ● |   |   |  |
| Climbing Galaxias      | <i>Galaxias brevipinnis</i>    | -   | +   | -    | -        | -       | Catadromous                 | Autumn to winter                                 | ●                                             | ●  |    | ●  | ●  | ●  | ● |   |   |  |
| Shorthead Lamprey      | <i>Mordacia mordax</i>         | +   | +   | -    | -        | -       | Anadromous                  | Late winter to early summer                      | ●                                             | ●  | ●  | ●  |    | ●  | ● |   |   |  |
| Black Bream            | <i>Acanthopagrus butcheri</i>  | +   | -   | -    | -        | -       | Estuarine                   |                                                  |                                               |    |    |    |    |    |   |   | ● |  |
| Yellow-eye Mullet      | <i>Aldrichetta forsteri</i>    | +   | -   | -    | -        | -       | Estuarine                   |                                                  |                                               |    |    |    |    |    |   |   | ● |  |
| Sea Mullet             | <i>Mugil cephalus</i>          | +   | -   | -    | -        | -       | Freshwater/estuarine/marine |                                                  |                                               |    |    |    |    |    |   |   | ● |  |
| Estuary Perch          | <i>Percalates colonorum</i>    | -   | -   | -    | -        | -       | Freshwater/estuarine        |                                                  |                                               |    |    |    |    |    |   |   | ● |  |
| Smallmouthed Hardyhead | <i>Atherinosoma microstoma</i> | +   | -   | -    | -        | -       | Estuarine                   |                                                  |                                               |    |    |    |    |    |   |   | ● |  |

| Common Name              | Taxonomic Name                       | ALA | IEC | PMST | EPBC Act | FFG Act | Life history                       | Timing of higher flows | Presence of species by Reach (VBA/Nature Kit) |    |    |    |    |    |   |   |   |   |
|--------------------------|--------------------------------------|-----|-----|------|----------|---------|------------------------------------|------------------------|-----------------------------------------------|----|----|----|----|----|---|---|---|---|
|                          |                                      |     |     |      |          |         |                                    |                        | 1                                             | 2a | 2b | 2c | 3a | 3b | 4 | 5 | E |   |
| Australian Herring       | <i>Arripis georgianus</i>            | +   | -   | -    | -        | -       | Freshwater/estuarine               |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Largemouth Goby          | <i>Redigobius macrostoma</i>         | +   | -   | -    | V        | -       | Estuarine                          |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Scary's Tasmangoby       | <i>Tasmanogobius lasti</i>           | +   | -   | -    | -        | -       | Estuarine                          |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Longsnout Flounder       | <i>Ammotretis rostratus</i>          | +   | -   | -    | -        | -       | Estuarine/marine                   |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Luderick                 | <i>Girella tricuspidata</i>          | +   | -   | -    | -        | -       | Estuarine/marine                   |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Silver Trevally          | <i>Pseudocaranx georgianus</i>       | +   | -   | -    | -        | -       | Estuarine/marine                   |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Smooth Toadfish          | <i>Tetractenos glaber</i>            | +   | -   | -    | -        | -       | Estuarine/marine                   |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Australian salmon^       | <i>Arripis trutta</i>                | -   | -   | -    | -        | -       | Estuarine / marine                 |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Blue Spot Goby^          | <i>Pseudogobius olorum</i> (assumed) | -   | -   | -    | -        | -       | Estuarine                          |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Tamar River Goby^        | <i>Afurcagobius tamarensis</i>       | -   | +   | -    | -        | -       | Estuarine                          |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Elongate hardyhead^      | <i>Atherinosoma elongatum</i>        | -   | -   | -    | -        | -       | Marine derived estuarine dependent |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Mulloway^                | <i>Argyrosomus sp.</i>               | -   | -   | -    | -        | -       | Marine derived estuarine dependent |                        |                                               |    |    |    |    |    |   |   |   | ● |
| King George Whiting^     | <i>Sillaginodes punctatus</i>        | -   | -   | -    | -        | -       | Marine derived estuarine dependent |                        |                                               |    |    |    |    |    |   |   |   | ● |
| Platypus                 | <i>Ornithorhynchus anatinus</i>      | +   | +   | -    | -        | V       | Freshwater                         |                        | ●                                             | ●  | ●  |    | ●  | ●  | ● | ● | ● | ● |
| Spiny Crayfish           | <i>Euastacus yarraensis</i>          | +   | +   | -    | -        | -       | Freshwater                         |                        | ●                                             | ●  | ●  |    |    |    | ● | ● |   |   |
| Common freshwater shrimp | <i>Paratya australiensis</i>         | -   | -   | -    | -        | -       | Freshwater                         |                        |                                               |    |    | ●  |    |    |   |   |   |   |
| Mussel                   | N.D**                                |     |     |      |          |         | Freshwater                         |                        | ●                                             | ●  |    |    | ●  |    |   |   |   |   |
| Burrowing crayfish       | N.D#                                 |     |     |      |          |         | Water-dependent                    |                        |                                               |    |    |    | ●  |    |   |   |   |   |

## A.2 Appendix 2 - Nearest streamflow gauges to each FLOWS study site in the Gellibrand catchment

This section explores Gellibrand system hydrology, based on Source modelled flow data for the Gellibrand River and tributaries (HARC 2025) at the nearest streamflow gauge to each FLOWS study site (Table 36). While many streamflow gauges have long periods of record, others (for example, Gellibrand River @ Rafferty's Lane) were installed relatively recently. Project Advisory Group representatives have expressed concerns about inaccurate gauging at some streamflow gauges or flow conditions (for example Yahoo Creek - a tributary of Love Creek), periods of gauge inactivity, and others related to the decommissioning and movement of streamflow gauges within reaches.

**Table 36. Nearest streamflow gauges to FLOWS study sites**

| Reach | Reach Name               | Nearest flow gauge                                                               | Gauged period                                                                                                                                         |
|-------|--------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | Love Creek               | 235234 (Love Creek @ Gellibrand)                                                 | 02/05/1979 to current as of April 2026                                                                                                                |
| 2a    | Gellibrand River (upper) | 235231 (Gellibrand River @ Raffertys Lane)<br>235236 (D/S Dam Site G5A inactive) | 27/05/2022 to current as of April 2026<br>29/06/1981 to 03/07/1990                                                                                    |
| 2b    | Gellibrand River (mid)   | 235227 (Gellibrand River @ Bunkers Hill)                                         | 10/03/1970 to 23/1/2026 (noting gauge burned out in Jan 2026 bushfire and has since been reinstated)                                                  |
| 2c    | Lardner Creek            | 235210 (Lardner Creek)                                                           | 18/06/1964 to current as of April 2026                                                                                                                |
| 3a    | Arkins and First Creeks  | 235205 (Arkins Creek West Branch at Wyelangta)                                   | 03/02/1958 to 18/02/2026 (as of April 2026)                                                                                                           |
| 3b    | Carlisle River           | 235200C (Carlisle River)                                                         | Data not publicly available                                                                                                                           |
| 4     | Gellibrand River (lower) | 235258 (South Otway pump station)                                                | 30/03/1999 to current as of April 2026. Note rating table not maintained above ~100 ML/day gauge is easily flooded                                    |
| 5     | Kennedys Creek           | 235211 (Kennedys Creek)                                                          | 17/06/1964 to current as of April 2026                                                                                                                |
| 6     | Gellibrand estuary       | 235224 (Burrupa)                                                                 | 20/03/1969 to current as of April 2026. Gauge represents freshwater inflows to top of estuary. Gauge is influenced by backups/flooding in the estuary |

## A.3 Appendix 3 – The Gellibrand River Source Model

### A.3.1 Hydrologic Model development

In 2025, HARC developed a harmonised Source hydrological model for the Gellibrand catchment to represent system inflows, demands and operating rules and their variability in space and time (HARC 2025). Four development scenarios were modelled, based on agency understanding of all inputs and impacts to each sub-catchment and storage:

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Modelled current and future climate scenarios:

1. Unimpacted daily flows (i.e. without development / natural flows)
  2. Current level of development and demand (current daily flows)
  3. Future demand – full use of licence volumes of sleeper licences
  4. Full demand – full use of licence volumes of sleeper licences including 1 GL of winterfill entitlement after the 2011 WRSWS and urban demands at yield.
- 

Key model flow inputs include inflows and rainfall. Key model impacts on flows include urban demands, rural demands, farm dam impacts, evaporation, groundwater pumping impacts, and losses (including to plantation forestry).

Several current and future climate conditions were modelled for each development scenario:

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Modelled current and future climate scenarios:

1. Historic climate
  2. Current climate (pre-1975 adjusted)
  3. Step climate change (pre- 1997 adjusted)
  4. Modelled RCP 8.5 2020 climate (low, medium and high climate projections)
  5. Modelled RCP 8.5 2040 climate (low, medium and high climate projections)
  6. Modelled RCP 8.5 2065 climate (low, medium and high climate projections)
- 

It is important to note that the Source model captures understanding of Gellibrand water system operations and demands at a given point in time, based on best available data and water resource modelling guidance. The model may need to be updated periodically as new data and guidance is developed.

**Consideration of groundwater:** The model included specific representation of Barwon Water’s historic groundwater pumping impacts associated with the Barwon Downs borefield on Yahoo Creek (Love Creek tributary) and Gellibrand River upstream of Bunkers Hill, and the impacts associated with the operation of

Wannon Waters Carlisle River bores. Impacts of groundwater pumping have been routed through downstream reaches. The temporal and spatial variation in broader groundwater – surface water interactions within the catchment remain captured/embedded in the streamflow data.

**Farm Dam impacts:** Farm dam impacts were derived using the current distribution of farm dams in the Boundary Creek and Gellibrand catchments, and their growth considered as part of future climate change scenarios. Farm dam assumptions were tested with the Barwon Downs Borefield Remediation Reference Group. Aerial imagery and satellite imagery was used to ensure no dams were missed.

**Gap filling:** Streamflow gauge data gaps were infilled and extended using calibrated rainfall runoff models and good quality stream flow gauge data. The Source model therefore provides a complete, gap free, quality-controlled streamflow data sets over an extended time period.

**Yahoo Creek data quality:** HARC 2025 notes that streamflow data in Yahoo Creek at Kawarren is not well rated for flows above 100 ML/day. Data measures >100 ML/day were removed from the model analysis. Quality codes for the remaining data were also considered as part of the model development process. The PAG also note periodic errors and gaps in streamflow gauge data (for example gauged flows of 0 ML/day in Yahoo Creek on days where the PAG representatives have seen the creek flowing) that may impact the reliability of the model. HARC acknowledge that some streamflow data for Yahoo Creek is not of high quality, and every effort has been made to account for the known limitations of this gauge.

**Sea level rise:** The Source model does not incorporate impacts of sea level rise in the estuary. It is acknowledged that estuary flooding causes backups (and data quality issues) at the Burrupa streamflow gauge.

### A.3.2 Source model uncertainties

The project team acknowledge that all models have assumptions, limitations and uncertainties, including the Gellibrand River Source Model. In this case, the source dataset is by far the best quality controlled and gauge-calibrated flow dataset available for the Gellibrand catchment, and the only dataset for flows under different climate and development scenarios (including unimpacted flows). The uses of Source modelled flow data in the FLOWS study are summarised below.

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Source modelled data is used in the FLOWS study to:

1. Understand the seasonality of flows and broader system hydrology and trends
  2. Determine the frequency and duration of peak flow components (fresches, bankfull and overbank flows) – gap-free flow data is required for these analyses.
  3. Determine low flow recommendations for Reach 3a creeks, which are not amenable to hydraulic modelling
  4. Check the reasonableness of flow recommendations
  5. Performance test the recommended flow regime, including under future climates
-

Flow recommendations are based on flows that, it is believed on the basis of existing scientific knowledge, will fulfil specific environmental objectives. Although their foundation is not the return to a 'natural' flow regime, recommendations are routinely subject to "sanity checks", whereby they are compared with modelled natural hydrographs, flow-duration curves, gauge data and observations.

## **A.4 Appendix 4 - Assumptions and limitations of applying the FLOWS method**

The FLOWS method is a technical approach for the determination of environmental flow recommendations in Victoria (DEPI 2013). The method was first developed in 2002 (DNRE 2002) and fundamentally designed to assist water managers to 'recover' water for the environment in overallocated, regulated river systems in poor condition. While the method is excellent for this purpose, there are several assumptions and limitations of the method that are important for managers to consider. These are detailed below.

### **A.4.1 Reach and site representativeness**

Reaches are river 'units' used in the FLOWS method. Reaches are delineated based on flow-dependent values, geomorphology, hydrology, system operation, gauge locations and major tributaries. These characteristics are assumed to be uniform within a reach. Within a reach, a site is selected for hydraulic modelling, and it is at this site that flow recommendations are determined. The FLOWS method assumes that the selected site is representative of the broader reach.

Flow recommendations are developed for physical features present during the site visits. Similarly, the site survey and hydraulic model represent each FLOWS study site at a particular point in time. Rivers are dynamic and physical form and features may change over time. The EFTP has endeavoured to select sites that are physically stable, and less likely to be subject to willow removal and other physical disturbances but cannot predict (un)natural events such as bushfires. Bushfires have significant potential to alter vegetation composition, affect physical form at sites, and drive sediment delivery, as occurred at Site 2b in early 2026.

### **A.4.2 The importance of instream features**

The FLOWS method uses a hydraulic approach for the determination of flow recommendations. The method relies upon the presence of physical features in the river (including but not limited to pools, riffles, runs, bars, benches, floodplain, flora and fauna etc.) that are targeted (inundated) to different extents by different flow components. Waterways in the Gellibrand River system typically have trapezoidal cross sections, with limited physical features. This poses a challenge to the setting of flow recommendations, as it is unclear 'what level' should be targeted by each component to support environmental values, and when. The EFTP will rely more heavily upon modelled hydrologic data to support the setting of 'reasonable' flow component magnitudes, in the absence of in-channel hydraulic features.

### **A.4.3 Minimum flow recommendations**

The hydraulic 'nature' of the FLOWS method results in a set of minimum flow recommendations to inundate hydraulic features and thereby support environmental values. Managers may choose to deliver

greater flows, however it is not unusual for managers to adopt the minimum flow recommendations. It is noted too, that flow recommendations are not legally binding or otherwise enforceable, and that in some instances, the delivery of such flow components (e.g. overbank events) may not be consistent with water law. Although some flow components such as overbank flows cannot be 'delivered' (due to operational and other constraints), the volumes required to achieve the recommendations should be protected from future allocation. It is noted that implementation of the flow recommendations is a management responsibility. The delivery of flows may be required to achieve broader agency objectives, but the flow recommendations are exactly that: recommendations.

#### A.4.4 The FLOWS method in regulated vs unregulated systems

The FLOWS method was originally conceived and designed to 'claw-back' water in regulated, over allocated systems, returning flow variability to systems through the delivery of different flow components. In rivers that had previously seen minimal and invariable flows through regulation, the delivery of greater flows with greater variability was essential to support environmental values and improve river condition.

In unregulated (freely flowing, dynamic) rivers, managers use flow recommendations to aid the setting of diversion restrictions and cease-to-pump rules. Recommendations may also protect flows from future harvesting and inform system licensing (for example, although the flow components cannot be 'delivered', the volumes required to achieve the recommendations should be protected from allocation). Application of the FLOWS method 'conceptually' reduces the high variability of the natural flow regime to a 'minimum' flow regime comprising a set of distinct flow components. The potential unintended consequence is that minimum flows recommendations could be less than that currently received by an unregulated waterway. The EFTP note a strategic outcome to *improve riparian extent and condition, hydrological regime and water quality in Otway Coast priority waterways* (See Section 5) and will be conscious of this when developing flow recommendations, such as to not adversely impact hydrological regimes.

#### A.4.5 Source of water to meet recommendations

Flow recommendations are set at a given location in a reach, based on known values in the reach, environmental objectives, flow-ecology relationships (hydraulic criteria) and the physical features captured in the hydraulic model. The FLOWS method is largely agnostic to the 'source' of water to meet recommendations. Although in reality the project team acknowledge that these may come from rainfall/runoff processes, Bulk Entitlements, Environmental Entitlements, temporary trades, or other sources.

#### A.4.6 Scope of the FLOWS study and implementation of flow recommendations

The FLOWS method has defined inputs and outputs. The method focusses on *flow-dependent values*, thus although a significant environmental value may be found at a site (for example Otway Black Snails), if it is not (stream) flow-dependent it will not feature in the recommendations.

During the site assessment, the EFTP noted several catchment management challenges that will limit the potential to achieve environmental improvement through flow. The study will make recommendations for future work and suggest complementary non-flow related actions to support the flow recommendations

in achieving environmental outcomes. The study's recommendations may also be used to inform future waterway management decisions.

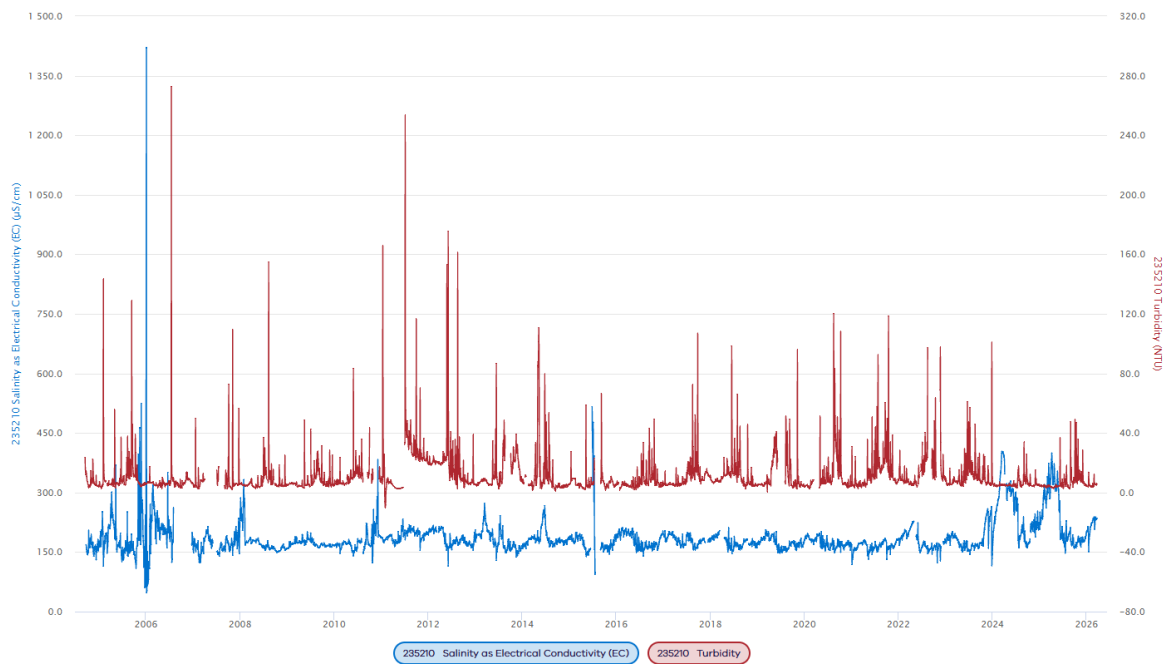
Implementation of the flow recommendations is a management responsibility. Flow recommendations are not legally binding, and in some circumstances may not be implementable due to constraints or the lack of management levers (i.e. flow recommendations cannot be 'delivered' in an unregulated reach). Some high magnitude flow components (for example, an overbank flow) may only be delivered naturally as such volumes might exceed what could feasibly be stored or released, or could contribute to the inundation of private property.

## A.5 Appendix 5 Available water quality data from streamflow gauges in the Gellibrand catchment

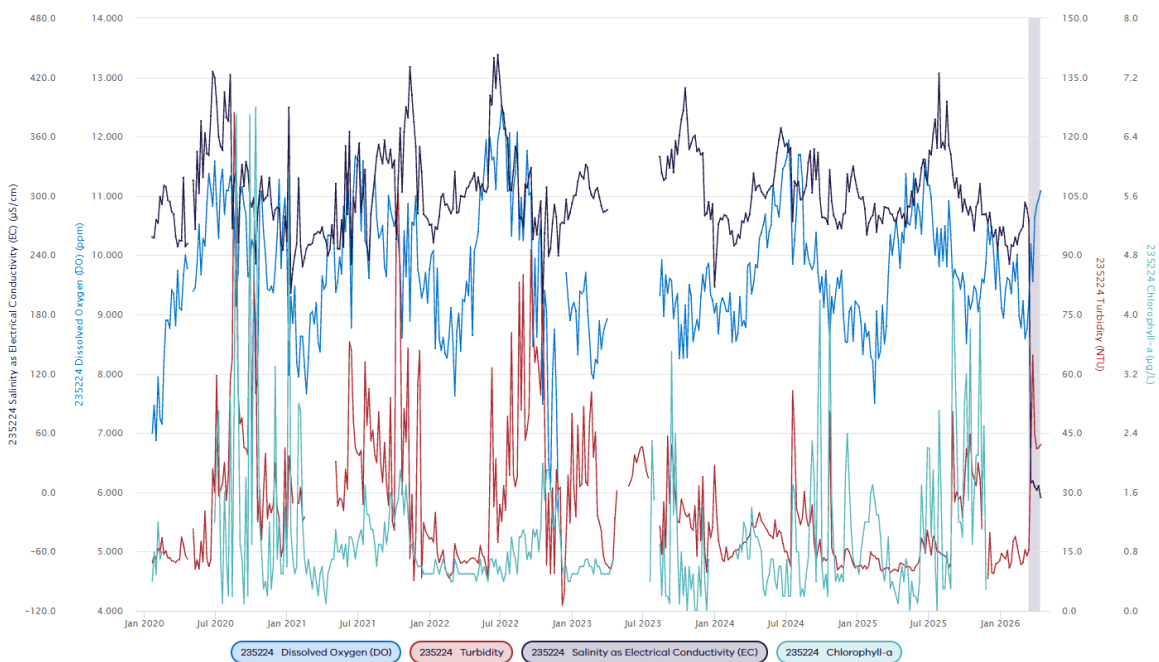
Reach 2b Gellibrand River at Bunkers Hill Gauge 235227 - Dissolved Oxygen data from 2008 - 2009



### Reach 2c Lardner Creek at Gauge 235210 - Salinity and Turbidity



### Gellibrand River at Burrupa (Reach 4 and estuary) - Dissolved oxygen, Turbidity, Salinity and Chlorophyll- $\alpha$



## Kennedys Creek - at Kennedys Creek gauge 235211 - Salinity

