



Site Paper

Gellibrand River FLOWS study

Prepared for
Barwon Water
November 2025





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. 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.

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

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1 Introduction

1.1 Background

Environmental flow recommendations were first set for the Gellibrand River and tributaries in 2006 (Earth Tech 2006 a, b and c) using what was then the State-endorsed approach to environmental flows and estuary flow studies: FLOWS (DNRE 2022). Much has changed since 2006, including updates to the FLOWS method itself, changes to Victorian policy and strategy (i.e. the inclusion of Traditional Owners in water management and consideration of climate change) and the generation of new knowledge on the Gellibrand catchment.

Alluvium Consulting Australia Pty Ltd (Alluvium) was engaged by Barwon Water to update the environmental flow recommendations for the Gellibrand River. In commencing this study, the environmental flows technical panel (EFTP) and Alluvium team undertook a review of the 2006 FLOWS study, and available literature, data and hydraulic models pertaining to the catchment that have been developed since 2006. The team also conducted a preliminary site visit to reconcile desktop-based understandings with field-based observations of 2006 FLOWS study reaches.

The EFTP recommended that the environmental flow recommendations for all six freshwater reaches of the 2006 FLOWS study be updated. The recommendation was based on the following factors:

- The existing Gellibrand FLOWS study is 19 years old, and much has changed since this time, including updates to the FLOWS method itself and approaches to the determination of environmental flow recommendations.
- Changes to the FLOWS method itself, with the current (Second) edition of the method requiring seasonal adaptiveness.
- Changes to broader water policy and strategy require consideration of climate, and the self-determined involvement of Traditional Owners in water management.
- Changes to the ways that values, environmental objectives and hydraulic criteria are articulated in the FLOWS method Ed.2 (DEPI 2013). The 2006 FLOWS study approached environmental values from an 'Index of Stream Condition' (ISC) perspective, which was appropriate at the time, but no longer fit-for-purpose. Contemporary FLOWS studies require specific environmental objectives and hydraulic criteria that are realistic and measurable.
- New flow-dependent values have been identified since 2006, requiring new objectives and hydraulic criteria. Relevant old values, objectives and criteria (such as water quality) need to be re-described in a manner that is consistent with current approaches to the setting of flow recommendations.

New reaches will be added to the study to inform future operations: Lardner Creek and the combined Arkins and First creeks reach (comprising Arkins Creek West Branch, Arkins Creek East Branch and First Creek). A full suite of FLOWS-method based flow recommendations will be developed for Lardner Creek. Only low flow recommendations will be developed for the Arkins Creek West, Arkins Creek East and First Creek, using a hydrological approach. Flow recommendations developed for the Gellibrand estuary using the estuary environmental flows assessment method (Lloyd et al. 2008) will be brought across into this 2025/26 Gellibrand FLOWS study. The Gellibrand estuary summer / autumn low flow

recommendation will be reviewed, and the implication(s) of the new freshwater reach flow recommendations for the Gellibrand estuary will be discussed.

1.2 This study

The aims of the Gellibrand River FLOWS study are to:

1. Use a transparent science-based approach to assess the flow requirements of the Gellibrand River and its major tributaries.
2. Examine the flow-dependent environmental values and objectives of the system and determine the flow regime required to meet these objectives.
3. Identify key system constraints and risks, including climate change risks.

1.3 This paper

The **site paper**, the first of three FLOWS study reports, describes the reaches and sites selected for further assessment and provides a rationale for that selection. The site paper provides site details for each reach and a description of the potential risks to the validity of the FLOWS approach using the chosen reaches and sites. The site paper is followed by a site visit by the environmental FLOWS technical panel, and an issues paper, which outlines flow-environmental responses, including relevant flow components, the functions provided by flow components, environmental objectives and flow objectives to support values within each reach.

1.4 Project Governance

1.4.1 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.

1.4.2 Environmental FLOWS Technical Panel

The 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 is providing technical advice on groundwater.

1.4.3 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).

1.4.4 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. Several workshops will be held with the PAG over the course of the project and the group is invited to provide feedback on the FLOWS study outputs (site, issues and final recommendations papers).

1.4.5 Traditional Owners

This FLOWS study is conducted within Eastern Maar Nation. The Gellibrand Catchment encompasses the lands and waters of the Gulidjan, Gadubanud and Keerraywoorrong Peoples, whose continuing custodianship, knowledge and deep connection to Country guide this work. 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.

First Nations community members are represented on the Project Advisory Group (PAG).

1.5 The FLOWS method

The FLOWS method (Second Edition) 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 primarily designed to assist water managers to recover water for the environment in overallocated, regulated river systems in poor condition. The method was reviewed and updated in 2013 to incorporate elements of seasonal adaptiveness (DEPI 2013), allowing different recommendations to be developed for dry, average and wet years. The FLOWS method was most recently reviewed by Alluvium on behalf of DEECA in 2024 (Alluvium 2024) but has not yet been updated. It is anticipated that future updates of the FLOWS method will include consideration of climate change adaptation, and the self-determined involvement of Traditional Owners in water management and decision-making. Key tasks, activities and outputs of the FLOWS method are shown in Figure 1.

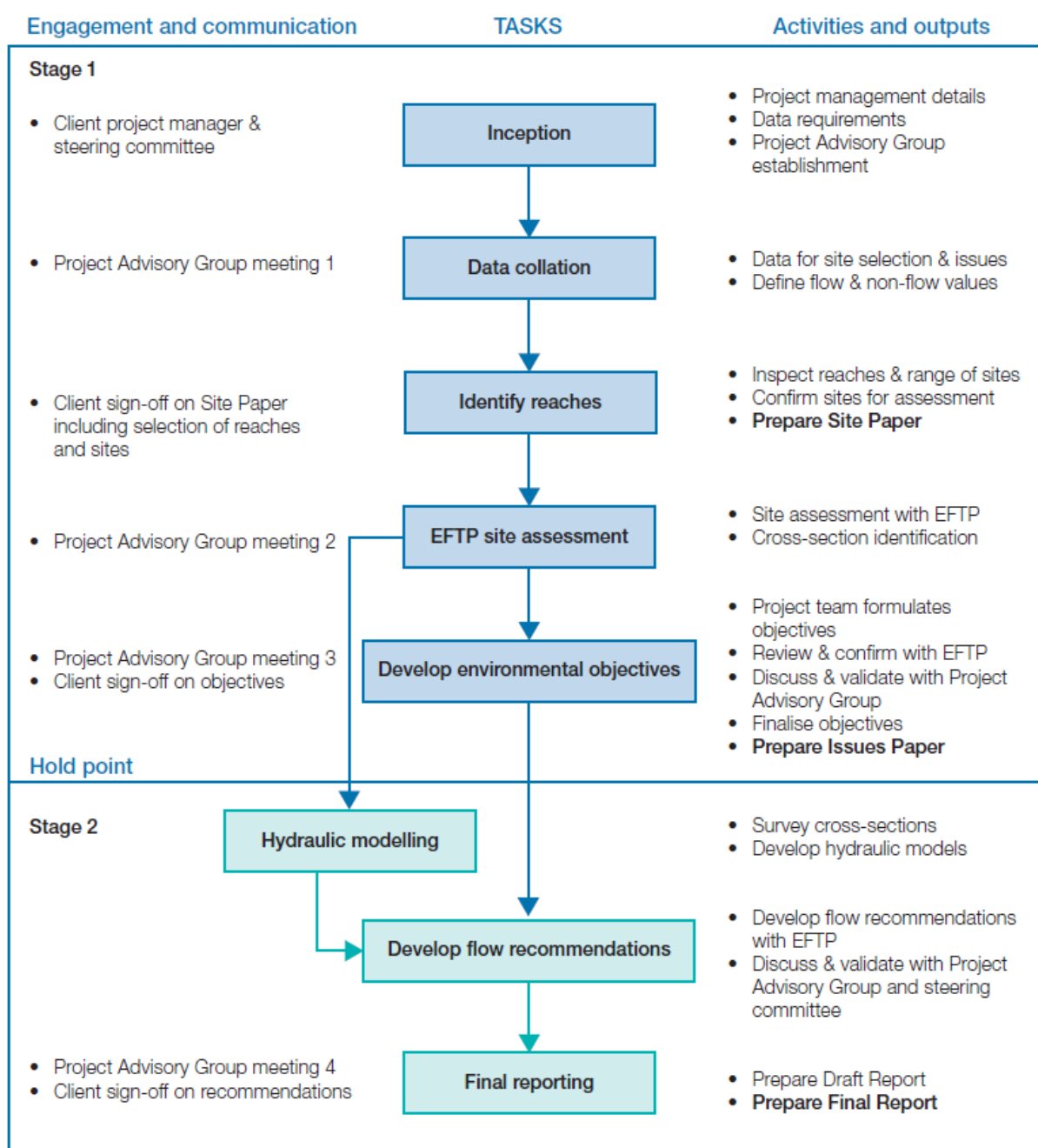


Figure 1.1 Outline of the environmental water requirements determination method.

Note: EFTP – Environmental Flows Technical Panel

Figure 1. FLOWS method tasks and outputs (DEPI 2013)

Note: Two additional Project Advisory Group meetings have been held for the Gellibrand FLOWS study. These included an introductory meeting (held soon after project inception), and a meeting (during site paper preparation) to discuss the Gellibrand hydrological model and its planned use in the FLOWS study.

1.6 Previous application of the FLOWS method in the Gellibrand River

Earth Tech (2006a, b, c), on behalf of Corangamite Catchment Management Authority (CCMA), undertook an assessment of the environmental flow requirements of six freshwater reaches of the Gellibrand River and tributaries using the first edition of the FLOWS method (DNRE 2002). The 2006 Earth Tech report also included a desktop assessment of the environmental flow requirements of the Gellibrand estuary. An estuary-specific environmental flow assessment was subsequently applied to the Gellibrand Estuary in 2008 (Lloyd et al 2008) as a pilot of the Estuary Environmental Flows Assessment Methodology (EEFAM) (Lloyd et al 2012a).

The 2008 Technical Audit Panel review of the 2006 Gellibrand FLOWS study noted the clear and realistic visions for each freshwater reach (TAP 2008a, 2008b). The assessment was described as “detailed, thorough and well documented, with scientifically defensible recommendations”. The review noted the need for better justification (documentation) of the basis for calculating flow component magnitudes, frequencies and durations and the documentation of uncertainties.

The 2006 flow recommendations are not seasonally adaptive (as this guidance was introduced in the 2013 revision of the method), nor did the project consider future climate or involve Traditional Owners. The 2006 FLOWS study focussed on fish fauna in the system and general descriptions of parameters from the Index of Stream Condition (ISC: Macroinvertebrates, fish, water quality, physical form and streamside zone), which was a Victoria-wide general assessment of river condition conducted in 1999, 2004 and 2010. It is noted that the ISC streamside zone encompasses riparian vegetation but does not include in-stream fringing or floodplain vegetation.

1.7 The 2025/26 FLOWS Study

The 2025/26 Gellibrand FLOWS study will primarily employ the 2013 FLOWS Method (second edition), with improvements to the method to consider climate change, and to support self-determined involvement of Traditional Owners. New flow recommendations will be developed for the six freshwater reaches from the 2006 FLOWS study. Lardner Creek and Arkins and First Creeks have been added as new study reaches. The Gellibrand estuary will be included as a reach, with the 2008 EEFAM recommendations by Lloyd and colleagues carried into the 2025/26 FLOWS study, and the estuary summer / autumn low flow recommendation reviewed.

2 The Gellibrand Catchment

2.1 Overview

The Gellibrand River catchment is located on Eastern Maar Country on the western side of Cape Otway, Victoria. The headwaters of the Gellibrand River and several tributaries are in the northern slopes of the Otway ranges, later flowing through the Otway Plains in the mid and lower catchment, and meeting the Southern Ocean in the Twelve Apostles Marine National Park, near Princetown (Dwyer and Lester 2021, Figure 2).

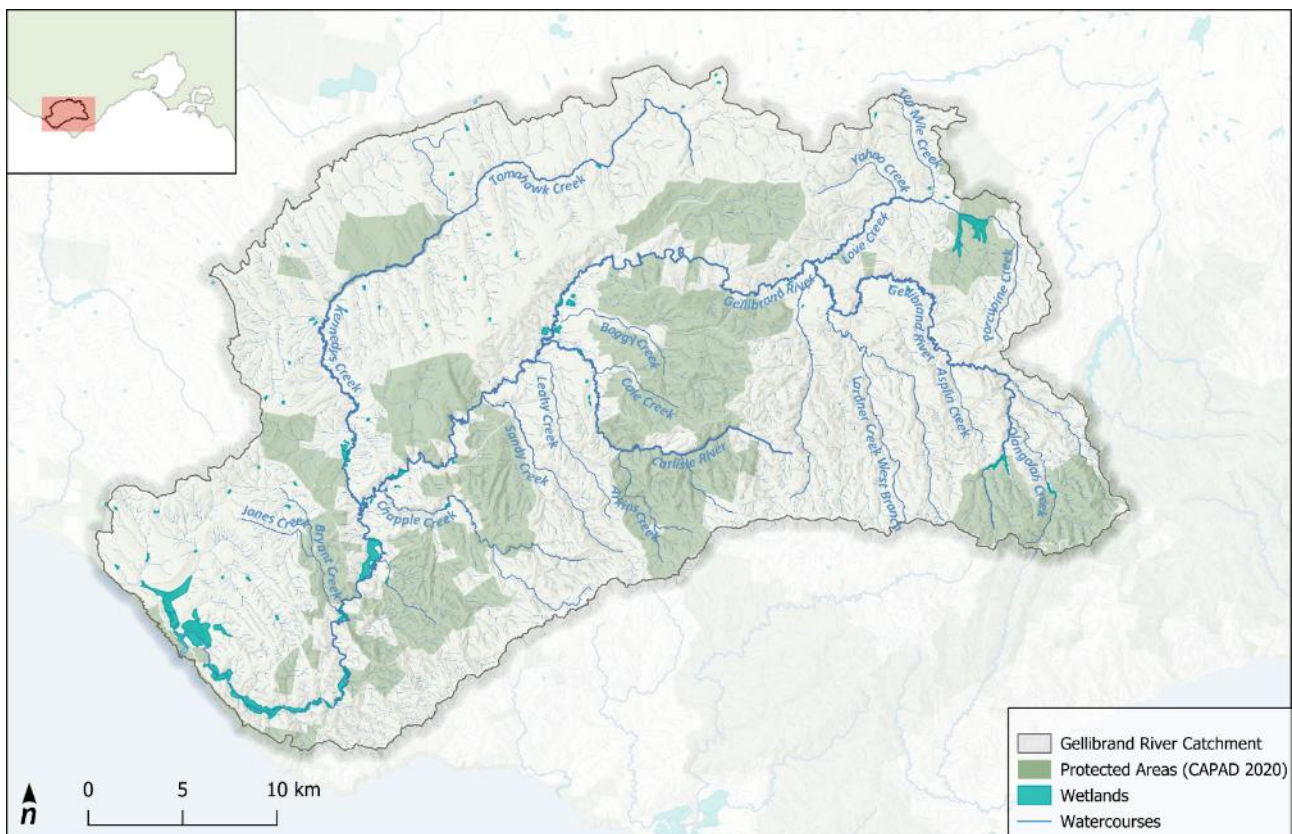


Figure 2. The Gellibrand River catchment, showing key waterways, wetlands and nationally protected (National Park) areas.

The Gellibrand catchment has an area of approximately 115,000 ha (Moss and Clifton 2018) and a high mean annual rainfall of 1012mm (Park and Roberts 2023). The catchment's geology of quaternary alluvial depositions of sand, silt, clay and gravels, together with multiple tertiary aged sequences, cretaceous sandstone and mudstone, underpin the Gellibrand River's physical form as a "single-channel of uniform width, unstable steep banks and sand substrate" (Dwyer and Lester 2021, p.7, and references cited therein). The Gellibrand River and its tributaries support a range of flow-dependent values, including but not limited to a diverse assemblage of native fish (most notably, River blackfish and Australian grayling), platypus and macroinvertebrates and ecological vegetation classes of bioregional conservation

importance. Receiving waters of Gellibrand freshwater flows - the Gellibrand estuary - is home to wetlands of national importance (the Princetown Wetlands).

The Gellibrand catchment is an important water source for urban, and stock and domestic purposes. Surface water harvesting for urban, and stock and domestic purposes, population growth, and the expansion of softwood and hardwood plantation forestry pose ongoing threats to catchment yield and flows in the Gellibrand catchment (Park and Roberts 2023).

Climate change poses a significant long-term challenge in the Corangamite catchment management area (CCMA 2021), with higher temperatures and longer periods without rainfall anticipated to reduce flows (CCMA Undated). The Gellibrand estuary is expected to be exposed to climate change impacts arising in the catchment (i.e. rising temperatures, declined and altered seasonal patterns of rainfall and runoff) and coast (for example, sea level rise and storm surge events) (CCMA 2017, DCCEEW 2018).

2.2 River operations and management

The roles of key agencies in managing the Gellibrand catchment, waterways and water resources are outlined below.

Barwon Water manages the taking, treatment and distribution of urban water supplies to Colac and the surrounding areas from the upper Gellibrand catchment. Barwon Water holds two Bulk Entitlements in the Gellibrand System: the 1997 Gellibrand Bulk Entitlement and the 2003 Colac Bulk Entitlement (see Table 1 and Appendix B). West Gellibrand Reservoir is the main storage on the West Branch of the Gellibrand River, with a total capacity of 1860 ML. Olangolah Reservoir (on Olangolah Creek - a tributary of the Gellibrand River) holds 129 ML at full capacity.

Wannon Water manages the taking, treatment and distribution of urban water supplies to South West Victoria from the lower Gellibrand catchment. Wannon Water holds one Bulk Entitlement (the Otway System bulk entitlement - enabling take from Arkins Creek West and East branches) and First Creek weirs and the North Otway and South Otway pump systems on the Gellibrand River. The water taken under the Otway System Bulk Entitlement supplies the towns of Carlisle River, Simpson, Cobden, Camperdown, Lismore, Derrinallum, Terang, Noorat, Glenormiston, Allansford and Warrnambool (SRW 2014). Wannon Water holds a Groundwater Licence to extract up to 6 ML / day from bores in Carlisle River (1800 ML / year, see Appendix A). The Carlisle River groundwater extractions enable Wannon Water to reduce surface extractions at the North Otway Pump Station during periods of low flow. There are no major instream storages in the lower Gellibrand catchment.

Table 1. Bulk entitlements in the Gellibrand system

Bulk Entitlement	Water authority	Volume (per 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)	Wannon Water	12,580	Carlisle River, Simpson, Cobden,	Arkins Creek West, Arkins Creek East, First Creek, North Otway

Bulk Entitlement	Water authority	Volume (per year)	Key town(s) supplied	Location of extraction
Conversion Order 1998			Camperdown, Lismore, Derrinallum, Terang, Noorat, Glenormiston, Allansford and Warrnambool	Pump Station and South Otway Pump station
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)

Corangamite CMA has waterway management functions in the Gellibrand catchment, and is responsible for the development and implementation of the Corangamite Regional Catchment Strategy, and the Corangamite Regional Waterway Strategy. CCMA works with DEECA, Parks Victoria, Wannon Water, Barwon Water, SRW, GORCAPA, the Environmental Protection Authority, citizen scientists and landholders to deliver the activities outlined in these strategies. Corangamite CMA is also the regulator for artificial Gellibrand estuary openings and is a delivery partner in the “improving summer flows in the Gellibrand River” action of the Central and Gippsland Region Sustainable Water Strategy (DELWP 2022a).

SRW manages take and use licences within the Gellibrand system (in the realm of 4,770 ML / year, refer Appendix A) in accordance with the Otway Coast Basin Local Management Plan, 2014 (SRW 2014, see Appendix A). For the management of direct pumping licenses, the Gellibrand River is divided into three zones: (1) Below North Otway Pump Station (2) Upstream of North Otway Pump Station (excluding Carlisle River) (3) Carlisle River. Each zone has its own five-stage roster and restrictions during periods of low flow (daily and 7-day rolling average, see Appendix A). Southern Rural Water also manages water in the Gellibrand Groundwater Management Area (GMA), Newlingbrook GMA and Paaratte GMA. The Permissible Consumptive Volume – i.e. the maximum amount of water that can be allocated per year – for the Gellibrand GMA is currently 0 ML, whereas for the Newlingbrook GMA is currently set at 1977 ML, and the Paaratte GMA is 4606 ML (see also Appendix A).

DEECA undertakes long term water resource assessments for Victorian catchments, coordinates development of sustainable water strategies (including the Central and Gippsland Region Sustainable Water Strategy (DELWP 2022a) and Western Region Sustainable Water Strategy (DSE 2011)), and produces the annual Victorian Water Accounts. The Victorian Water Accounts cover all water resource types under Victoria’s water entitlement and resource planning framework. DEECA also collects environmental contributions, which fund activities that promote sustainable water management, and water-related environmental activities.

2.3 Community involvement in the FLOWS study to date

2.3.1 Community concerns

The first Project Advisory Group (PAG) workshop was held at Gellibrand Public Hall on 6 March 2025. The meeting was attended by 15 members of the PAG, representatives from Project Steering Committee agencies, and the Alluvium project management team.

The PAG identified that there was concern about:

- the lack of flows in the Gellibrand River and tributaries and deterioration of river condition
- low flows in the estuary, attributing the recent fish kill event due to a lack of flows from the Gellibrand River
- the level of extraction of water from the Gellibrand River
- future impacts of climate change on river flows and ecology
- impacts of future expansion of plantations on water yield and flows
- lack of water in the river to support firefighting activities during the summer of 2024/2025
- inter-agency management of the river. The PAG are concerned that agencies aren't managing the Gellibrand catchment as an integrated system.

2.3.2 Community values and threats identification

A second PAG workshop was held on 21 June 2025 at Echidna House, Kawarren, to discuss the flow dependent values and threats in the Gellibrand catchment. Reach values are provided in summary tables in Section 6. At the workshop, the PAG reiterated concerns about extractions from the Gellibrand system. The PAG also noted the important role that billabongs and soaks play in slowing water, storing water on the floodplain, and allowing water to recharge groundwater.

3 Delineation of reaches

The EFTP reviewed the 2006 FLOWS study reports, existing literature and conducted a preliminary site assessment of the Gellibrand catchment. Part of this review included an examination of the suitability of reach boundaries. Overall, the EFTP could not justify shifting 2006 reach boundaries on the basis of major tributaries, morphology and physical form, values, or the ability to deliver flows. As described below, two new reaches have been added to the 2025/26 study [Lardner Creek, and Arkins and First creeks (Arkins Creek West Branch, Arkins Creek East Branch and First Creek)], as both reaches are subject to extractions/diversions under Bulk Entitlements. The 2008 EEFA recommendations (Lloyd et al 2008) will be documented for the estuary reach, the estuary summer / autumn low flow functions will be reviewed, and the implication(s) of the new freshwater reach flow recommendations for the Gellibrand estuary will be discussed. The 2025/26 FLOWS study reach boundaries are largely delineated based on major tributary confluences, as were the 2006 FLOWS study reaches.

3.1 Changes to reaches in this FLOWS study

3.1.1 Addition of the Lardner Creek Reach (Reach 2c)

Lardner Creek, located in the upper Gellibrand catchment, has been added as standalone reach (Reach 2c) in the 2025/26 FLOWS study to reflect system operation, the existing Gellibrand Bulk Entitlement and the relatively intact flow regime. Previously, Lardner Creek was included as a major tributary in Reach 2a (Gellibrand River). The new reach (designated Reach 2c for consistency with nomenclature used in the Gellibrand Source model reports, HARC 2025a) includes Lardner Creek West Branch, Lardner Creek East Branch, and Lardner Creek 'proper' to its confluence with the Gellibrand River. As noted in Section 0 above, Bulk Entitlement (Gellibrand) Conversion Order 1997, authorises Barwon Water to take a share of flow up to 60 ML from Lardner Creek at the Lardner Creek pump station in any year. The water is used for the Gellibrand Water supply system (primarily to supply the Gellibrand township). A full suite of environmental flow recommendations will be developed to inform future operations.

3.1.2 Addition of the Arkins and First Creeks Reach (Reach 3a)

The new reach consists of First Creek, and Arkins Creek (including Arkins Creek East Branch and Arkins Creek West Branch), to the confluence of Arkins Creek with Carlisle River. These creeks were included in the 2006 FLOWS study as tributaries of Carlisle River. The new reach is designated Reach 3a, for consistency with the 2006 FLOWS study and its position in the catchment relative to Carlisle River, with Carlisle River proper now designated Reach 3b.

Each of the three creeks in Reach 3a has a diversion weir, with the water being diverted into the North Otway pipeline for use as potable water for regional towns in southwestern Victoria (Camperdown, Cobden, Simpson, Noorat, Terang etc.) under the Bulk Entitlement (Otway System) Conversion Order 1998 (Section 0). The bulk entitlement does not stipulate passing flows below any of the diversion weirs, and as a result the waterways cease-to-flow when the weirs are not overtopped by inflows. The environmental values associated with these creeks and their physical form substantially differ to those of Carlisle River which warrant establishment of the new reach, separate to Carlisle River.

We note that the geomorphology of these creeks (steep, bedrock confined, no depositional features) precludes development of hydraulic models for the constituent creek sites. Consequently, a hydrologic approach will be used to develop low flow recommendations for each of the constituent creeks, to inform future operations. A full flow regime will not be developed for these creeks.

3.1.3 Consideration of the estuary reach

The Gellibrand estuary was included as a reach in the 2006 FLOWS study, and a dedicated estuary environmental flows assessment method (EEFAM) applied to the estuary in 2008 (Lloyd et al 2008). An EFTP review of the 2008 EEFAM-based estuary recommendations found that estuary values and objectives have not substantially changed, and the recommendations therefore remain generally applicable. Therefore, new Gellibrand estuary flow recommendations will not be developed as part of the FLOWS study. Instead, the 2008 EEFAM recommendations will be documented for the estuary reach, and the implication(s) of the new freshwater reach flow recommendations for the Gellibrand estuary will be discussed. There is uncertainty regarding whether the previously recommended 100 ML/day magnitude of summer / autumn low flows is sufficient for 'keeping the estuary mouth open'. What the 2008 EEFAM study authors meant by 'keeping the estuary mouth open' in the context of an intermittently open and closed estuary is also unclear. The function of the summer / autumn low flow recommendation will therefore be reviewed in a workshop involving the EFTP and Steering Committee. The EFTP will then recommend further work, separate to the FLOWS study, to achieve greater certainty on the recommended summer / autumn low flow magnitude.

3.2 FLOWS study reaches

The FLOWS study reaches are presented in Table 2, and shown in Figure 3.

Table 2. Gellibrand FLOWS study reaches

Reach number	Waterway name	Reach Boundaries	Upstream storage
1	Love Creek	Love Creek and upstream tributaries to confluence with Gellibrand River	No
2a	Gellibrand River (upper)	Downstream of West Gellibrand Dam, to confluence with Love Creek	Yes (West Gellibrand Reservoir and Olangolah Weir)
2b	Gellibrand River (mid)	Confluence with Love Creek to confluence with Carlisle River	Yes (West Gellibrand Reservoir and Olangolah Weir)
2c	Lardner Creek	Lardner Creek (including West and East branches) to confluence with the Gellibrand River	No
3a	Arkins and First Creeks	First Creek, Arkins Creek West and Arkins East branches, and Arkins Creek to confluence with Carlisle River	No
3b	Carlisle River	Carlisle River and upstream tributaries (excluding creeks of Reach 3a) to confluence with the Gellibrand River	No

Reach number	Waterway name	Reach Boundaries	Upstream storage
4	Gellibrand River (lower)	Between the confluence of Carlisle River and the upstream extent of the Gellibrand Estuary (approximately the Great Ocean Road Bridge)	Yes (West Gellibrand Reservoir and Olangolah Weir)
5	Kennedys Creek	Kennedys Creek and upstream tributaries to confluence with Gellibrand River	No
6	Gellibrand estuary	Great Ocean Road bridge to estuary mouth	Yes (West Gellibrand Reservoir and Olangolah Weir)

3.3 The positioning of 'representative sites' within FLOWS study reaches

The EFTP visited sites from the 2006 FLOWS study, and other accessible sites within each reach where possible. While some sites were largely unchanged since 2006 (for example, Site 2b and Site 5), others had substantially changed (Site 2a and Site 3), were inaccessible (Site 1 and Site 2a), or were deemed no longer representative of the broader reach (Site 4). Rationales for site selection are provided in tables in Section 6.

While efforts were made to select study sites that are representative of the broader reach, it is acknowledged that in some cases access to alternative sites was precluded by road or site closures (e.g. Carlisle River alternative sites within the Great Otway National Park, Site 1 at the Love Creek Picnic Ground). Site safety, accessibility, representativeness, physical features, proximity to flow gauges, data availability, and mobile and GPS coverage were all important considerations in the selection of FLOWS study sites.

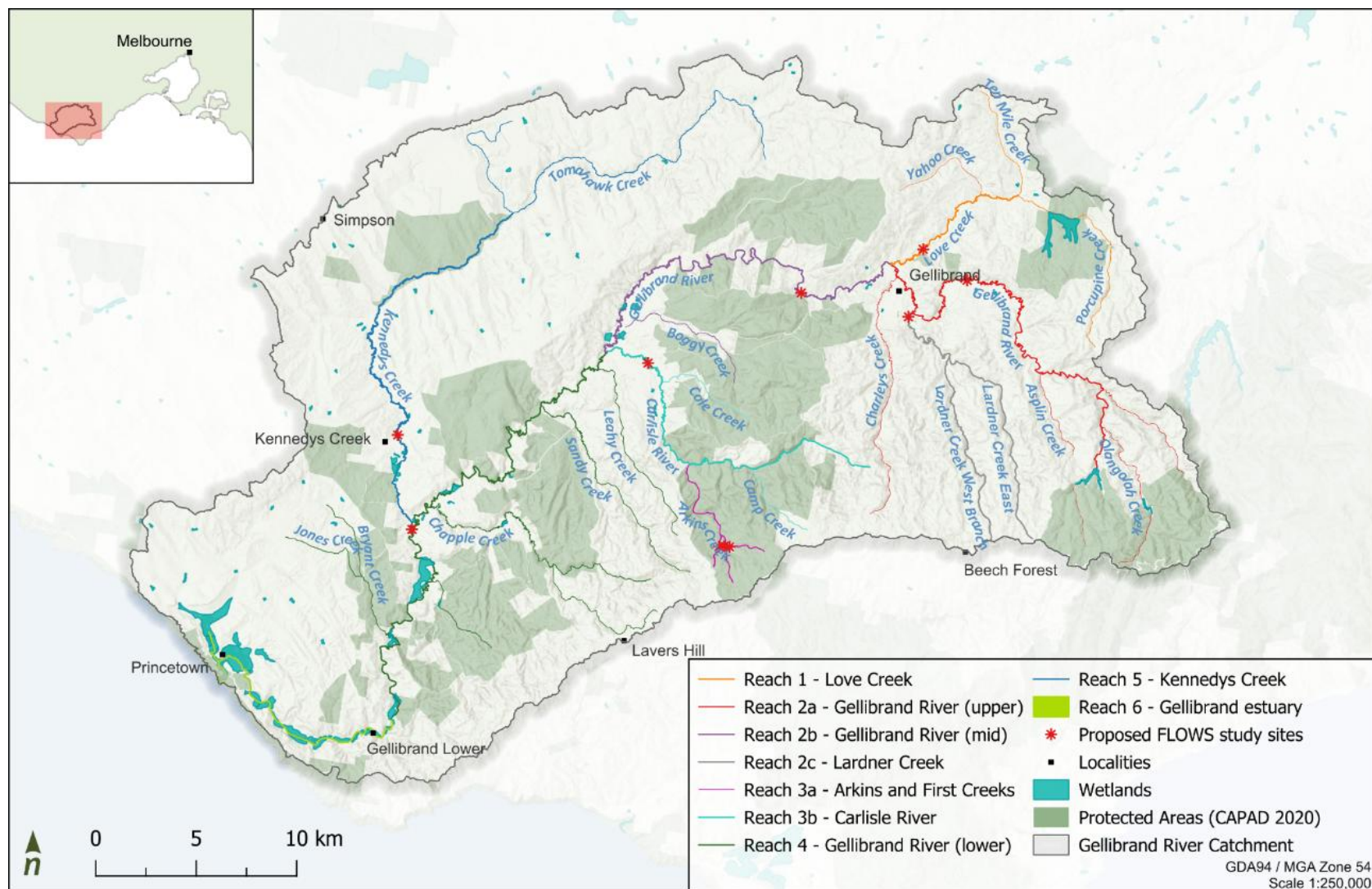


Figure 3. Gellibrand FLOWS study reaches and sites

4 Catchment values

4.1 Geology and geomorphology

The Gellibrand River catchment, located within the Otway Ranges, is characterised by a complex geological framework that strongly influences hydrology and streamflow behaviour. The catchment spans approximately 1,200 km² and drains into Bass Strait near Princetown. Its geology is dominated by sedimentary formations of the Otway Basin, primarily Cretaceous sandstones and mudstones, overlain in places by Tertiary sediments and volcanic deposits. These formations exhibit varied permeability, which impact on groundwater-surface water interactions and baseflow in the Gellibrand River and tributaries.

4.1.1 Geological framework

The upper catchment consists largely of the Eastern View Formation, a thick sequence of permeable sandstones that form major regional aquifers. These aquifers store substantial groundwater reserves and sustain perennial flows in the Gellibrand River, even during extended dry periods. In contrast, the lower catchment includes finer-grained sediments and clay-rich soils that limit infiltration and promote surface runoff. The rugged topography of the Otway Ranges, combined with deeply incised valleys, enhances orographic rainfall capture, making this one of Victoria's highest rainfall zones (exceeding 1,200 mm annually).

Land Conservation Council investigations (LCC 1978) highlighted the importance of these geological units for water supply reliability. The Gellibrand catchment was proclaimed under the *Land Conservation Act 1970* due to its role in supplying potable water to towns such as Warrnambool, Colac, and Camperdown. The Council noted that land use activities—such as forestry, dairying, and road construction—could exacerbate erosion and sediment delivery to streams, affecting water quality and flow regimes.

4.1.2 Implications for stream flow

The geological heterogeneity of the catchment creates distinct hydrological responses. In areas underlain by sandstone aquifers, infiltration is high, and groundwater discharge contributes significantly to baseflow. A multi-tracer study by Atkinson et al. (2015) between June 2011 and June 2012, quantified groundwater inflows along a 27 km reach of the Gellibrand River (between James Access and Bunkers Hill), finding that groundwater accounted for 10–50% of river flow, with contributions exceeding 40% during summer low-flow periods. Most discharge occurs where the river intersects the Eastern View Formation, underscoring the geological control on streamflow persistence.

Conversely, zones dominated by clay-rich sediments exhibit flashy runoff patterns, with rapid streamflow response to rainfall and limited capacity to sustain flows during dry spells. This variability influences environmental flow management: maintaining ecological health requires protecting groundwater-fed reaches that buffer seasonal extremes. Previous environmental flow assessments for the Corangamite Catchment Management Authority (Earth Tech 2006c) identified that reduced recharge—due to land clearing or climate change—could diminish baseflows, increasing the frequency of estuary mouth closures and associated ecological risks.

4.1.3 Specific geologic and geomorphic values of the Gellibrand River catchment

Various investigations have identified specific geologic and geomorphic values of the Gellibrand River catchment. These identified values and investigations include:

Rosengren's Otway Study (1984) documented numerous sites of geological and geomorphological significance in the Shire of Otway, including:

- Coastal cliffs and marine terraces near the Gellibrand mouth, showing Quaternary sea-level changes.
- River meanders and floodplain deposits along the Gellibrand River, which are important for understanding fluvial processes in high-rainfall environments.

The Princetown Wetlands and estuarine zone are listed in the *Directory of Important Wetlands in Australia*. While primarily ecological, they also have geomorphic significance as examples of a dynamic coastal estuary system influenced by sediment transport, tidal exchange, and intermittent sandbar closures.

Douglas (1976) and The Land Conservation Council (1978) highlighted the geomorphic diversity of the Otway Ranges including steep dissected slopes, fault scarps, and waterfalls. The LCC (1978) recommended protection of these features for their scientific and educational value. More recent investigations have provided greater detail on these features (Geoscience Australia 2023, Sandford 2003).

Similarly, the LCC (1978) noted the karstic terrain near Princetown and Peterborough as being of geomorphic significance, recommending protection due to vulnerability to land-use impacts. More recent investigations have provided greater understanding of these features (White 2009 and Radke et al 2021).

4.1.4 Waterway geomorphology

The Gellibrand River system river rises near Upper Gellibrand at an elevation of about 356 m and flows approximately 100 km before discharging into Bass Strait at Princetown. Over its length, the river traverses deeply dissected uplands, confined valleys, and low-gradient floodplains.

Upper catchment reaches

The headwaters of the Gellibrand River and its tributaries are located in the Otway Ranges and are characterised by:

- wet sclerophyll forest and remnant cool temperate rainforest.
- steep gradients, and narrow valleys, and confined channels flowing through resistant sandstones of the Eastern View Formation.
- step-pool and pool-riffle sequences, typical of high-energy streams in forested uplands.

As indicated, the waterways are laterally confined or partly confined by bedrock associated with the valley margins. Some fluvial geomorphic processes, such as channel meander migration are limited as a result of the confinement imposed by the bedrock valley margins. In these confined and partly confined reaches, the channel is less active with limited erosional change in response to changes in hydrologic and sediment regime, than the unconfined channel found in the mid and lower reaches.

Middle reaches

The middle and lower reaches of the Gellibrand River system are characterised by:

- a transition to a meandering stream system with point bars and undercut banks.
- a widening floodplain that supports riparian forests and wetlands. These areas are subject to overbank flows during flood events, depositing fine alluvium and forming natural levees.
- a shallow, single-channelled form with steep banks and a sand substrate
- a morphology that reflects adjustments to sediment supply and discharge, maintaining a graded profile.

As indicated, the river is partly confined or unconfined by the valley margins. As a consequence, the channel form and processes can adjust in response to changes in inputs such as the hydrologic and sediment supply regime. Clearing of riparian zones and /or of past channel modifications has led to increased rates of erosional adjustments in some reaches, while some remnant wet sclerophyll forests and intact geomorphic form remain in others.

Lower (estuary) reach

Near Princetown, the river enters a low-gradient zone dominated by Holocene alluvium and dune calcarenite, forming the Princetown Wetlands and estuary.

The estuary is an intermittently closed and open system, where a sandbar periodically seals the mouth due to longshore drift and wave action. Major flow events can result in a breach of the sand bar and the opening of the estuary. This dynamic process influences salinity gradients, sediment deposition, and aquatic habitat structure. Artificial openings of the estuary have been undertaken, among other reasons, to prevent impacts on Great Ocean Road traffic.

Coastal cliffs and terraces composed of Gellibrand Marl and Port Campbell Limestone flank the estuary, adding complexity to the estuary geomorphology.

Stream diversions

West Gellibrand Reservoir and Olangolah Reservoir capture flows in the upper catchment. Water is also diverted or taken from the river at several locations (North Otway pump station, South Otway pump station, Lardner Creek offtake, Arkins/First Creek weirs, at licenced pumps and for stock and domestic use), affecting the flow and contributing to the potential for some channel change. Weirs at Arkins Creek East, Arkins Creek West and First Creek do not have passing flow requirements. The waterways do not flow downstream of the weirs unless the weirs are overtopped.

Geomorphologic descriptions of each of the FLOWS study reaches is provided in Section 6.

4.2 Catchment vegetation values

4.2.1 Bioregions

The Gellibrand River and its various tributaries spans – and in many locations forms the boundary between – two Victorian bioregions: the Warrnambool Plain bioregion to the west, and the Otway Plain

bioregion to the north and east. The eastern-most sections of the Carlisle River and the upper reaches of the Gellibrand River extend into a third bioregion, the Otway Ranges bioregion.

4.2.2 Woody (riparian) vegetation

The earliest relevant investigation on vegetation is the original environmental flows report by Earth Tech (2006 a, b, c). The Site Paper (Earth Tech 2006a) did not provide detailed information on vegetation values, in large part because it was structured along the lines of an Index of Stream Condition investigation and therefore concentrated on considerably broader criteria such as 'streamside zone'. The 2006 Issues Paper (Earth Tech 2006b, p. 7) did note that "The Riparian Forest EVC [i.e. EVC 18] dominates the main stem of the Gellibrand River and its major tributaries. Although not reliant on episodic events like flood for species recruitment, EVC 18 is described in the EVC benchmarks as 'regularly inundated and permanently moist'." (DSE 2016)

In an analysis of the Gellibrand catchment as a whole, Dwyer & Lester (2021, p. 7) reported that "Significant Ecological Vegetation Classes (EVCs) are present in the catchment, for example Riparian Forest (EVC 18; Vulnerable), Grassy Forest (EVC 128; Endangered), Plains Grassy Woodland (EVC 55; Endangered), Floodplain Riparian Woodland (EVC 56; Endangered), Swampy Riparian Woodland (EVC 83; Endangered), Coastal Saltmarsh Aggregate (EVC 9; Endangered), Herb-rich Foothill Forest (EVC 23; Vulnerable), and Swamp Scrub (EVC 53; Endangered)."

The NatureKit webpage provides information (mostly modelled rather than fully ground-truthed) on the current ("2005 EVCs") and presumed pre-European ("1750 EVCs") distribution of native vegetation. A complex mosaic of native vegetation is modelled across the various freshwater reaches of the Gellibrand River (Figure 5). The major vegetation types within each reach (indicated in the NatureKit) are described in Section 6.

The available vegetation mapping (much of it modelled and not ground-truthed) indicates that the most common riparian vegetation type along the three freshwater reaches of the Gellibrand River and the four in-scope tributaries (Love Creek, Carlisle River, Lardner Creek and Kennedy Creek) is EVC 18 Riparian Forest. For the Warrnambool Plain bioregion this EVC is described (DSE 2016) as having a canopy layer of Manna Gum (*Eucalyptus viminalis*) and an extremely wide range of shrub-and ground-layer taxa, including Blackwood (*Acacia melanoxylon*), Hazel Pomaderris (*Pomaderris aspera*), Prickly Currant-bush (*Coprosma quadrifida*), Scented Paperbark (*Melaleuca squarrosa*) and Austral Mulberry (*Hedycarya angustifolia*). Clearly water-dependent taxa in EVC 18 include Round Water-starwort (*Callitriche muelleri*), Red-fruit Saw-sedge (*Gahnia sieberiana*), Tall Sedge (*Carex appressa*), Variable Sword-sedge (*Lepidosperma laterale* var. *majus*), Fishbone Water-fern (*Blechnum nudum*), Hard Water-fern (*Blechnum wattsii*) and Common Filmy Fern (*Hymenophyllum cupressiforme*). A similar description holds for EVC 18 in the Otway Ranges bioregion; surprisingly, vegetation benchmarks for EVC 18 seem not to be available for the Otways Plain bioregion.

The critical point about the vegetation benchmark for EVC 18 Riparian Forest is that the main canopy tree is Manna Gum, a species of eucalypt not recognised as requiring regular inundation for sexual recruitment or for the health of the adults. Other, smaller, woody riparian species however are clearly water-dependent, including Scented Paperbark. The regional vegetation benchmarks for this vegetation type note specifically that "Soils are fertile alluvium, regularly inundated and permanently moist" (DSE 2016, emphasis added). This means that any determination of environmental flows for the freshwater

reaches of the Gellibrand River and its tributaries would need to consider the flow requirements of these non-canopy species.

4.2.3 Non-woody submerged and fringing vegetation

Instream submerged and floating leaved vegetation communities (e.g. Water Ribbons *Cyanogeton procerum* (formerly *Triglochin procera*; Eelweed *Vallisneria australis* etc.) were observed in a number of freshwater reaches during the March 2025 site inspection. Figure 4 shows some examples from the Gellibrand River and Love Creek. In contrast, fringing non-woody vegetation such as rushes, reeds and sedges were not commonly observed during the site inspection. Of course, they may be present on parts of the river not examined during the site inspection, and a fuller reconnaissance would be needed to better determine their distribution and floristics.



Figure 4. Submerged vegetation of the freshwater reaches of the Gellibrand River

The diversity of submerged, emergent and amphibious plants in (upper left) the Gellibrand River at Ashes Road, Reach 2a; (upper right) at Love Creek, Reach 1; (lower left) the Gellibrand River at James Access Road in Reach 2a. Photographs taken by PI Boon, March 2025.

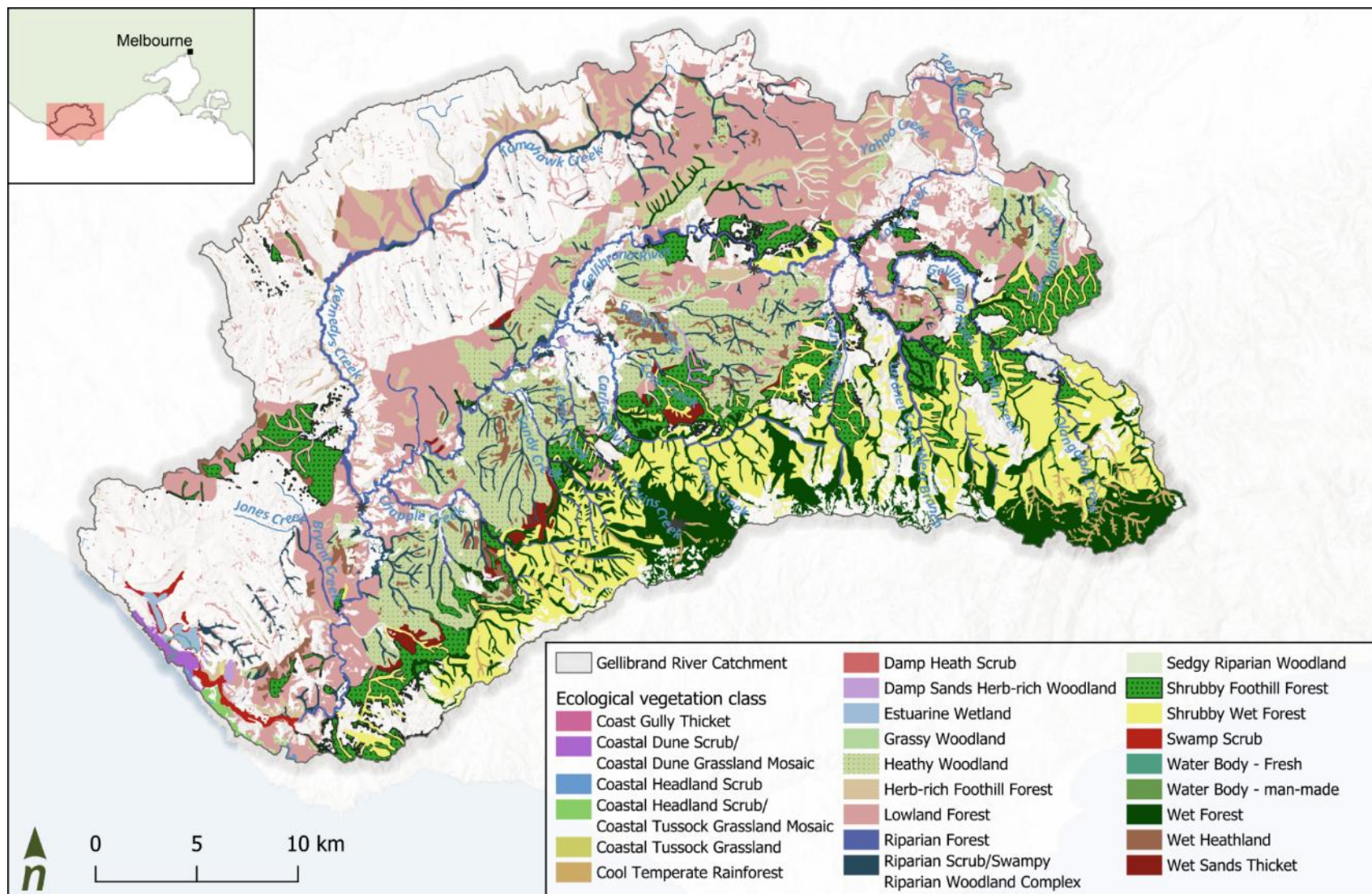


Figure 5. Ecological Vegetation Classes (modelled 2005, Datashare.vic.gov.au) in the Gellibrand catchment

4.2.4 Algal biofilms

Algal biofilms on submerged surfaces are abundant across the Gellibrand River system (e.g. Figure 6) and are crucial in fuelling aquatic food webs and consolidating sediments etc. As such they are an important value to be included in the FLOWS study.



Figure 6. Algal biofilms on submerged rocks in the Gellibrand River at Bunker Hill (Reach 2b). Photograph taken by PI Boon, March 2025

4.2.5 Micro-climate effects

As described above, the freshwater reaches of the Gellibrand River and its tributaries are understood to be lined along many sections by a near-continuous band of EVC 18 Riparian Forest. The EVC/bioregion benchmark for this vegetation type describes it as "A tall forest to 30 m tall along river banks and associated alluvial terraces with occasional occurrences in the heads of gullies leading into creeks and rivers. Soils are fertile alluvium, regularly inundated and permanently moist" (DSE 2016). Also as noted earlier, the relevant part of this description is "regularly inundated and permanently moist".

Water remaining in the stream is essential to the maintenance of the cool, moist conditions required for this specific riparian EVC. The presence of permanent (or at least persistent) in-stream water combines with the sheltered topography and generally high rainfall of the Otway Ranges to create a localised gully/valley microclimate with lower temperature and higher relative humidity than would otherwise be the case. While not all plant taxa in the riparian EVC 18 are directly water-dependent, they often require the cool, moist climatic conditions generated by the presence of a nearby permanent waterway. The presence of permanent water is likely to be particularly important for fringing ferns, the two water-ferns, Fishbone Water-fern (*Blechnum nudum*) and Hard Water-fern (*Blechnum wattsii*), as well as the Common

Filmy Fern (*Hymenophyllum cupressiforme*), all taxa reported as frequent components of EVC 18. It is therefore likely that under a scenario of prolonged and repeated cease-to-flow events the vegetation characteristic of EVC 18 would be unlikely to remain dominant.

Identifying the causal relationship between microclimate and vegetation recognises the role played by upland streams in modifying nearby riparian and terrestrial microclimates. To our knowledge this relationship has been invoked in only a few environmental flows studies to date and the mechanism and required flows to maintain specific microclimates are poorly understood. The converse relationship – how riparian and fringing vegetation alters stream temperature – is well understood (e.g. Moore et al. 2005; Johnson and Wilby 2015; Dugdale et al. 2018; Davis et al. 2019). The relationship posited here – that stream flow alters the gully/valley microclimate and thus nearby riparian and terrestrial vegetation in a complex two-way inter-relationship is described by Ryan and McAlpine (2005), who mentioned the existence of 'reciprocal feedbacks' in their review of riparian revegetation activities in south-eastern Australia. Davis et al. (2019) also concluded that some forests in the western USA could lose their capacity to buffer local climate extremes as they became drier and more water-stressed. The application of this theory to environmental flows studies remains a significance knowledge gap.

4.2.6 Estuary Vegetation

The Gellibrand estuary is one of 25 estuaries in western and central Victoria containing 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 (Princetown Wetlands), which provide habitat for EPBC-listed migratory birds and aquatic fauna.

Alluvium (2017, p. 29) described vegetation values of the estuary in the following terms: "The endangered Coastal Saltmarsh (EVC 009) vegetation community occurs at the estuary, as well as stands of sea grass meadows and riparian native vegetation providing important habitat for aquatic and semi aquatic fauna. Significant patches of the vulnerable Swamp Greenhood Orchid (*Pterostylis tenuissima*) occur at the Princetown Wetlands..."

Other water-dependent values were not addressed except in passing in the Alluvium 2017 study, most significantly submerged vegetation (i.e. seagrasses) and the extensive and floristically diverse non-woody, emergent, saline and semi-saline vegetation that occurs on the floodplain of the lower estuary. The latter was described in Alluvium (2017) in terms of EVC 9 Coastal Saltmarsh Aggregate alone whereas, as shown below, this EVC is not common along the lower estuary. Available evidence indicates that the most abundant emergent vegetation on the floodplain of the lower estuary is a mosaic of EVC 10 Estuarine Wetland and EVC 952 Estuarine Reedbed.

In the original EEFA investigation, Lloyd et al (2008, p. 26) described the estuary and its vegetation as follows: "The estuary comprises a low-relief floodplain, into which the river channel is set, surrounded by high sandy and limestone country. Groundwater discharge at the foot of the surrounding slopes provides habitat for dense shrubby vegetation (Swamp Scrub) and frequently inundated, low-lying areas of the floodplain near the estuary entrance support extensive *Phragmites australis* beds (Estuarine Reedbed). The floodplain further upstream is flooded less frequently and generally by less saline water. These areas have been extensively cleared for pasture but support remnants of Woolly Tea Tree. Woodland vegetation occurs on the floodplain near the upper limit of the estuary. Depressions on the floodplain

capture water when estuary levels are high and support salt tolerant herbland communities (Coastal Saltmarsh and Estuarine Sedgeland)." Lloyd et al (2008, p. 17) concluded that, "Nevertheless within these zones, the plant species and vegetation structure is remarkably uniform."

These descriptions are difficult to tally with the complex mosaic of estuarine vegetation types mapped on the NatureKit webpage (Table 3). and with other, more recent, information sources of the water-dependent vegetation of the site.

Table 3. Major Water-dependent vegetation types (2005 EVCs) on the floodplain of the lowe Gellibrand estuary, as mapped on the NatureKit webpage

Ecological Vegetation Class (EVC)	Bioregion	Bioregional Conservation Status (BCS)
EVC 3 Damp Sands Herb-rich Woodland*	Warrnambool Plain	Endangered
EVC 10 Estuarine Wetland	Warrnambool Plain	Depleted
EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex	Warrnambool Plain	Vulnerable
EVC 53 Swamp Scrub	Warrnambool Plain	Endangered
EVC 201 Shrubby Wet Forest*	Warrnambool Plain	Least Concern

Most recently, the *Gellibrand River Estuary Management Plan* (CCMA 2017, p. 26) describes the values of the estuary as including 16 EVCs, including "extensive areas of EVC 10 (Estuarine Wetland)", "a highly significant area of remnant vegetation at Kangaroobie that has not been grazed" and which contains areas of EVC 821 Tall Marsh and EVC 53 Swamp Scrub around the margin. This description tallies well with available published information and the (limited) observations made during the field inspection of late March 2025, except that EVC 952 Estuarine Reedbed is probably a better descriptor than EVC 821 Tall Marsh (the difference is primarily in the dominance of *Phragmites australis* and the presence of a halophytic ground-layer in the latter; see DSE 2012).

A number of the types of saline and semi-saline coastal wetland vegetation types were mapped in detail (1:10,000) and comprehensively ground-truthed in the 2011 State-wide assessment of Victoria's saline and semi-saline wetlands (Boon et al. 2011, 2015) (Figure 7).

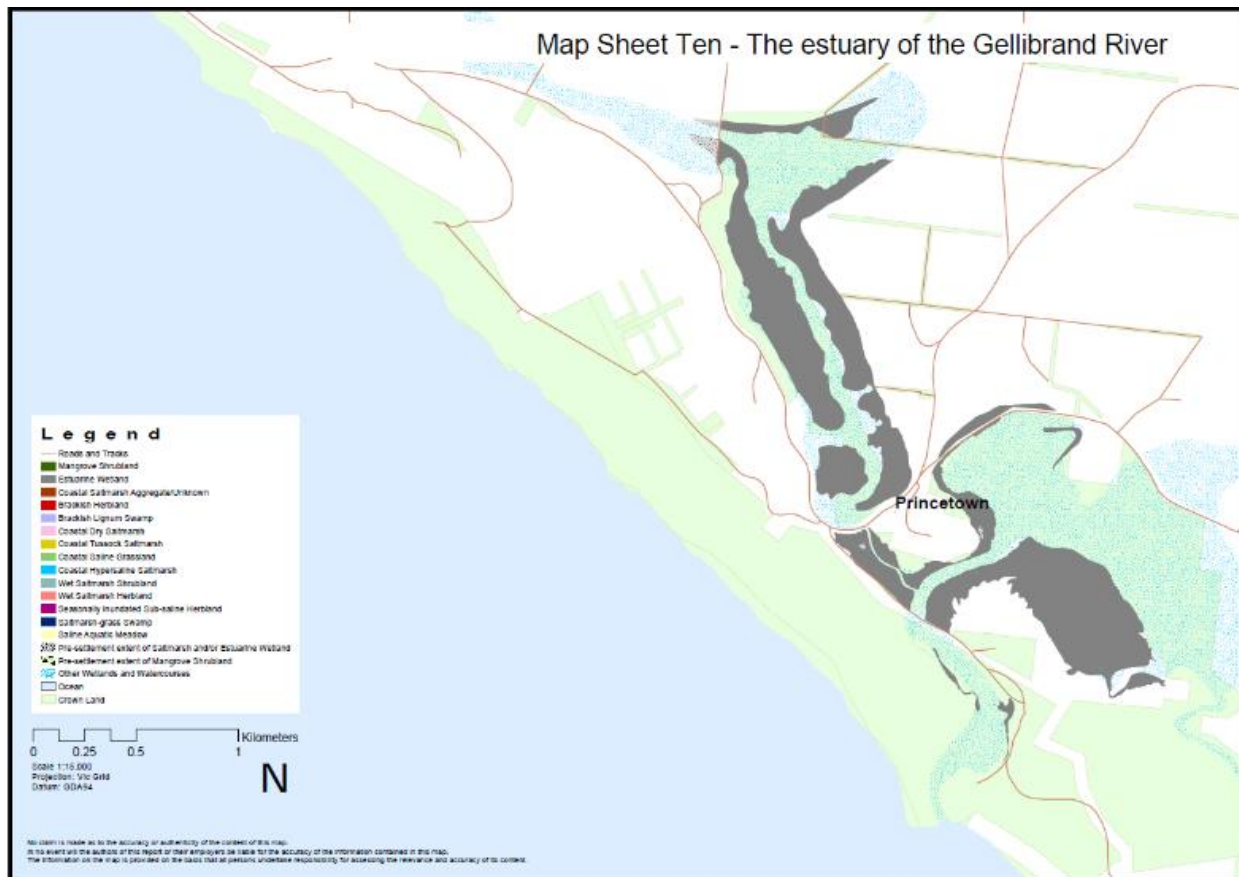


Figure 7. Saline and semi-saline coastal wetland vegetation of the Gellibrand estuary. The dark grey areas are EVC 10 Estuarine Wetland. Source: Boon et al (2011, 2015).

Extensive areas of emergent vegetation were seen during the site inspection in late March 2025. The main taxa present are Common Reed (*Phragmites australis*), a mix of Sea Rush (*Juncus kraussii*), Knobby Club-sedge (*Ficinia nodosa*), and an estuarine grass (*Poa* sp.). This vegetation could be best described as a complex mosaic of EVC 10 Estuarine Wetland and EVC 952 Estuarine Reedbed.

Coastal Saltmarsh Aggregate (EVC 9) was not observed to be widespread in the lower estuary during the site inspection, nor was it mapped as present in the 2011 State-wide survey (Boon et al. 2011, 2015; see Figure 7) or in the modelled vegetation distributions available on the NatureKit webpage. Coastal saltmarsh may be present in the mid and upper estuary, where, however, it is likely to be highly degraded and fragmented on account of the widespread cattle grazing evident in this section of the river during the field inspection. If this is the case, the most likely type of coastal saltmarsh is EVC A107 Wet Saltmarsh Herbland, a vegetation type dominated by low-lying chenopods such as Beaded Samphire (or Glasswort) *Sarcocornia quinqueflora*.

4.3 Aquatic fauna values

The fish of the Gellibrand River and Estuary can be classified into six groups that have different requirements (Lloyd et al. 2012b). These groups are classified based on their presence within different parts of the system, their use of the estuary, life histories and their migration patterns, all of which affect their flow requirements (Figure 8).

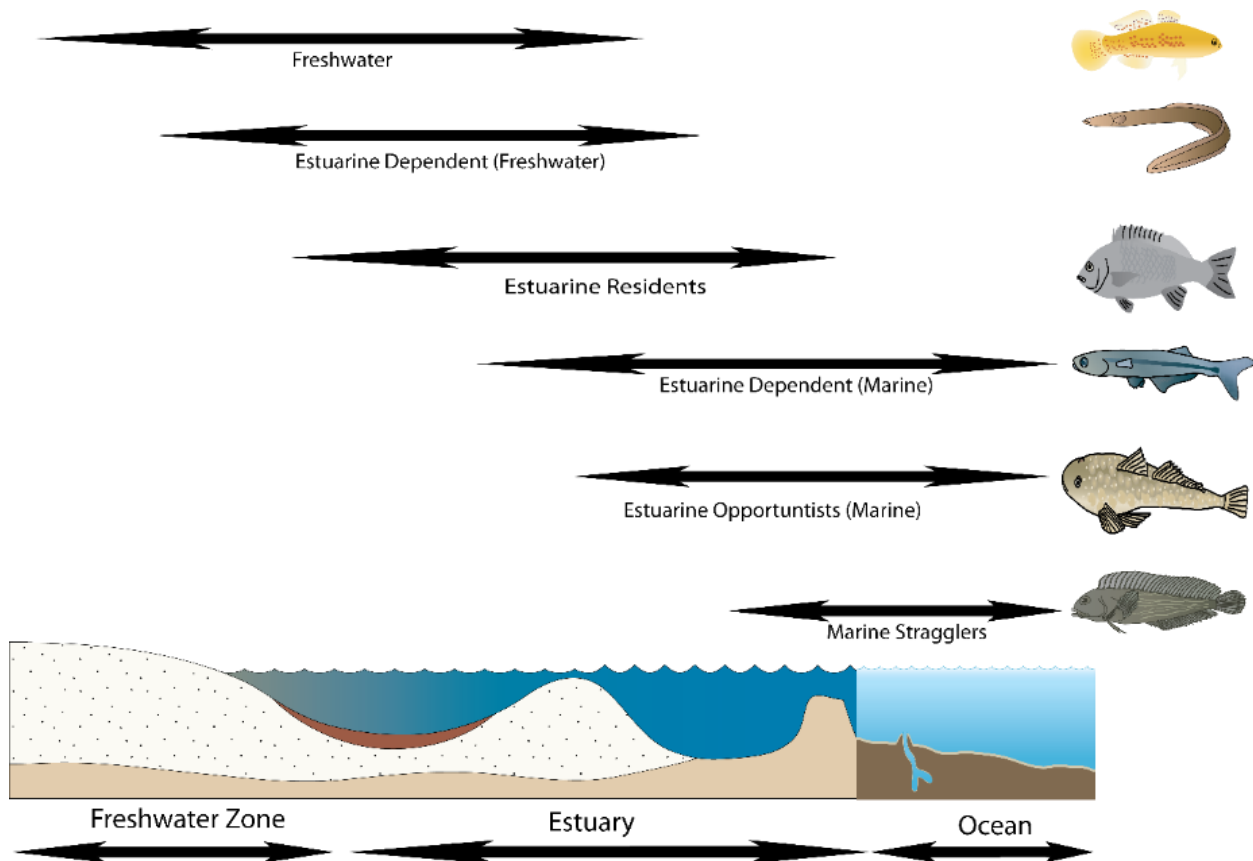


Figure 8. Fish groups in the Gellibrand River and Estuary (Source: Lloyd et al., 2012b)

Freshwater fish spend their entire life cycle within freshwater reaches and are reliant upon freshwater flows and pools in the Gellibrand River. Key freshwater species in the Gellibrand River include Flathead gudgeon (*Philypnodon grandiceps*), River blackfish (*Gadopsis marmoratus*), Ornate galaxias (*Galaxias ornatus*) and Southern pygmy perch (*Nannoperca australis*).

Estuarine Dependent fish (freshwater and marine) depend upon the estuary for at least one part of their life cycle, such as for spawning, as a nursery ground or for feeding. This group therefore includes estuarine specialists and migratory species. The Gellibrand River contains catadromous and anadromous migratory species:

- **catadromous** fish – species that are borne in marine / estuarine ecosystems, juveniles migrate to freshwater ecosystems for growth, adults return to marine/estuarine ecosystems to spawn. Species include Common galaxias (*Galaxias maculatus*), Southern shortfin eel (*Anguilla australis*) and Australian grayling (*Prototroctes maraena*).

- **anadromous** fish – species that are borne in freshwater, juveniles migrate to marine or estuarine ecosystems to grow, and adults migrate upstream to spawn in freshwater ecosystems. Shorthead lamprey (*Mordacia mordax*) is an anadromous species in the Gellibrand River.

Estuarine residents – species that complete their entire life cycle within the estuary. Species include Black bream (*Acanthopagrus butcheri*).

Estuarine opportunists - mostly live in marine or freshwater environments and use the estuary and its resources on an opportunistic basis. Freshwater derived species include Australian smelt (*Retropinna semoni*) and River blackfish (*Gadopsis marmoratus*).

Marine stragglers venture into estuaries, but do not use the estuary for completion of their life cycle.

Freshwater resident (particularly River blackfish), estuarine dependent (freshwater and migratory, particularly Australian grayling) and estuarine resident fish are of particular interest to this study as these species are reliant upon freshwater flows in the Gellibrand River.

Fish species recorded in the Gellibrand River system are shown in Table 4, together with their life histories and the required timing of higher flows to support migratory species. No fish surveys were undertaken as part of this environmental FLOWS assessment.

The Protected Matters Search Tool (PMST, <https://pmst.environment.gov.au>) indicated that the Gellibrand catchment contains *habitat* that would support Australian grayling and Yarra pygmy perch. While Australian grayling has been recorded in the Gellibrand catchment, there are no historic records for Yarra pygmy perch (to our knowledge), thus this species will not be further considered in the study.

The Gellibrand River has been touted as harbouring the best population of River Blackfish of any river in Victoria in number and size of fish including a high percentage of large River Blackfish (greater than 24cm) that comprise up to 33% of the population (Earth Tech 2006a). However, over the past two decades catches of juvenile blackfish have declined and recruitment rates appear to be low in the mainstem (albeit with a high collection of River Blackfish, 19% juveniles in the 2025 Native Fish report card survey, ARI 2025). Population dynamics of River Blackfish in the Gellibrand River and causes for general decline are still not well understood. Whilst flow is likely part of the answer (flushing flows to remove sediment and low flows to maintain habitat), other factors impacting blackfish populations in the catchment could include the removal of in-stream woody debris and competition with brown trout.

Fish migration barriers influences the achievement of flow objectives and ecological outcomes. In response to an assessment of instream barriers conducted in 2010 (Ryan et al 2010), Corangamite CMA removed many of the fish barriers in the Gellibrand River Catchment. Significant infrastructure-based barriers to fish passage still remain, including West Gellibrand Reservoir and Olangolah Reservoir, diversion weirs in Arkins Creek West, Arkins Creek East and First Creeks, and the Gellibrand River North and South Offtakes (DCCEEW 2018). Stevensons Falls is a significant natural fish barrier in the upper Gellibrand River.

Platypus occurrence is acknowledged in the Gellibrand River mainstem and some tributaries (CCMA 2024), however Platypus population dynamics for the Gellibrand River appear unknown. Likewise, freshwater crayfish are found in the Gellibrand River system and their population dynamics are unknown.

Table 4. 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>Phylpnodon 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										●	
Australian Herring	<i>Arripis georgianus</i>	+	-	-	-	-	Freshwater/estuarine										●	
Largemouth Goby	<i>Redigobius macrostoma</i>	+	-	-	V	-	Estuarine										●	
Scary's Tasmanogoby	<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										●	

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	
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</i> sp.	-	-	-	-	-	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						●					

^{**}Mussel identified in Gellibrand River in 2025 ARI Native Fish Report Card survey (ARI 2025), and identified by representatives of the Project Advisory Group

[^]Species identified as present in the Gellibrand estuary by Lloyd et al 2008 (species does not appear in VBA records for the Gellibrand estuary).

[#] Crayfish burrows observed in Reach 3a by representatives of the EFTP

4.4 Groundwater

The Gellibrand River flows over multiple aquifer systems, and the degree of surface water – groundwater connectivity varies spatially and seasonally. Groundwater discharge from the Lower Tertiary Aquifer (LTA) is well understood in the upper reaches of the Gellibrand catchment, due to the work undertaken to understand the impacts associated with Barwon Water’s historic groundwater pumping activities at the Barwon Downs Borefield.

BlueSphere Environmental undertook a hydrogeological assessment of the Love Creek catchment area to develop a conceptual site model for the groundwater system, to identify potential groundwater-dependent ecosystems and their relationship with the Lower Tertiary Aquifer (LTA), and to understand the environmental impacts of historic groundwater pumping (BlueSphere Environmental 2024). It is understood that Ten Mile Creek and Yahoo Creek (both Love Creek tributaries) flow over LTA outcrops (Love Creek itself does not itself receive direct inputs from the LTA). While direct calculation of the contribution of groundwater pumping to baseflow reductions in Yahoo Creek and Love Creek was not possible, BlueSphere estimate that 65-85% of baseflow reduction in Yahoo Creek (18-23% reduction relative to total flow) and 55-75% in Love Creek (19-25% reduction relative to total flow) is potentially due to a combination of a climate driven reductions in rainfall, recharge to the aquifer, streamflow and historical extraction from the borefield. Therefore, groundwater inputs influence flows in Love Creek (Reach 1 of the 2006 FLOWS study) and the nature of this influence changes spatially and temporally.

The Gellibrand River from downstream of James Access bridge to the confluence with Love Creek (within Reach 2a of the FLOWS study), is a known discharge zone for the LTA. At Bunkers Hill (Reach 2b), historical extractions are thought to account for 5-10% of observed reduction in baseflow, with groundwater discharges from the LTA into the Gellibrand River approximating 1.4 ML/day/km (BlueSphere Environmental 2024). This rate equates to a baseflow of approximately 21 ML/day into the Gellibrand River. As noted earlier, Atkinson et al. (2015) used a tracer approach to quantify groundwater inflows in the Gellibrand River between James Access and Bunkers Hill, finding that groundwater accounted for 10-50% of river flow, with contributions exceeding 40% during summer low-flow periods.

Broader groundwater inputs to the Gellibrand Catchment, to our knowledge, have not been investigated.

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>). The Atlas does not distinguish the source aquifer that supplies groundwater to these systems.

4.4.1 Consideration of groundwater in the FLOWS study

While the FLOWS method is agnostic to the ‘source’ of flows (and thus groundwater is not a direct input for the setting of flow recommendations), the location of known reductions in groundwater discharge have been considered in the positioning of reach boundaries and FLOWS study sites within reaches. We note that the proposed site 2a is located within the LTA discharge zone (refer to Section 6.2), whereas the 2006 study site 2a was positioned on the upstream edge of the LTA (at James Access bridge) and may not have captured groundwater inputs.

Groundwater pumping impacts are also captured in the Source hydrological model for the Gellibrand Catchment (HARC 2025a), which is a key input to the FLOWS study. In the model, reductions in baseflow due to Barwon Water's historic groundwater pumping activities were adopted from the Hydrogeological Investigation of the Kwararren Sub-basin (BlueSphere Environmental, 2023 as amended 2024), and reductions in baseflow due to Wannon Water's pumping from the Carlisle River bores were adopted from the Carlisle River Bores Hydrogeological Review (GHD, 2014). In the model, groundwater pumping impacts on flow are represented in the reaches that are directly impacted by groundwater pumping and routed downstream to account for the flow on effects.

The Source hydrological model outputs will be used in the FLOWS study to:

- understand seasonality of flows
- determine the frequency and duration of 'peak' flow components
- check the reasonableness of flow recommendations
- performance test the new flow regime.

5 Threats

Threats to flows in the Gellibrand catchment, are also partially driven by land use in the catchment. According to the Victorian Land Use Information System (VLUIS) 2016 dataset (updated 2018), approximately 16% of the Gellibrand catchment is subject to plantation forestry (3% hardwood, 13% softwood), and 33% pasture and grassland (assumed primarily dairy and beef cattle). The 2024 Vicmap Vegetation – Plantation polygon dataset presents a slightly different picture, suggesting that softwood plantations occupy 2.6% and hardwood plantations occupy 5.4% of the Gellibrand catchment area (spatial dataset provided by Barwon Water).

Plantation forestry (rotational cycles of plantation growth and clearance) have the potential to impact surface water availability in the catchment (HARC 2025b) and to affect water quality through erosion and subsequent sediment transport, and chemical runoff. The impact of plantations on water resources is site-specific, owing to local climate, topography, geomorphology and hydrogeological conditions (Vines and Beverley 2019, cited in HARC 2025b, not available for review). Unrestricted stock access to streams also impacts water quality and aquatic biota, through pugging of the beds and banks and effluent runoff.

Exotic flora and fauna species were noted in all reaches, predominantly in stream sites adjoined by agricultural and plantation operations. Blackberry was prevalent at several sites, at times impeding physical access to the site and visual inspection of stream form. Willows were also noted in mid and lower waterways.

Brown trout (*Salmo trutta*) is a key introduced species that predated upon native fish in the Gellibrand system. Anthropogenic barriers to fish movement (instream dams and weirs) impact hydrology and reach connectivity.

Glover (2014) identified upper soil layers of Porcupine Creek (a Love Creek tributary) as a low-risk sulfidic soil, and soil at depth as a potential acid sulfate soil (Glover 2014). Davison and Lancaster (2011) had earlier reported that soils of wetlands along Porcupine Creek have significant acid-generating potential, although the potential threat to Gellibrand catchment waterways is unclear. Potential inland acid sulfate soils have been identified in Kennedys Creek and Carlisle River (Soil Health Knowledge Base 2025)

Water operations and extractions for urban, rural and industrial uses impact Gellibrand River hydrology.

Climate change poses a significant long-term challenge in the Corangamite catchment management area (CCMA 2021). The Gellibrand River system is thought to be more resilient to climate change than other river systems in south west Victoria, noting that this 'resilience' was due to the Gellibrand system being highly regulated, and already degraded (CCMA Undated). Upper (unregulated) tributaries with intact flow regimes (such as Lardner Creek) will provide important refugia for aquatic flora and fauna in a future climate. Higher temperatures and longer periods without rainfall are anticipated to reduce flows (CCMA Undated). The Corangamite region is also projected to experience greater fire weather, increased bushfire frequency and severity, and greater requirement for fire prevention and fire suppression activities with subsequent implications for catchment flora and fauna, rainfall/runoff and flows (CCMA undated). The Gellibrand River is anticipated to become even more important as a water source as users experience hotter and drier conditions and increase water supply demands (Dwyer and Lester, 2021, CCMA 2021). Indeed, the HARC Source modelling suggests that under a drier climate scenario, the

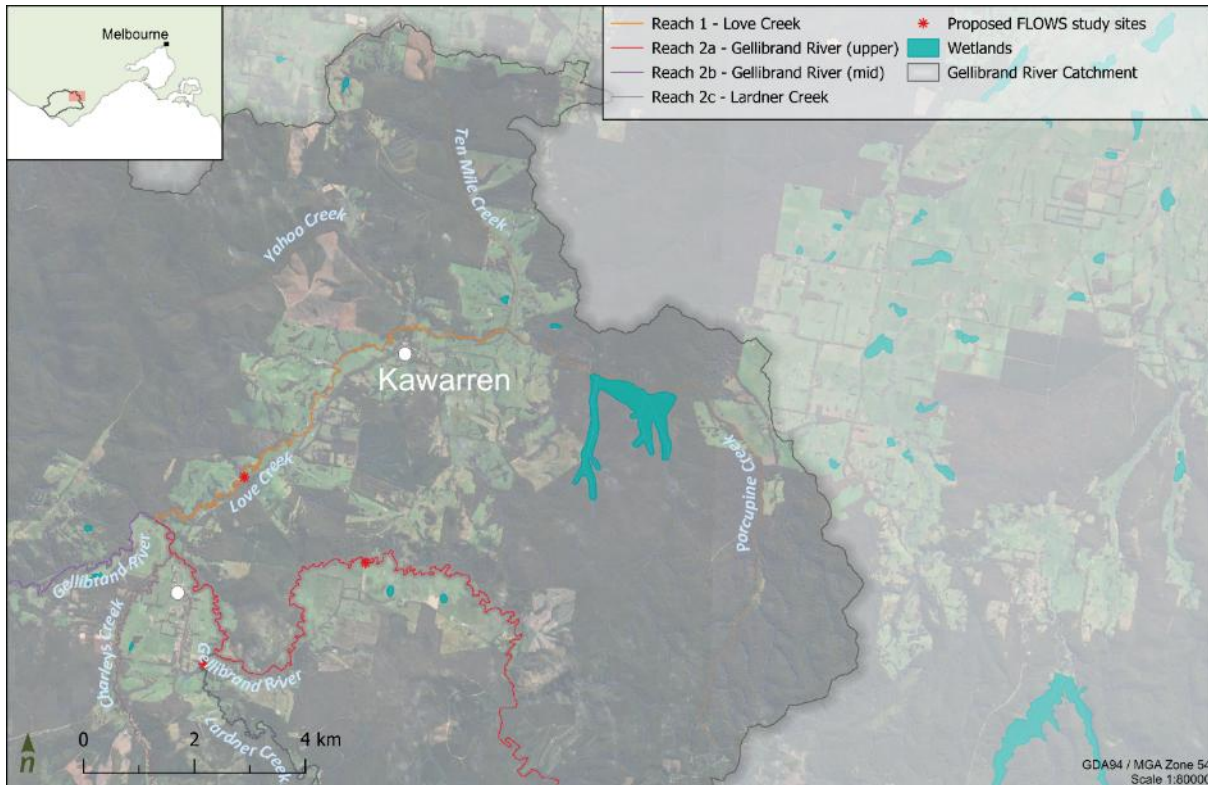
Otway supply system requires augmentation and system upgrades to provide the 2065 level of demand (HARC 2025a).

The Gellibrand estuary is expected to be exposed to climate change impacts arising in the catchment (i.e. rising temperatures, declined and altered seasonal patterns of rainfall and runoff) and coast (for example, sea level rise and storm surge events) (CCMA 2017, DCCEEW 2018). Estuary entrance modification and artificial estuary openings pose an ongoing threat to the Gellibrand estuary. Coastal wetlands are also vulnerable to climate change, through rising sea levels and reduced freshwater inflows (CCMA Undated).

Traditional Owners have emphasised that Traditional Owner values are affected by past, present and future flows, and that cumulative pressures should be considered when developing flow recommendations.

6 Reach descriptions

6.1 Reach 1 - Love Creek



6.1.1 Geomorphology

The 2006 FLOWS study site was closed at the time of the preliminary site inspection (March 2025) due to hazardous trees. A site immediately upstream of the 2006 site was inspected at the Old Beechy Rail Trail crossing of Love Creek (Figure 9). The waterway is partly confined with floodplain pockets. The site comprised a 2-metre-wide sand bed stream with instream large wood. The channel was inset into the floodplain with limited depositional features. No major erosional adjustments were evident. Another site, located at the Wonga Road bridge crossing of Love Creek was visited, and determined to have better accessibility and instream physical features than the Rail Trail site (Figure 10). For this reason, the EFTP propose that the FLOWS study site be shifted to the Wonga Road location.

6.1.2 Vegetation communities

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).

The sites visited had submerged and floating leaved aquatic plant communities and algal biofilms on submerged surfaces. Parts of the Love Creek catchment had a wet microclimate proximal to the waterway.

6.1.3 Aquatic fauna

Fish species in Reach 1 include native and introduced species. Native species include Common galaxias, Ornate galaxias and River blackfish (Table 4). Common Galaxias have a plastic (flexible) life history and can successfully reproduce in land-locked lakes and waterways. In the Gellibrand system, they are likely to be catadromous with spawning occurring within the estuary/close to the ocean. Spotted galaxias, Southern shortfin eels and Tupong are catadromous and undertake migrations to the estuary to complete their life cycles.

Love Creek has been recognised as important for River blackfish in the past with a high abundance and a broad range of size classes identified in annual surveys (ARI 2015, ARI 2025). Spiny crayfish have also been identified in Reach 1 (NatureKit).

Citizen science activities at Waterbug Blitz Love Creek site LOV012 identified a very high diversity of aquatic macroinvertebrates (28 taxa) in Reach 1 (CCMA 2024). Waterbug blitz assessments were performed using ALT (agreed level taxonomy, where identified taxa are at mixed taxonomic levels with some identified at genus level, some identified at species level and others identified at higher level). Each aquatic invertebrate is given an ALT SIGNALT (Stream Invertebrate Grade Number – Average Level) score, depending on taxa sensitivity to pollutants. A low SIGNALT score (< 4) indicates a highly impacted waterway. High SIGNALT scores represent excellent condition (scores from 6 to 10). In 2023, Site LOV012 received a SIGNALT score of 4.9. In 2021 Porcupine Creek (a Love Creek tributary) scored 5.9, with 9 taxa.



Figure 9. Love Creek at rail trail crossing, looking (left) upstream (right) downstream. Image taken 24 March 2025.



Figure 10. Love Creek at Wonga Road bridge crossing (left) looking upstream (right) looking downstream. Image taken 24 March 2025

6.1.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at Gauge 235234 in Love Creek. Data has been plotted for the following development scenarios (HARC 2025a):

Scenario 1 – Modelled flows with a current level of development (LOD), in a historical climate

Scenario 2 – Modelled unimpacted flows (i.e. what the flows are likely to have been had the catchment not been developed and without all extractions) in a historical climate

Scenario 4 – Modelled flows with a full level of rural and urban development, in a historical climate (Full LOD)

Day of year flow percentile plots for modelled scenario 1 (current level of development, historical climate, Figure 11) provide an indication of the seasonality and variability of flows across the year, and aid in identifying 'seasons' (i.e. summer / autumn, and winter / spring) for the development of flow recommendations. Flow duration curves provide an indication of variability across the entire flow range within a given time period for different scenarios. Flow duration curves are plotted for development scenarios 1, 2 and 4, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 12). Fuller discussion of hydrology will be provided in the issues paper.

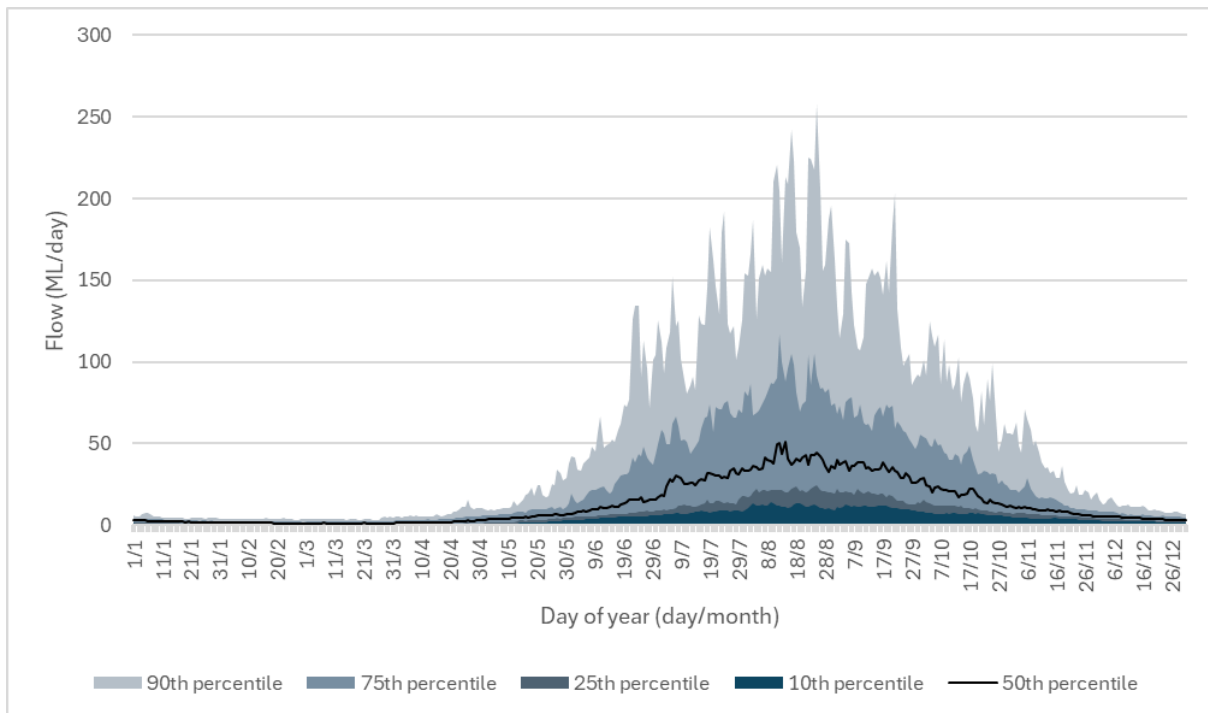


Figure 11. Day of year flow percentile plot for Reach 1, modelled current level of development, historic climate.

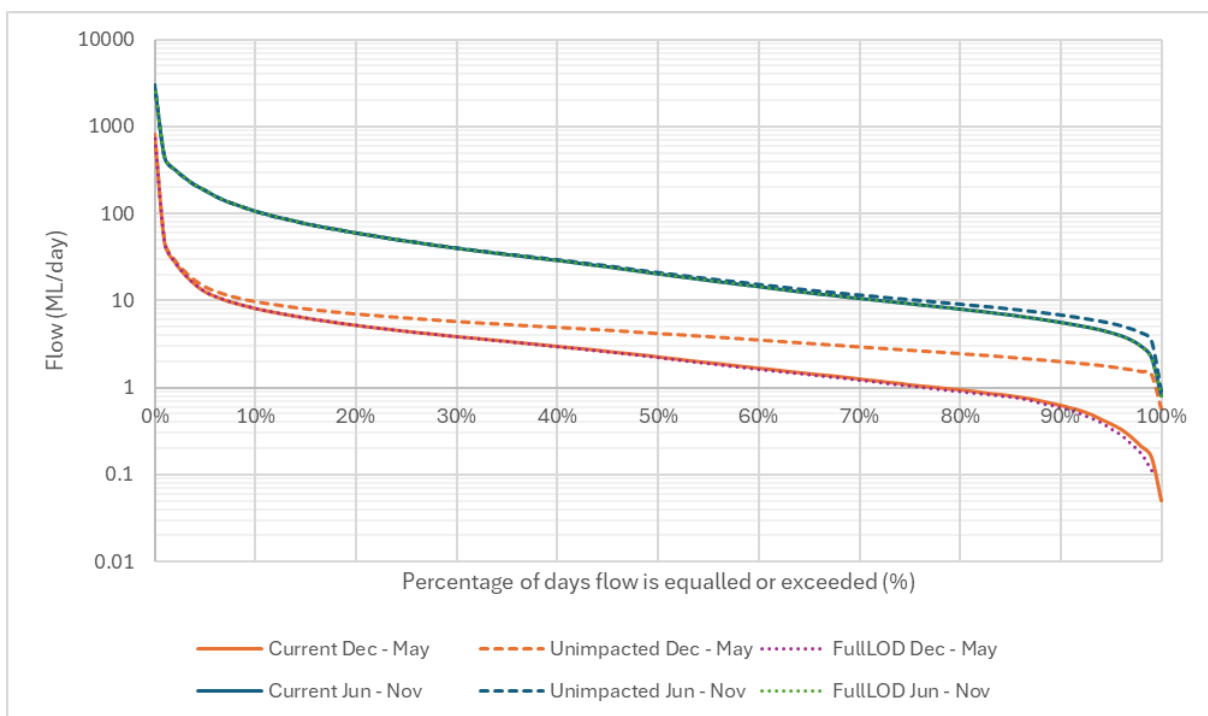


Figure 12. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate

6.1.5 Notes on site selection for Reach 1

The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 1 - Love Creek	
Reach Boundaries	Confluence of Love Creek and Gellibrand River
Major tributaries	• Yahoo Creek • Ten Mile Creek • Porcupine Creek
Proposed site	Wonga Road (<u>38°30'13.1"S 143°33'08.7"E</u>) Site was easily accessible with physical features including pool and a riffle. Instream vegetation was observed (Water ribbons). The EFTP noted some stream confinement at the bridge, which is unlikely to significantly impact the setting of flow recommendations.
Alternative sites	• 2006 FLOWS study Site 1 (<u>38°28'48.4"S 143°34'55.1"E</u>). The site was closed in March 2025 due to hazardous trees. Hydraulic model indicates trapezoidal channel. • Old Beechy Rail Trail crossing of Love Creek: Trapezoidal Stream, without clear in-channel physical features. • Downstream of Pompa Bill Creek (<u>38°29'42.9"S 143°33'54.9"E</u>): In-channel physical features were present and site was accessible, although dominated by willows and blackberries. This location could be a candidate for future willow removal works, which would disturb physical form.
Nearest flow gauge	Gauge 235234
Assessment and survey requirements	A new site survey and hydraulic model is required due to the change in site location
Flow-dependent and instream values	• Significant fish assemblage • Freshwater crayfish • Platypus habitat • Very high macroinvertebrate diversity • Submerged and floating leaved aquatic plant communities • Algal biofilms on submerged surfaces • Wet microclimate • EVC 18 Riparian Forest, and EVC 198 Sedgy Riparian Woodland • <i>Instream wood and flow diversity (fast and slow flowing habitat niches)</i>

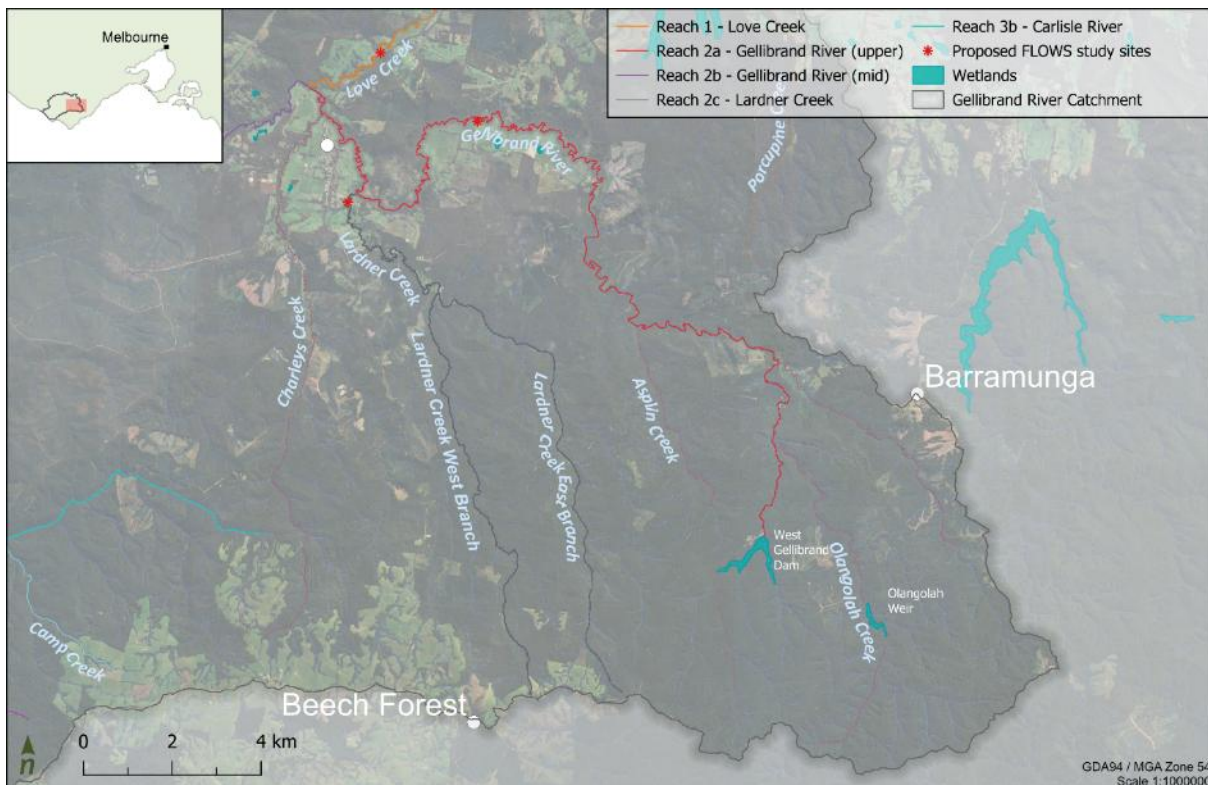
Reach 1 - Love Creek

Threats

- Low risk Acid Sulfate Soils are known to be present Porcupine Creek (Davison and Lancaster, 2011, Glover, 2014)
- Willows and blackberries (invasive and exotic plant species)
- Climate change
- High litter input from surrounding non-flow dependent riparian vegetation (from wet sclerophyll forest) has potential to impact water quality
- High numbers of brown trout (introduced) in Ten Mile Creek.
- *Pesticide use (Yahoo Creek, north of Kawarren)*
- *Siltation*
- *Livestock access*
- *Clear-felling of plantation forests nearby Love Creek causing ongoing remnant tree fall across the creek*

Note, purple shaded values and threats were provided by the PAG

6.2 Reach 2a - Gellibrand River (upper)



6.2.1 Geomorphology

The 2006 site at James Access bridge was reinspected and the EFTP confirmed the incised stream form. The site inspection also revealed limited instream features suitable for an environmental flow assessment and limited accessibility due to blackberry growth (Figure 13). An alternate site was assessed at Ashes Road (Figure 14). The waterway at the site is partly confined and inset within the floodplain. The Ashes Road site included deep pools and large volumes of large wood. Like the 2006 site, the bank material at Ashes Road appeared to be comprised of clay materials, limiting the potential for erosional adjustments.

6.2.2 Vegetation communities

Reach 2a (Gellibrand River) 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.

Submerged and floating leaved aquatic plant communities, algal biofilms on submerged surfaces and a wet microclimate were observed.

6.2.3 Aquatic fauna

Reach 2a is home to a diverse native fish assemblage including Broad-finned galaxiids, Short finned eels, Flat-headed gudgeons, River blackfish, Australian grayling and many small-bodied fish (Table 4). Spotted galaxias, Southern shortfin eels, Tupong and Australian grayling are catadromous and undertake migrations to the estuary to complete their life cycles. Australian grayling is a listed species (Table 4) and

the Gellibrand River is recognised to support good populations of the species. A lack of juvenile River blackfish in the main stem of the Gellibrand River was noted in a population assessment by O'Connor et al. in 2015, however in 2025, Gellibrand main stem survey collected 27 River blackfish, the highest since report card sampling started (ARI, 2025).

Platypus and Spiny crayfish are both present in Reach 2a (Table 4). Platypus are listed as vulnerable under the *FFG Act 1988* and positive records for the upper Gellibrand exist (Clanceys Access road) (CCMA 2024).

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, noting however, that the vast majority of Reach 2a and all of Reach 2b is located downstream of Stevensons Falls.

A variety of instream habitat for macroinvertebrates was reported in Reach 2a, including instream macrophytes and large woody debris. A relatively high abundance of aquatic invertebrates has been reported (Dwyer and Lester 2021), with 57 taxa from 12 Orders recorded at the reference site (Saddler et al. 2005). Three Waterbug Blitz sites are in Gellibrand Reach 2a (GEL 016, GEL017 and GEL019), with 8-16 taxa identified at the sites, and SIGNALT scores ranging from 4.4 to 6.2 (both recorded at GEL019 at Gellibrand in 2022 and 2023, respectively) (CCMA 2024).



Figure 13. Reach 2a existing site at James Access bridge (Left) looking upstream (right) looking downstream. Image taken 24 March 2025.



Figure 14. Reach 2a proposed site (Ashes Road) looking (left panel) across the river (right panel) upstream. Image taken 24 March 2025.

6.2.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235236 in Reach 2a. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 15), while the flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 16). Please refer to Appendix B for a brief description of scenarios and flow duration curves. Fuller discussion of hydrology will be provided in the issues paper.

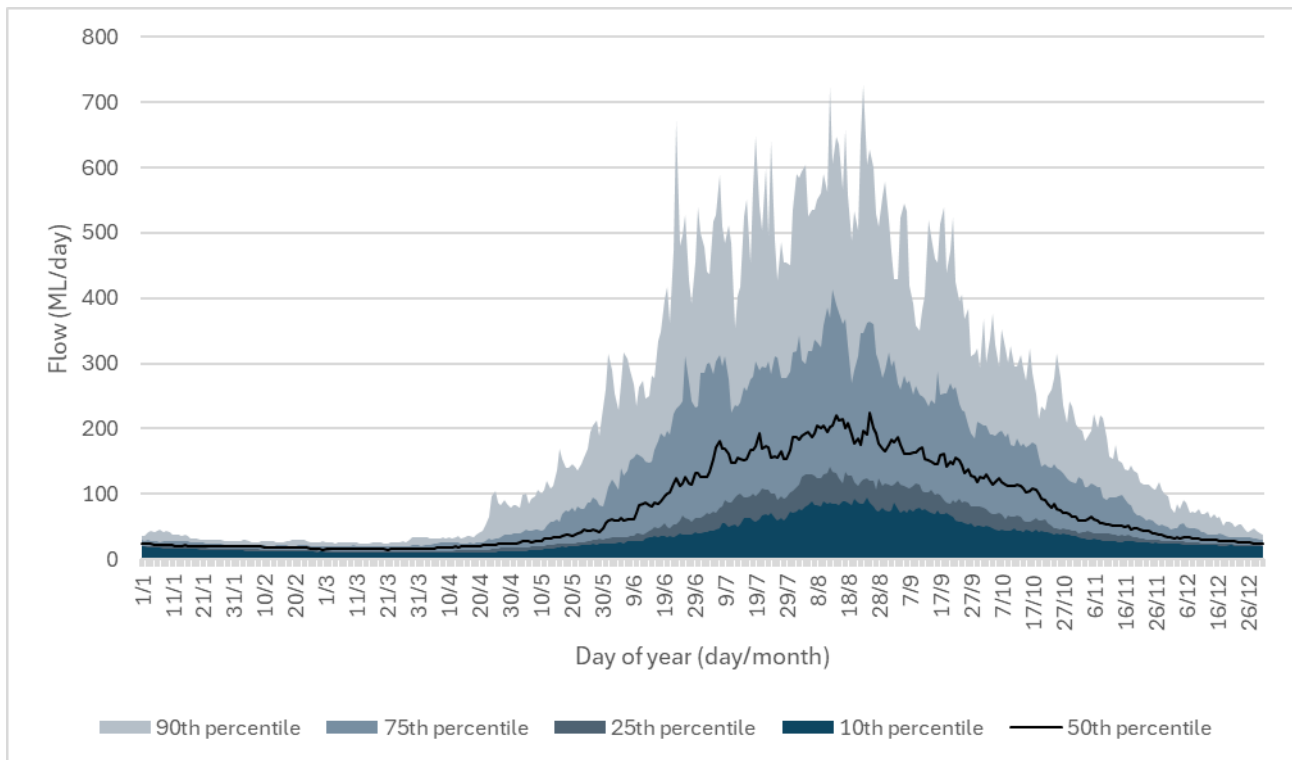


Figure 15. Day of year flow percentile plot for Reach 2a, modelled current level of development, historic climate.

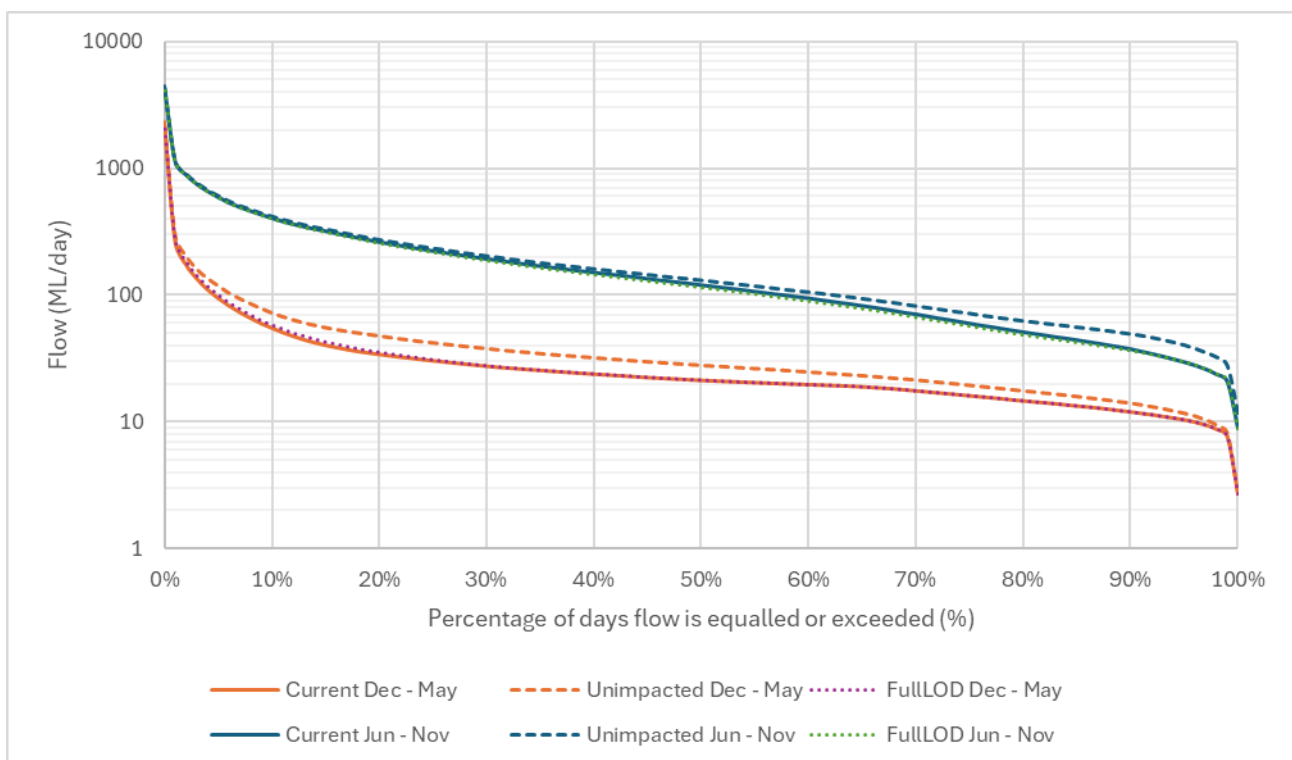


Figure 16. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 2a

6.2.5 Notes on site selection for Reach 2a

The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 2a - Gellibrand River	
Reach Boundaries	West Gellibrand Dam to the Gellibrand River confluence with Love Creek
Major tributaries	• Charleys Creek • Asplin Creek • Olangolah Creek • Barramunga Creek • Lardner Creek (Reach 2c)
Proposed site	Ashes Road (<u>38°30'57.8"S 143°34'41.2"E</u>) - site was determined by the EFTP to have the best instream features of all sites visited, and better habitat condition and habitat diversity than at James Access Bridge. Ashes Road has improved access to the stream for surveying cross sections. The Ashes Road site is located within the LTA discharge zone, and closer to the active flow gauge
Alternative sites	• James Access Bridge (Site 2a <u>38°31'45.1"S 143°36'28.7"E</u>): Site has changed markedly since 2006 study and is overgrown with blackberries. The site is now difficult to access survey and blackberries obscures physical features. James access bridge has gaps, which pose a safety hazard. Site 2a is upstream of the Lower Tertiary Aquifer (LTA) discharge zone. No mobile phone coverage, which may preclude site survey. • Rafferty's Lane (<u>38°31'47.2"S 143°33'48.3"E</u>) - new flow gauge has been installed at Rafferty's Lane. Typical platypus habitat was observed.
Nearest flow gauge	• Gauge 235256 at James Access is inactive • A new flow gauge (235231) has recently been installed at Rafferty's Lane
Assessment and survey requirements	A new site survey and hydraulic model is required due to the change in site location

Reach 2a - Gellibrand River

Flow-dependent and instream values

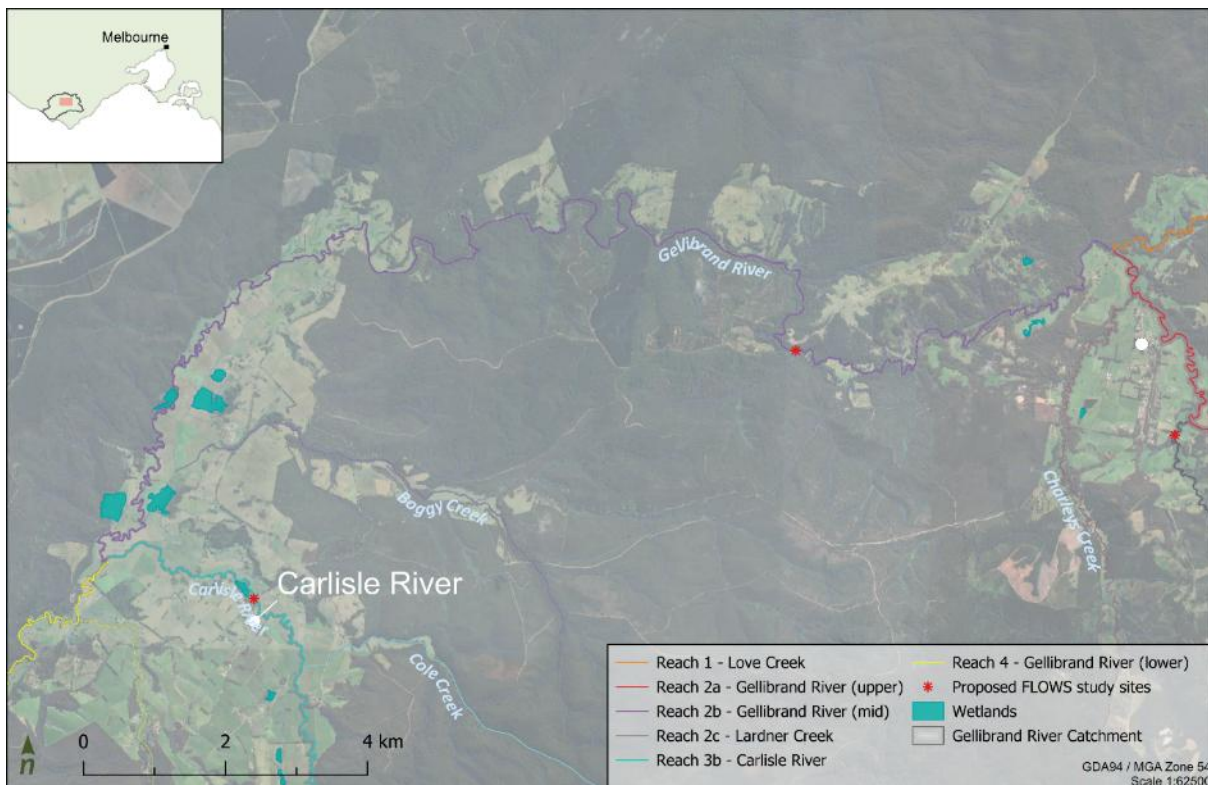
- Diverse native fish assemblage
- Freshwater crayfish
- Platypus
- Macroinvertebrate diversity
- Wet microclimate
- Submerged and floating leaved plant communities
- Algal biofilms on submerged surfaces
- EVC 18 Riparian Forest, EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex
- *Rakali*
- *Mussels*
- *Otway Black Snail and Hairy Burrowing Crayfish (not flow dependent)*
- *Instream wood and flow diversity (fast and slow flowing habitat niches)*
- *Riverine flora and fungal communities*
- *Groundwater inflows*
- *Billabong soaks*

Threats

- Exotic vegetation (willows, blackberries)
- Land use change
- Potential for nutrient enrichment
- Regulated reach and subject to Bulk Entitlement (with passing flows)
- Instream barriers (natural and built)
- Climate change
- *Siltation following rainfall (grazing, plantation and recreational vehicle use)*
- *Removal of billabong soaks (development and land use change)*
- *Stock access to river*
- *Change in hydrology - limited understanding of complex hydrology*
- *Expansion of plantations (including chemical use and erosion)*
- *Chemical runoff from plantations*
- *Impacts from historic groundwater pumping*
- *Introduced fauna (Brown Trout)*

Note, purple shaded values and threats were provided by the PAG

6.3 Reach 2b - Gellibrand River (mid)



6.3.1 Geomorphology

The proposed representative site for Reach 2b is partly confined with an exposed rock bar and large upstream pool. Upstream from the rock bar the waterway contains floodplain pockets, the cross section includes depositional benches, a sand bed and presence of large wood (Figure 17, Figure 18). The site is stable with no sign of contemporary erosional or depositional channel change. Site 2b is located at the same site as that used in the 2006 FLOWS study.

6.3.2 Vegetation communities

Reach 2b (Gellibrand River) 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.

Site 2b has intact riparian vegetation extending into forest cover. Submerged and floating leaved aquatic plant communities, algal biofilms on submerged surfaces and a wet microclimate were observed.

6.3.3 Aquatic fauna

Like Reach 2a, Reach 2b supports a diverse native fish assemblage (9 species, including freshwater resident and migratory species, refer to Table 4), including Australian grayling and River Blackfish. Platypus and Spiny crayfish are also present in Reach 2b.

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 (wet forest and cool temperate rainforest, SWIFFT 2025).

Macroinvertebrate surveys using National Waterbug blitz method have not been reported for Reach 2b, although they are presumed present (Site GEL019 is in the Gellibrand River at Gellibrand, upstream of the Reach 2a / Reach 2b boundary, and therefore included in Reach 2a).



Figure 17. Rock bar at existing (and proposed) site for Reach 2b. Image taken 24 March 2025.



Figure 18. Proposed Reach 2b site looking upstream from rock bar. Image taken 24 March 2025.

6.3.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235227 in Reach 2b. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 19). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 20). Please refer to Appendix B for a brief description of scenarios and flow duration curves. Fuller discussion of hydrology will be provided in the issues paper.

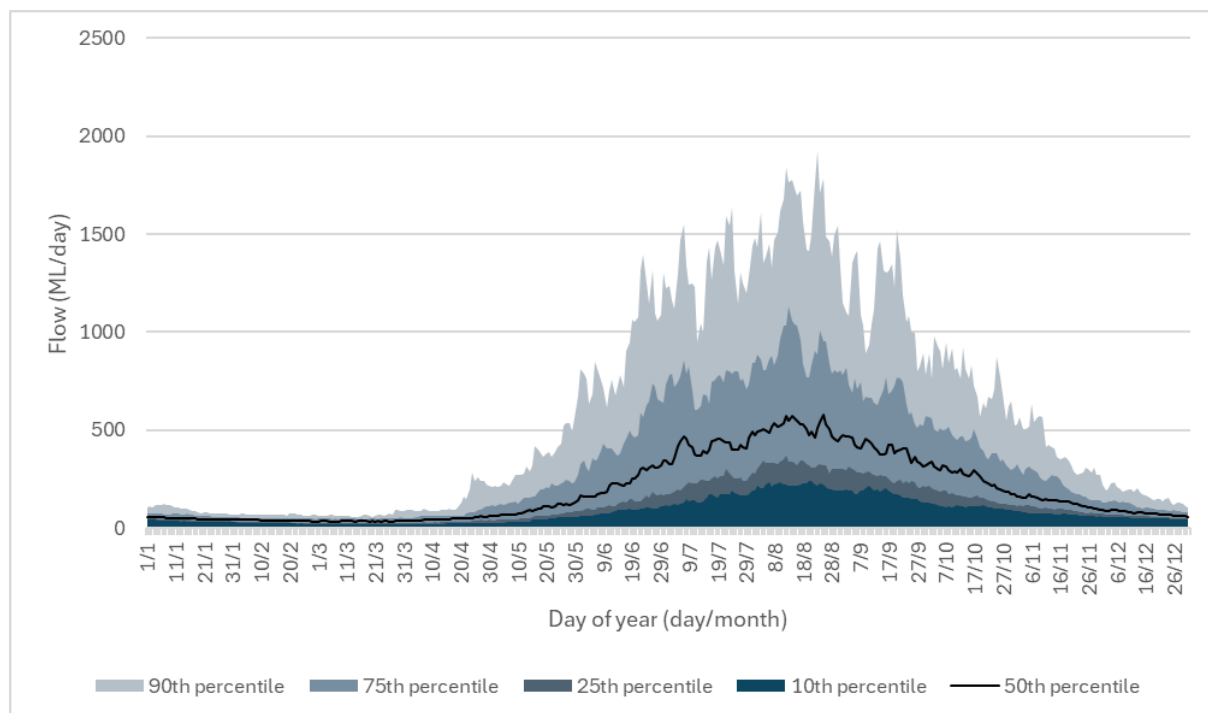


Figure 19. Day of year flow percentile plot for Reach 2b, modelled current level of development, historic climate.

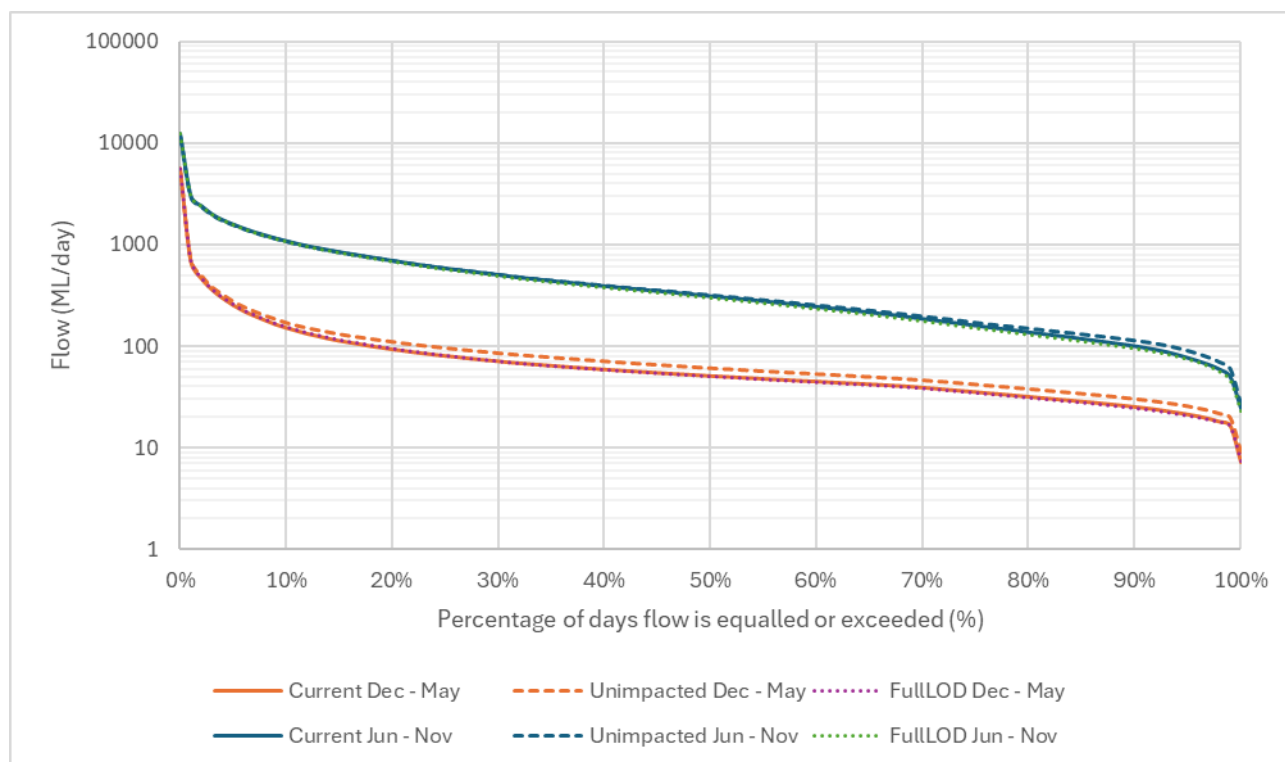


Figure 20. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 2b

6.3.5 Notes on site selection for Reach 2b

The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 2b - Gellibrand River	
Reach Boundaries	From confluence with Love Creek to confluence with Carlisle River
Major tributaries	- Gum Gully Creek - Boggy Creek
Proposed site	Site 2b (Gellibrand Gauge 235227, off Gellibrand River Road <u>38°31'29.0"S 143°28'58.6"E</u>). Physical conditions at Site 2b have not changed since 2006. Site has intact riparian vegetation extending into forest cover. Site has good physical features for setting flow recommendations (floodplain, benches, instream rocks and backwaters), and generally good access.
Alternative sites	Carlisle Road crossing of Gellibrand (<u>38°30'49.9"S 143°24'49.2"E</u>). Agricultural operations on one side, forested on other side.

Reach 2b - Gellibrand River	
	Silks Access Road (<u>38°32'34.7"S 143°22'43.3"E</u>). Agricultural activities on both sides of river. Both sites are inferior to the existing FLOWS study site
Nearest flow gauge	Gauge 235227
Assessment and survey requirements	A new site survey and hydraulic model are required. The 2006 model requires extension and existing survey data was obtained relative to an arbitrary local datum, which precludes this extension.
Flow-dependent and instream values	- Diverse native fish assemblage - Freshwater crayfish and mussels - Platypus - Diverse macroinvertebrates, including the threatened Otway Stonefly - Wet microclimate - Submerged and floating leaved plant communities - Algal biofilms on submerged surfaces - EVC 18 Riparian Forest, EVC 198 Sedgy Riparian Woodland <i>Rakali</i> <i>Mussels</i> <i>Instream wood and flow diversity (fast and slow flowing habitat niches)</i> <i>Billabong soaks</i>
Threats	- Exotic vegetation (willows, blackberries) - Land use change - Potential for nutrient enrichment - Regulated reach and subject to Bulk Entitlement (with passing flows), corresponding changes in hydrology - Onsite wastewater from residential development - Climate change <i>Removal of billabong soaks (development and land use change), and altered overland flow</i> <i>Introduced fauna (Brown Trout)</i>

Note, purple shaded values and threats were provided by the PAG

6.4 Reach 2c – Lardner Creek

(For map, please refer to Reach 2a map in Section 6.2)

6.4.1 Geomorphology

Lardner Creek downstream of the Barwon Water offtake comprises a partially confined meandering single thread, sand bed stream with a bed width of 3 to 5 metres, a top width of approximately 20 metres and a channel depth of approximately 3.5 metres (Figure 21). As the river is partially confined the channel has both adjoining floodplain pockets and valley margins. The channel has banks comprising clay, silt and sand. The stream channel has moderate levels of large wood, providing channel bed form and hydraulic habitat diversity. The channel has depositional benches on the inside of meander bends (Figure 22, left panel). 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.

6.4.2 Vegetation communities

The major types of native vegetation surrounding 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)). Other vegetation types in the surrounding area include EVC 48 Heathy Woodland and EVC 8 Wet Heathland, but being located some distance from the creek are not of direct concern in this investigation. There are also substantial areas of cleared land in the surrounding catchment. Mosses and algal biofilms were observed on submerged surfaces and instream rocks at the proposed study site (Figure 21, left panel).

6.4.3 Aquatic fauna

Lardner Creek has a largely intact flow regime, and although there are impacts from forestry that may result in cyclical hydrologic impacts dependent on forestry rotations and harvesting, other extractions (for example, under the Bulk Entitlement) appear to be limited. The limited extractions and close to natural flows may mean that this tributary functions as an important habitat for aquatic values in the context of the broader Gellibrand catchment. While not surveyed, it is possible that the unregulated flow supports and attracts flow dependent species such as Australian grayling. Other migratory fish species such as Common galaxias, eel, tupong, lamprey could be more prevalent in this tributary as well (historic records for these species exist from 1999, NatureKit).

The Otway Black Snail (*Victaphanta compacta*) and Hairy burrowing crayfish (*Engaeus sericatus*) have been found in the Lardner Creek catchment (NatureKit), and although these species are water dependent, they are not flow-dependent. There are no Waterbug Blitz survey sites in Reach 2c, however macroinvertebrates are presumed present. Key aquatic species predicted to occur in Lardner Creek include, Spiny crayfish, River blackfish (suitable habitat exists and there are historic records), Australian grayling and Platypus.



Figure 21. Lardner Creek at Gellibrand East Road bridge, near the offtake (left) looking downstream (right) looking upstream. Images taken 21/07/2025 PI Boon.



Figure 22. Lardner Creek looking downstream at the northern end of Yagher Bushland Reserve. (Right) Lardner Creek mid reach site, near the confluence of the west and east branches of Lardner Creek. Both images taken 21/07/2025 J Bolden

6.4.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235210 in Reach 2c. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 23). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec - May) and winter / spring (June - November) (Figure 24). Please refer to Appendix B for a brief description of scenarios and flow duration curves.

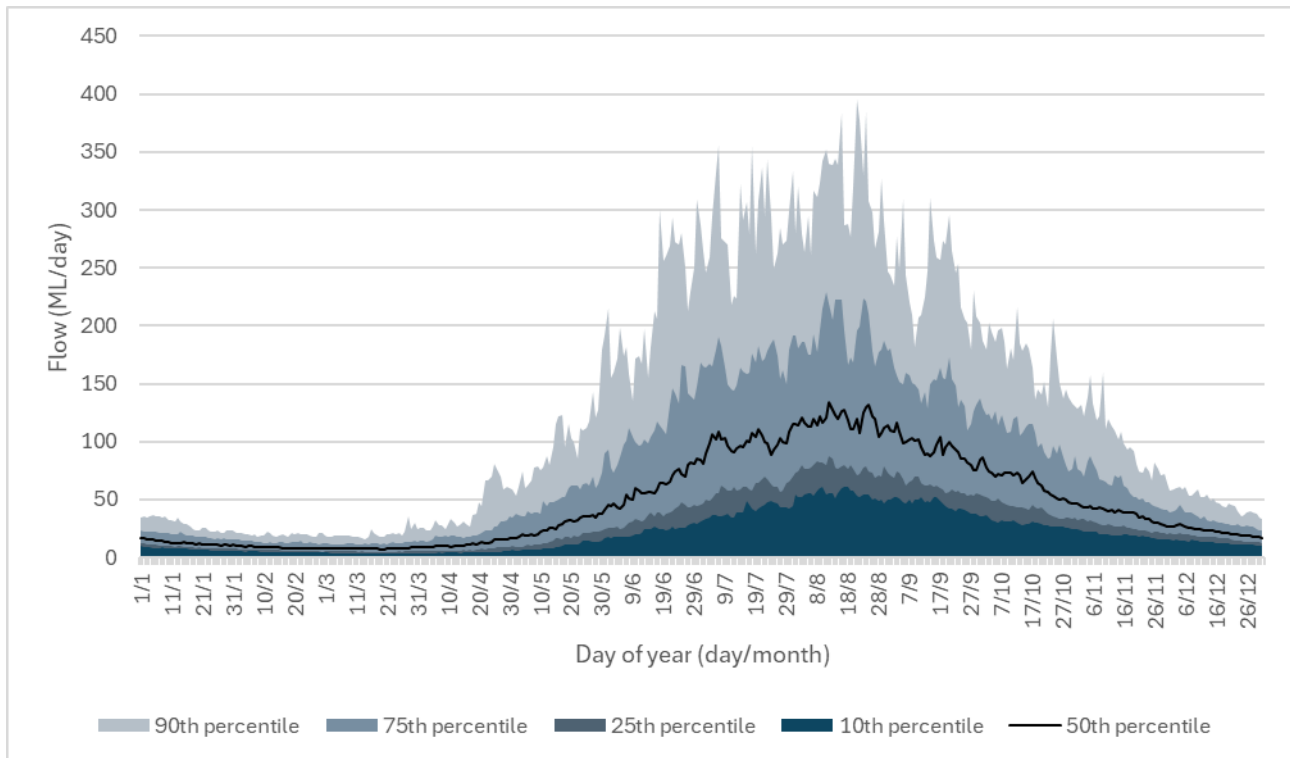


Figure 23. Day of year flow percentile plot for Reach 2c, modelled current level of development, historic climate.

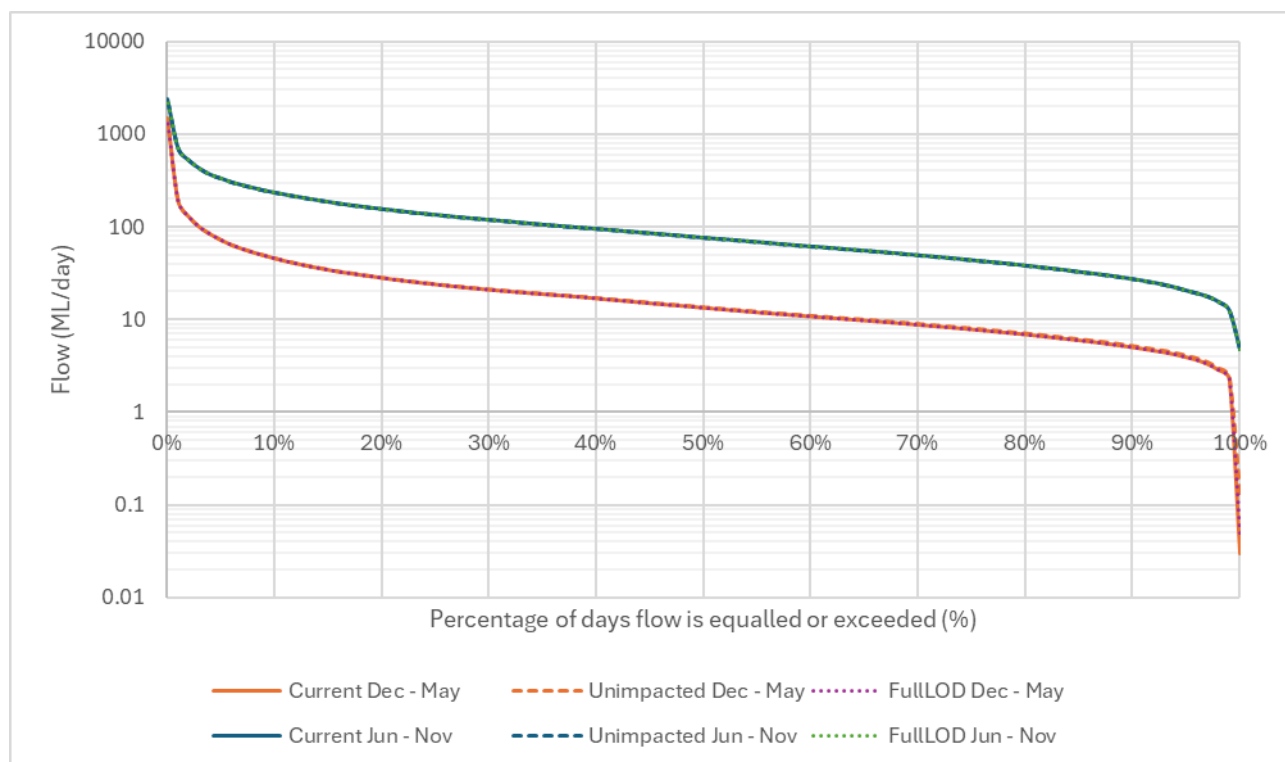


Figure 24. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 2c

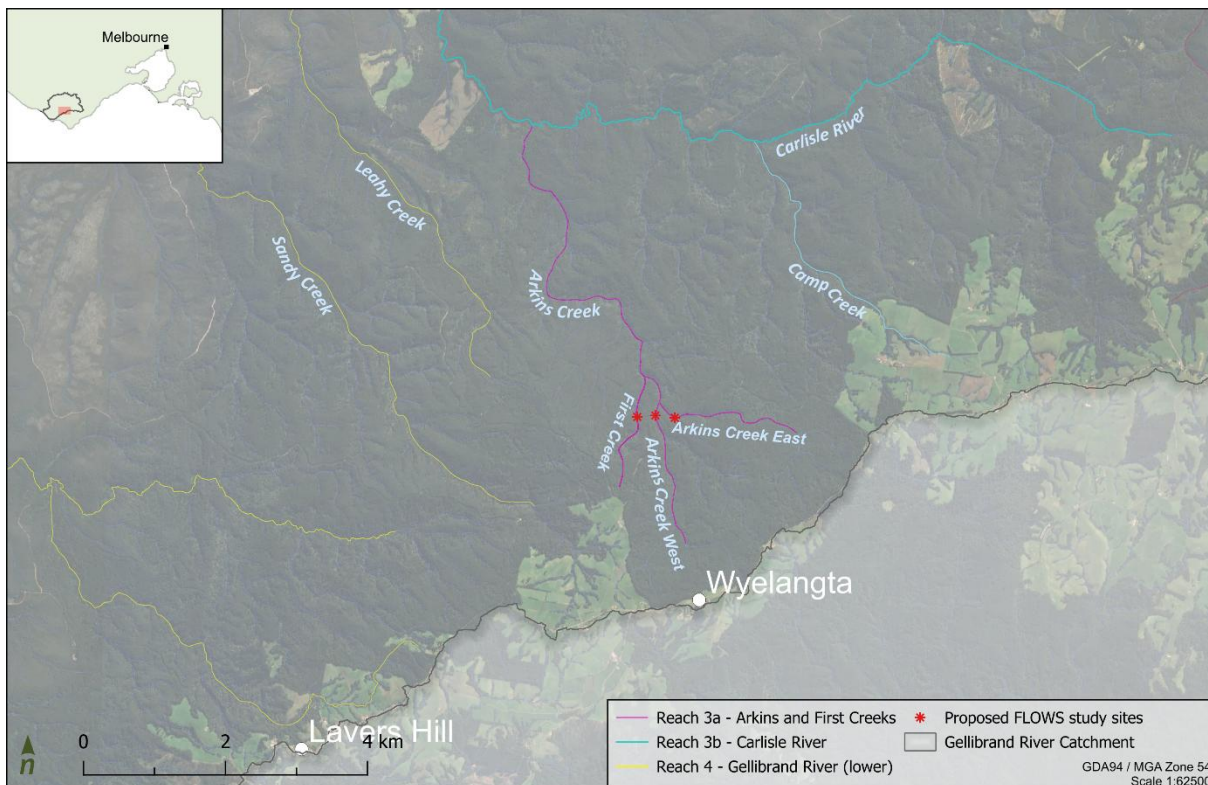
6.4.5 Notes on site selection for Reach 2c

The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 2c - Lardner Creek	
Reach Boundaries	Lardner Creek (including west branch and East Branch) to confluence with the Gellibrand River
Major tributaries	Nil.
Proposed sites	Yagher Bushland Reserve (downstream of the offtake, and downstream of the Gellibrand East Road Bridge) is accessible and has similar physical features to Gellibrand River site 2a. <u>38°32'01.6"S 143°32'38.8"E</u>
Alternative sites	Nil. - The headwaters of the upper west branch of Lardner Creek were inaccessible via the softwood plantation on Ryan Track. - A site near the confluence of the west and east branches of Lardner Creek was visited <u>38°33'01.1"S 143°34'11.3"E</u>, but poor waterway access precludes use of this site in the FLOWS study

Reach 2c - Lardner Creek	
Nearest flow gauge	Gauge 235210
Assessment and survey requirements	A new site survey and hydraulic model are required.
Flow-dependent and instream values	• Native fish assemblage • Crustacea (Southern Victorian spiny crayfish, and common freshwater shrimp) • Platypus habitat (assumed presence) • Mosses and Algal biofilms on submerged surfaces • EVC 18 Riparian Forest • Abundant fallen and instream wood • Intact flow regime
Threats	• Exotic vegetation (blackberries and willows) • Introduced fauna (Brown trout) • Land use change • Plantation forestry (18% plantation cover) impacting catchment yield and therefore stream flow • Nutrient enrichment (excessive macrophyte and algal growth) • Climate change

6.5 Reach 3a - Arkins and First Creeks



6.5.1 Geomorphology

First Creek, Arkins Creek West and Arkins Creek East are steep, and bedrock confined waterways, with no observed depositional features, such floodplains, benches or bars, at the sites inspected (Figure 25 - Figure 29). Sediment (silt, sand and gravel) is supplied from hillsides to the waterways and transported through the system, leaving behind rocks and boulders. As such, the subject waterways have few physical features that could be surveyed and used for developing hydraulic-based flow recommendations.

6.5.2 Vegetation communities

First Creek at the diversion weirs is a steep, narrow waterway surrounded by wet forest EVC (EVC 30, Bioregional conservation status of least concern), and in some spots closer to the waterway, EVC 31 Cool Temperate Rainforest (Endangered in the Otway Ranges Bioregion, NatureKit). Arkins Creek East and Arkins Creek West are surrounded by EVC (directly along the creek lines), and EVC 30 Wet Forest located in some cases directly along the creek lines and in others on the hillsides along the waterways. The EFTP noted the high ecological and social value of the surrounding tall forest, but the limited flow-dependent values of the vegetation in and fringing the three waterways.

The three creeks (upstream of the diversion weirs) contain abundant water-dependent ferns (Figure 26). Algal biofilms occur on submerged surfaces in sunny patches of the creeks. Low light levels in the waterways correspond to a general lack of submerged and fringing aquatic plants in these reaches (Figure 26).



Figure 25. Vegetation at First Creek weir. (Left) below the weir (right) above the weir. Images taken 21/07/2025 PI Boon.



Figure 26. Left) Water-dependent ferns - the dominant type of water-dependent vegetation in this part of the river system. (right) low light levels in the waterway, and corresponding lack of submerged and fringing aquatic plants in Arkins Creek East. Images taken 21/07/2025 PI Boon.

6.5.3 Aquatic Fauna

Crayfish burrows (formed by burrowing crayfish, spp. not determined) were observed in Arkins Creek West and Arkins Creek East (Figure 27). These larger creeks are anticipated to support Spiny crayfish (*Euastacus yarraensis*), Climbing galaxias (*Galaxias brevipinnis*), and various small macroinvertebrates. Platypus habitat is also 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 and several similar aged records of fish species including blackfish, lamprey, galaxias, eel and trout also exist ([NatureKit Victoria](#)).

First Creek is considerably smaller than the two Arkins Creek branches, with smaller inflows and limited (i.e. lack of) pool habitats, other than that at the weir pools. Fauna values in First Creek are anticipated to be predominantly forest-dependent, rather than streamflow dependent. An Otway black snail (*Victaphanta compacta*, non-streamflow dependent) was observed by an Alluvium representative at the First Creek site, and crayfish burrows were also observed at Arkins Creek West. Suitable habitat for this species is also likely to occur within the broader Arkins Creek catchment. There are no Waterbug Blitz survey sites in Reach 3a, however macroinvertebrates are presumed present.



Figure 27. Arkins Creek West (left) crayfish burrow, marked by top of arrow (right) Arkins Creek West below the weir and road crossing, looking downstream. Images taken 21/07/2025 J Bolden.



Figure 28. Arkins Creek West branch weirs (left) lower weir (centre) middle weir (right) upper weir. Images taken 21/07/2025 J Bolden.



Figure 29. Arkins Creek East (left) looking upstream towards the weir and wheel (right) looking across the creek, downstream of the weir. Images taken 21/07/2025 PI Boon.

6.5.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled inflows to each of the diversion weirs. The estimated split for catchment inflow to the Arkins Creek West weir, Arkins Creek East Weir and First Creek weirs was based on the proportion of catchment area estimated by spatial analysis (Appendix B).

Arkins Creek West Branch: Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 30). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 31).

Arkins Creek East Branch: Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 32). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 33).

First Creek: Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 34). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 35).

Please refer to Appendix B for a brief description of scenarios, flow duration curves, and the split of total inflows across the three weirs.

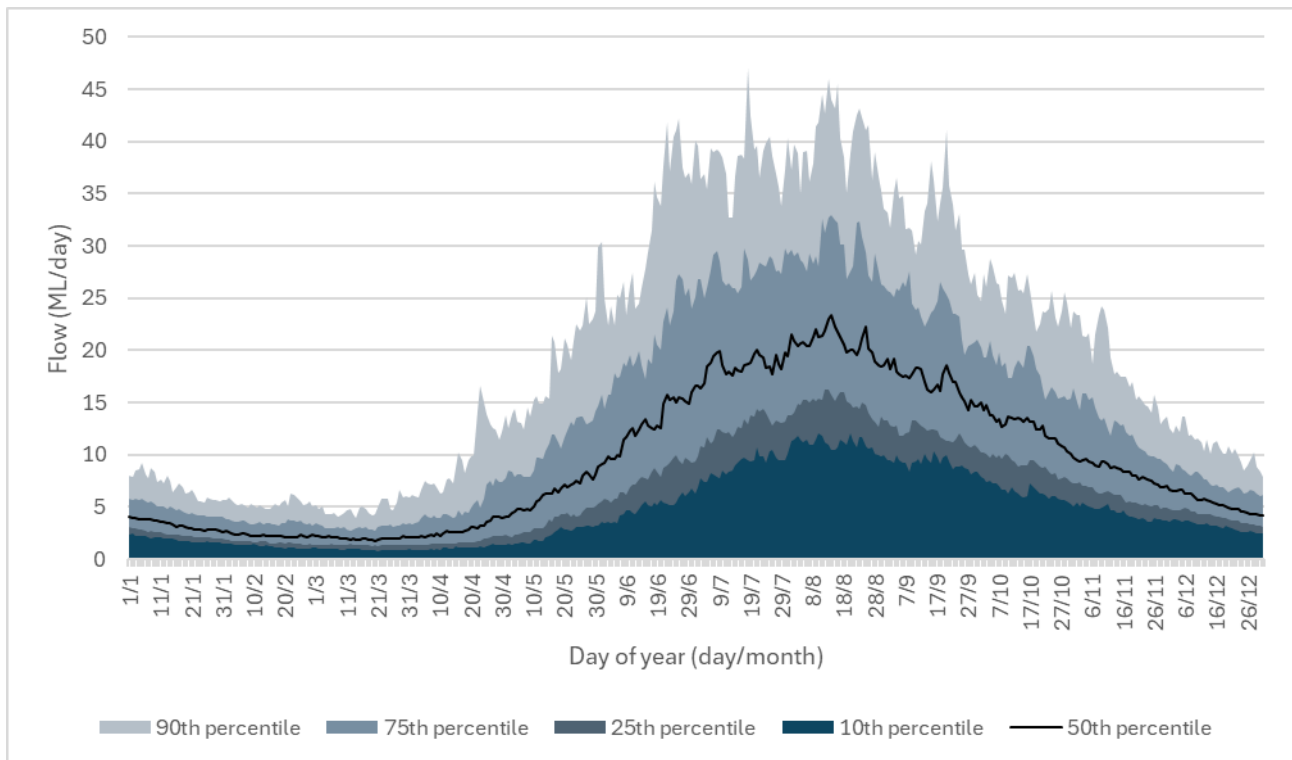


Figure 30. Day of year flow percentile plot for inflows to Arkins Creek West weir, modelled current level of development, historic climate.

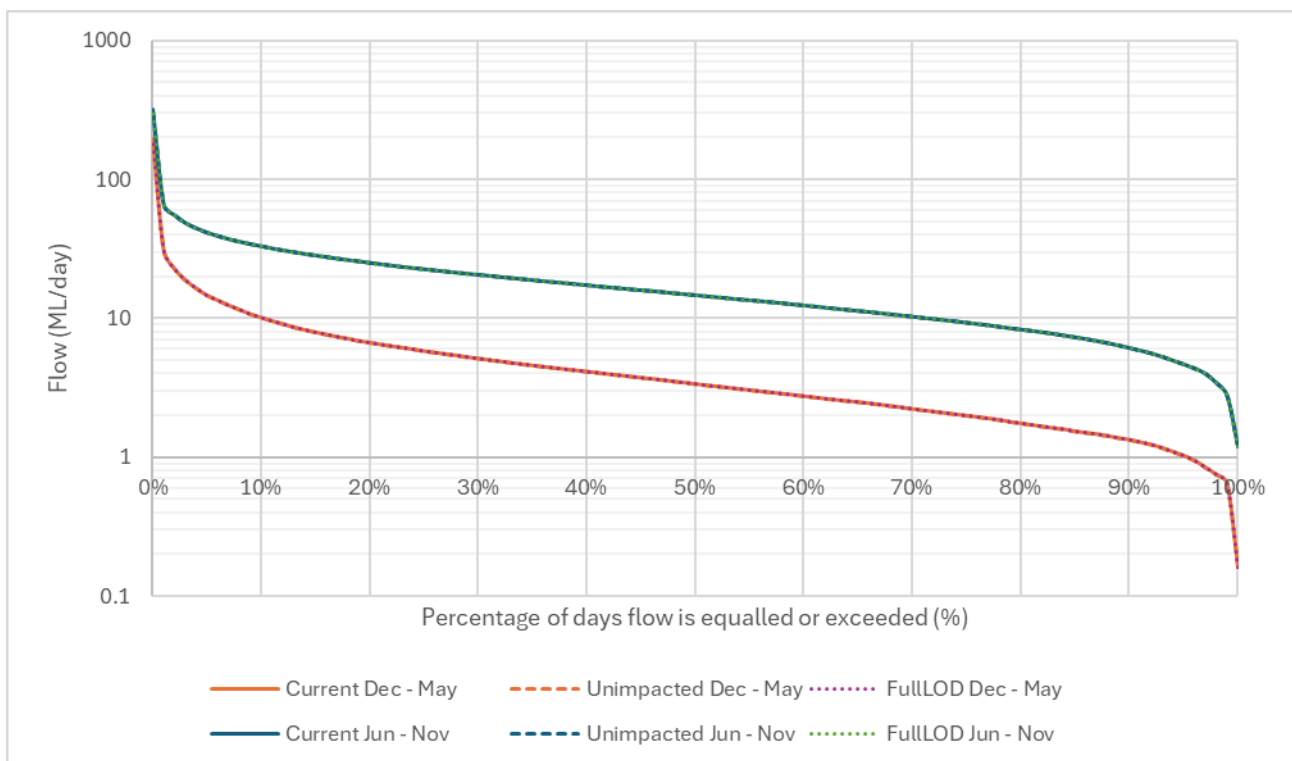


Figure 31. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate at Arkins Creek West weir.

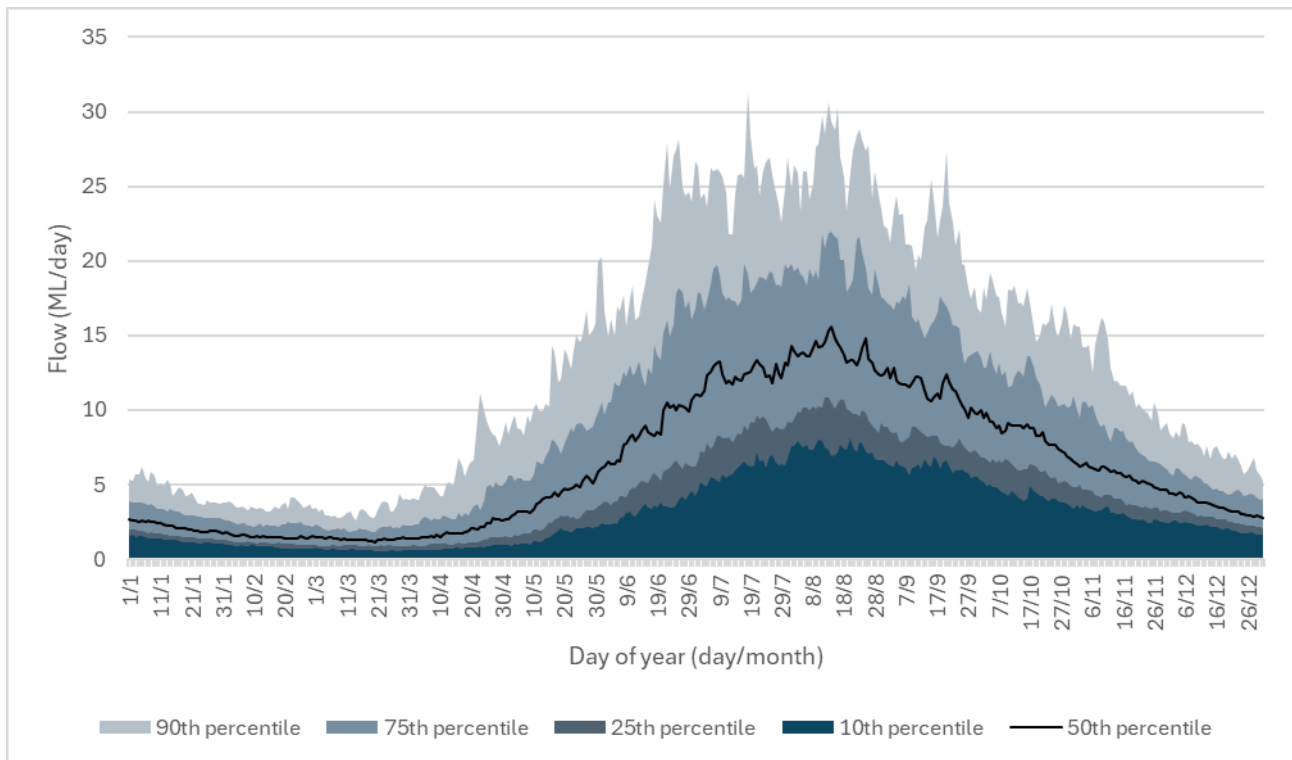


Figure 32. Day of year flow percentile plot for inflows to Arkins Creek East weir, modelled current level of development, historic climate.

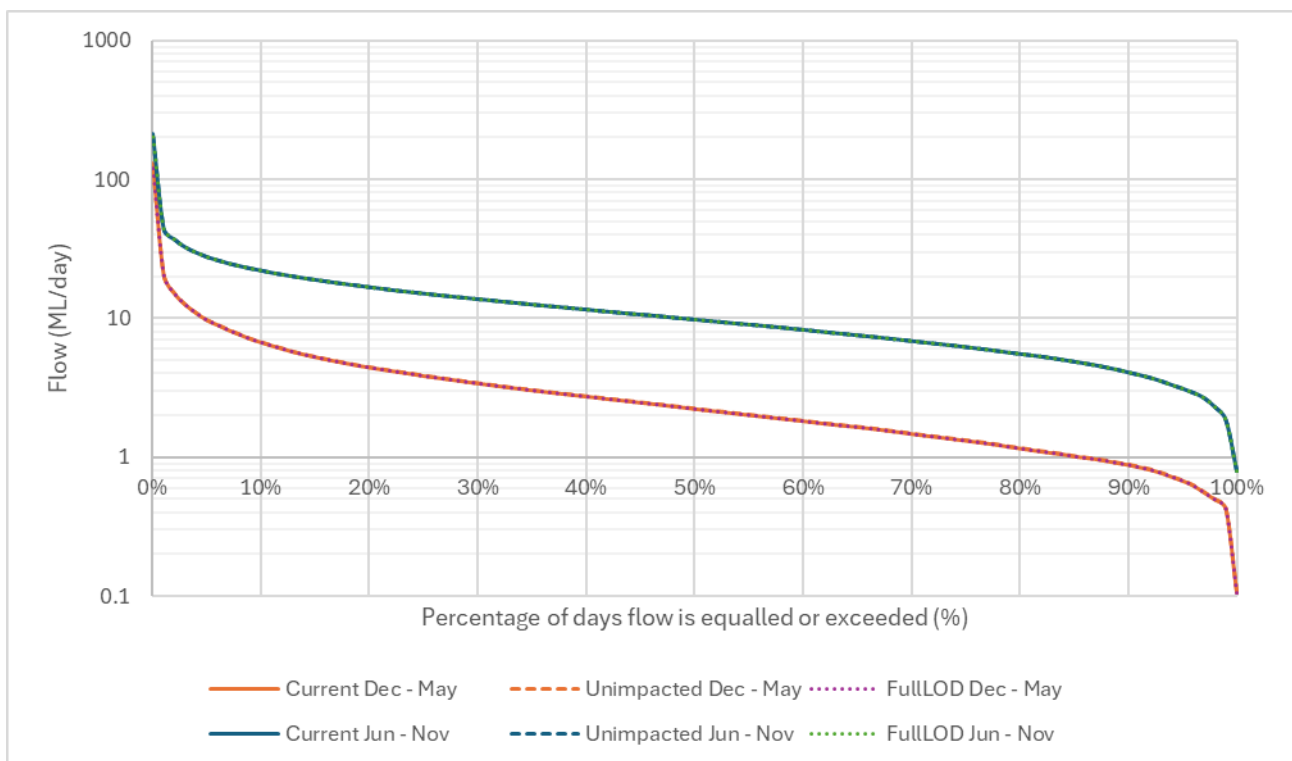


Figure 33. Flow duration curves for modelled current, unimpacted and full level of development scenario inflows, historic climate at Arkins Creek East weir.

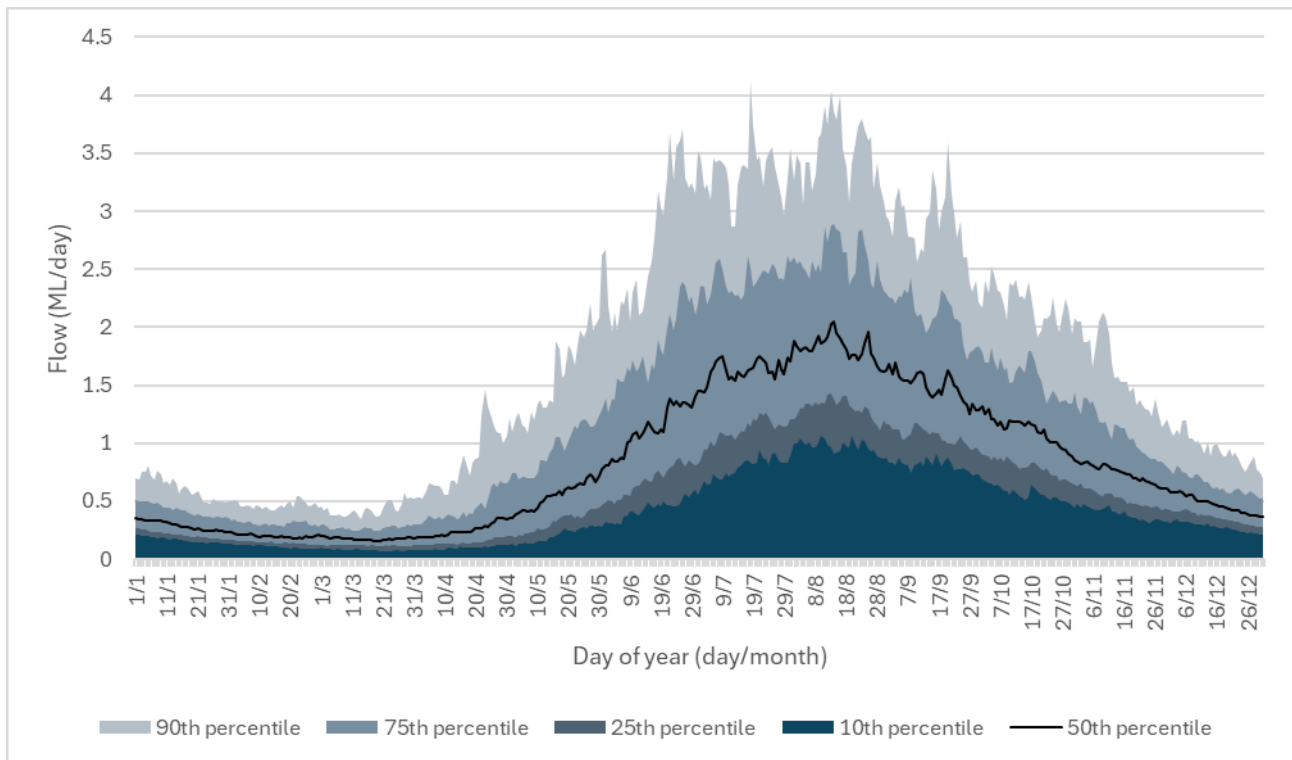


Figure 34. Day of year flow percentile plot for inflows to First Creek Weir, modelled current level of development, historic climate.

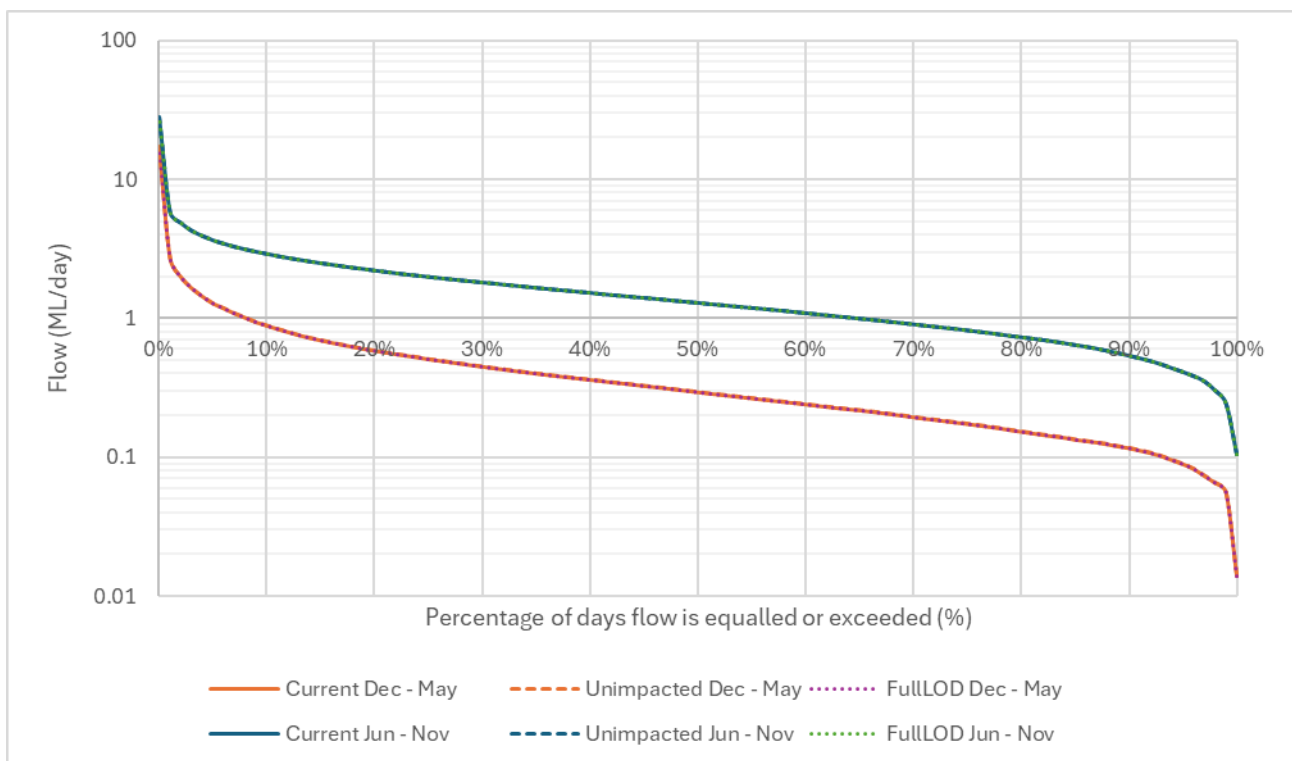


Figure 35. Flow duration curves for modelled current, unimpacted and full level of development scenario inflows, historic climate at First Creek weir.

6.5.5 Notes on site selection for Reach 3a

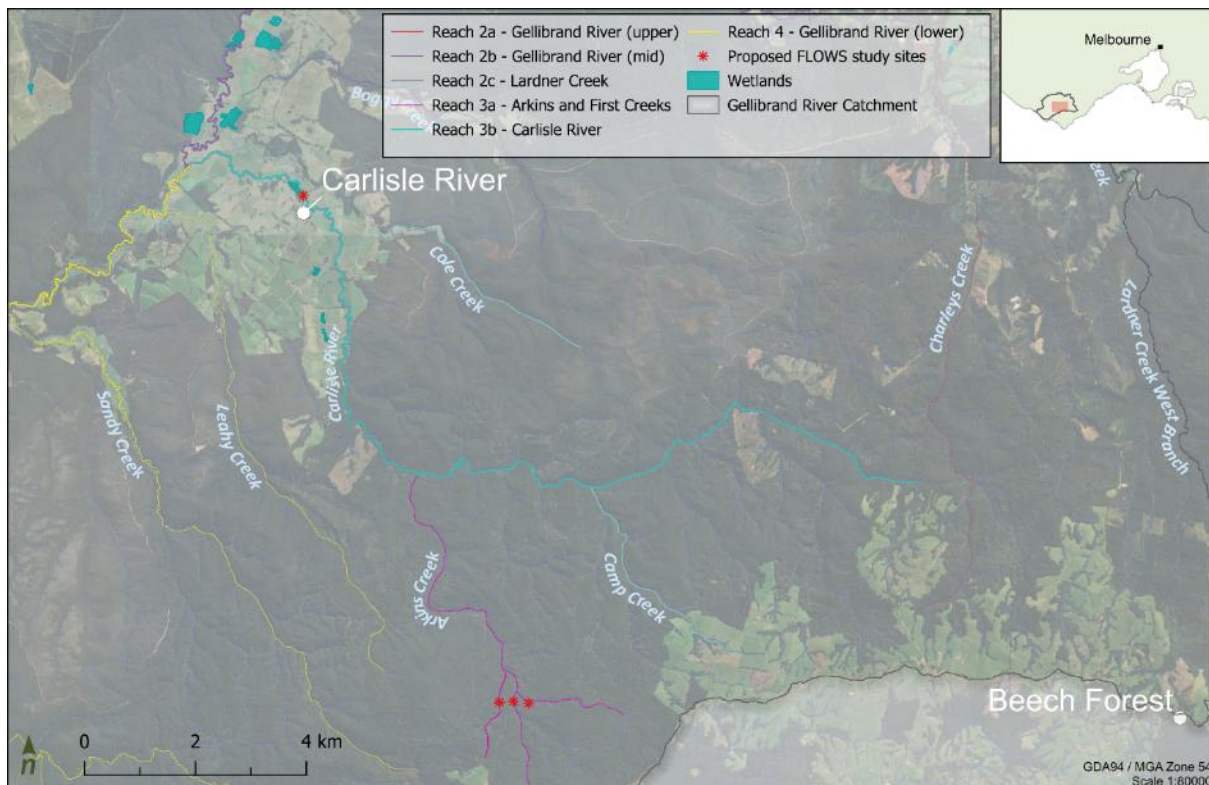
The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

As noted above in Section 3.1.2, a hydrologic approach will be used to develop low flow recommendations for each of the constituent creeks, to inform future operations. A full flow regime will not be developed for these creeks. A site assessment and hydraulic modelling is not required for this reach.

Reach 3a - Arkins and First Creeks	
Reach Boundaries	First Creek, Arkins Creek (including west and East Branches)
Major tributaries	Nil.
Proposed sites	First Creek diversion weir <u>38°38'20.5"S 143°26'23.3"E</u> Arkins Creek West Branch diversion weir <u>38°38'19.7"S 143°26'33.4"E</u> Arkins Creek East Branch diversion weir <u>38°38'20.5"S 143°26'45.1"E</u>
Alternative sites	Nil.
Nearest flow gauge	Gauge 235205 (Arkins Creek West Branch and Wyelangta)
Assessment and survey requirements	Physical form precludes development of a hydraulic model. A hydrologic approach will be taken to determine low flows at each weir, based on Source modelled hydrologic data
Flow-dependent and instream values	• Water-dependent ferns • Cool Temperate Rainforest EVC 31 (not flow-dependent) • Algal biofilms on submerged surfaces in sunny patches • Burrowing crayfish • Spiny crayfish • Climbing galaxias • Macroinvertebrates • Platypus
Threats	• Hydrologic change - creeks are subject to Bulk Entitlement diversions without passing flow requirements • Climate change • Population growth (increased demand)

Note, purple shaded values and threats were provided by the PAG

6.6 Reach 3b - Carlisle River



6.6.1 Geomorphology

The channel at Site 3b had an incised stream appearance with a low (5:1) width depth ratio, the bed approximately 3 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. As described in 2006, there is no bedrock evident in the bed or banks (Earth Tech 2006a). The EFTP was unable to visit other sites in Carlisle River due to the closure of forest roads.

6.6.2 Vegetation communities

The Carlisle River reach mostly cleared but 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, 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.

The revegetation at the site used in the 2006 has matured to produce a narrow corridor of tall manna gum at floodplain level adjoining the waterway with an associated shrub-layer native vegetation, albeit with a ground-layer dominated by exotics such as blackberry (Figure 36, Figure 37). Instream vegetation, including diatoms and algal biofilms on submerged surfaces were observed in this reach.

6.6.3 Aquatic Fauna

The main fish species of significance present in Reaches 3b are River blackfish and Australian grayling. There are other small-bodied fish present, both migratory and resident. Other fish species found in reach 3b include Short Finned Eel, Brown Trout, Short Headed Lamprey, Spotted galaxias and Common Galaxias. Platypus also have been recorded in Carlisle River (NatureKit).

Thirteen invertebrate taxa have been identified at Waterbug Blitz site CRL080 (Carlisle River bridge), with a SIGNALT score of 4.2 Indicating impacted conditions (CCMA 2024).



Figure 36. Carlisle River existing (and proposed) site 3 looking upstream. Image taken 24 March 2025



Figure 37. Photograph of Carlisle River, Reach 3b, showing the single-tree line of eucalypt trees along both banks and occasional Blackwood (*Acacia melanoxylon*) riparian shrubs. Photograph taken by PI Boon, March 2025.

6.6.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235200 in Reach 3b. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 38). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 39). Please refer to Appendix B for a brief description of scenarios and flow duration curves.

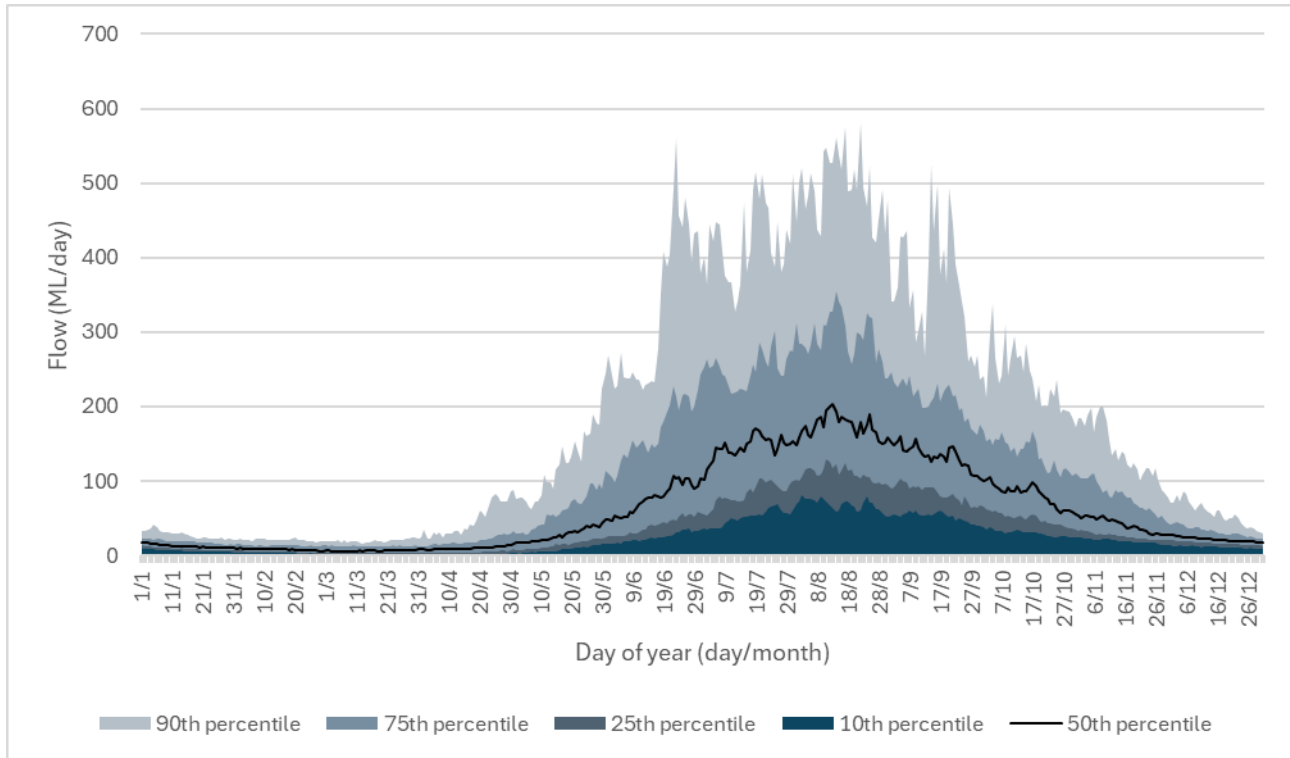


Figure 38. Day of year flow percentile plot for Reach 3b, modelled current level of development, historic climate.

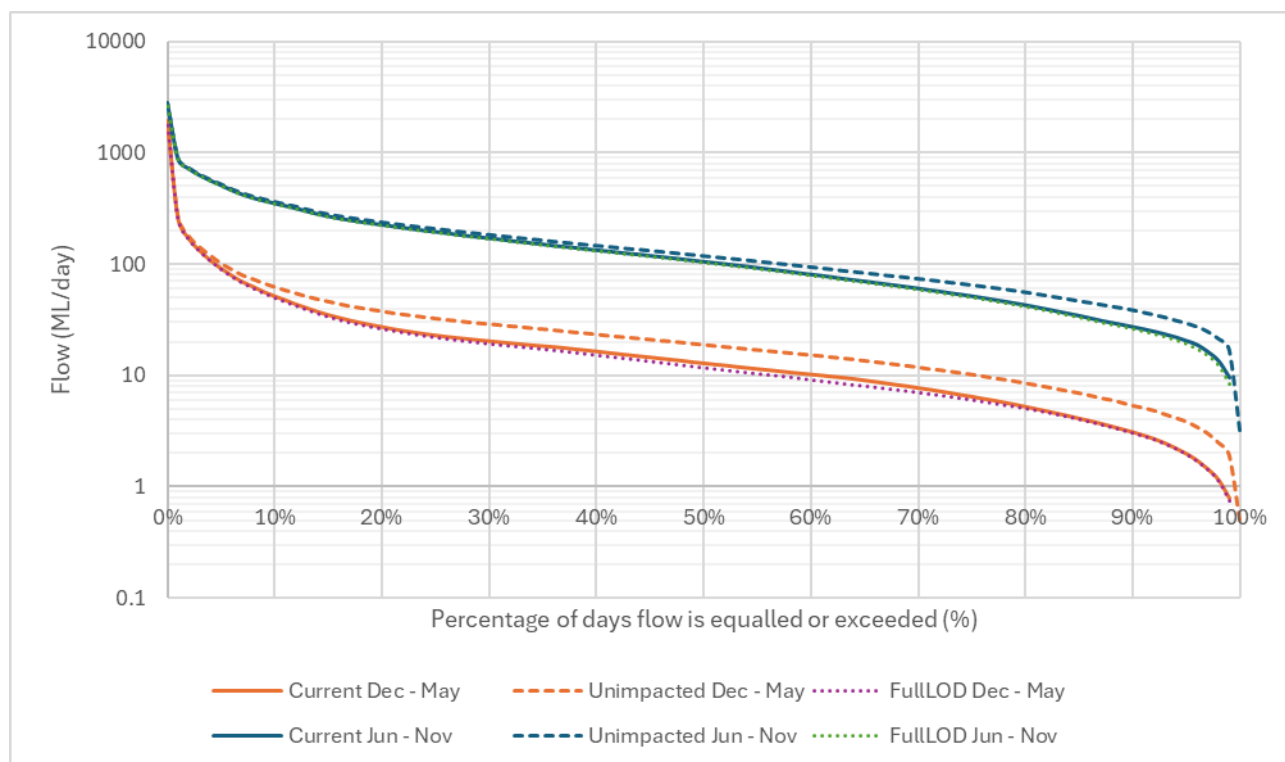


Figure 39. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 3b.

6.6.5 Notes on site selection for Reach 3b

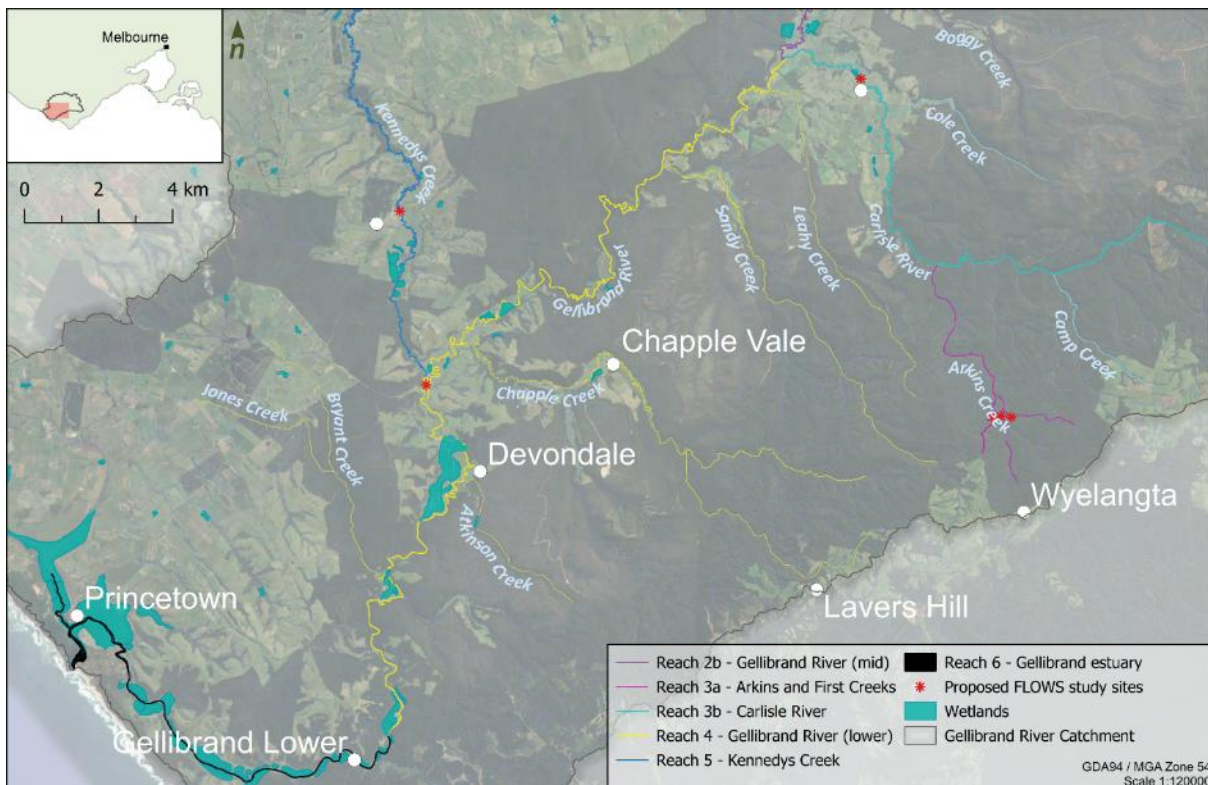
The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 3b – Carlisle River	
Reach Boundaries	Upstream tributaries (excluding Arkins and First creeks) to confluence with the Gellibrand River
Major tributaries	• Cole Creek • Camp Creek • Arkins Creek (Reach 3a)
Proposed site	Site 3b: <u>38°33'27.0"S 143°23'48.8"E</u> Physical conditions (streamside zone / riparian vegetation) at Site 3b have significantly changed, with the banks now supporting a single-line of healthy eucalypts and associated shrub-layer native vegetation, albeit with a ground-layer dominated by exotics such as blackberry.
Alternative sites	Nil Delaneys Track was closed to vehicle access, which prevented viewing of alternative Carlisle River sites within the Great Otways National Park.

Reach 3b - Carlisle River	
Nearest flow gauge	Gauge 235200C (Southern Rural Water) is located at Site 3b
Assessment and survey requirements	The existing model is usable in its current form, however due to the model's age, the survey having been relative to an arbitrary local datum, and uncertainty regarding the positioning of cross sections in the 'with levee' model, a new survey and hydraulic model are recommended.
Flow-dependent and instream values	• Native fish assemblage • Freshwater crayfish • Platypus • Instream vegetation, including diatoms • Algal biofilms on submerged surfaces • EVC Riparian Forst, EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex • <i>Mussels</i> • <i>Instream wood and flow diversity (fast and slow flowing habitat niches)</i>
Threats	• Exotic vegetation (blackberries) • Land use change (increased plantation operations) • Potential for nutrient enrichment • Livestock access to waterways • Dairy effluent • Farm Dams • Onsite wastewater management systems

Note, purple shaded values and threats were provided by the PAG

6.7 Reach 4 - Gellibrand River (lower)



6.7.1 Geomorphology

The EFTP visited three potential sites in the catchment, noting that the 2006 FLOWS study site was not representative of physical form across the reach (the site was considerably wider and better vegetated in 2025) (Figure 40). The EFTP propose the site be shifted to the vicinity of the Wannon Water South Otway pump station (Figure 41), which was representative of reach stream width and broader physical form. Consistent with the 2006 description, the site comprises an alluvial, unconfined, meandering, single channel continuous, stream system (Earth Tech 2006a). The site has in-channel depositional bars and benches, with benches comprised of silts and sands. The proposed site and much of the reach is subject to uncontrolled grazing, and the floodplain cleared of vegetation.

6.7.2 Vegetation communities

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 such as EVC 16 Lowland Forest, EVC 23 Herb-rich Foothill Forest and EVC 48 Heathy Woodland.

The representative site supports algal biofilms on submerged surfaces and instream vegetation, including diatoms.

6.7.3 Aquatic fauna

Like Reach 3b, the main fish species of significance present in are River blackfish and Australian grayling. There are other small-bodied fish present, both migratory and resident. Other fish species found in reach

4 include Short Finned Eel, Brown Trout, Short Headed Lamprey, Spotted galaxias and Common Galaxias. Freshwater crayfish and Platypus have been identified (Table 4, Earth Tech 2006b). There are no Waterbug Blitz sites in Reach 4, however macroinvertebrates are presumed present.

O'Connor et al. 2015 report recent declines in River blackfish recruits and juveniles in the main stem of the Gellibrand River (O'Connor et al., 2015). The Native Fish Report Card (NFRC) program has been surveying the Gellibrand River at six sites for fish, annually since 2017 (DEECA 2023, ARI 2025). No change in species richness has been observed in this program, although Flatheaded gudgeon has not yet been detected in NFRC surveys, despite reported presence in the Gellibrand River. The program has noted recent, consistent records of Australian grayling presence, and increased distribution (DEECA 2023, ARI 2025).



Figure 40. Reach 4, Gellibrand River 2006 FLOWS study site 4. Image taken 25 March 2025.



Figure 41. Proposed Reach 4 site (South Otway pump station) looking upstream. Image taken 25 March 2025.

6.7.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235258 in Reach 4. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 42). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 43). Please refer to Appendix B for a brief description of scenarios and flow duration curves.

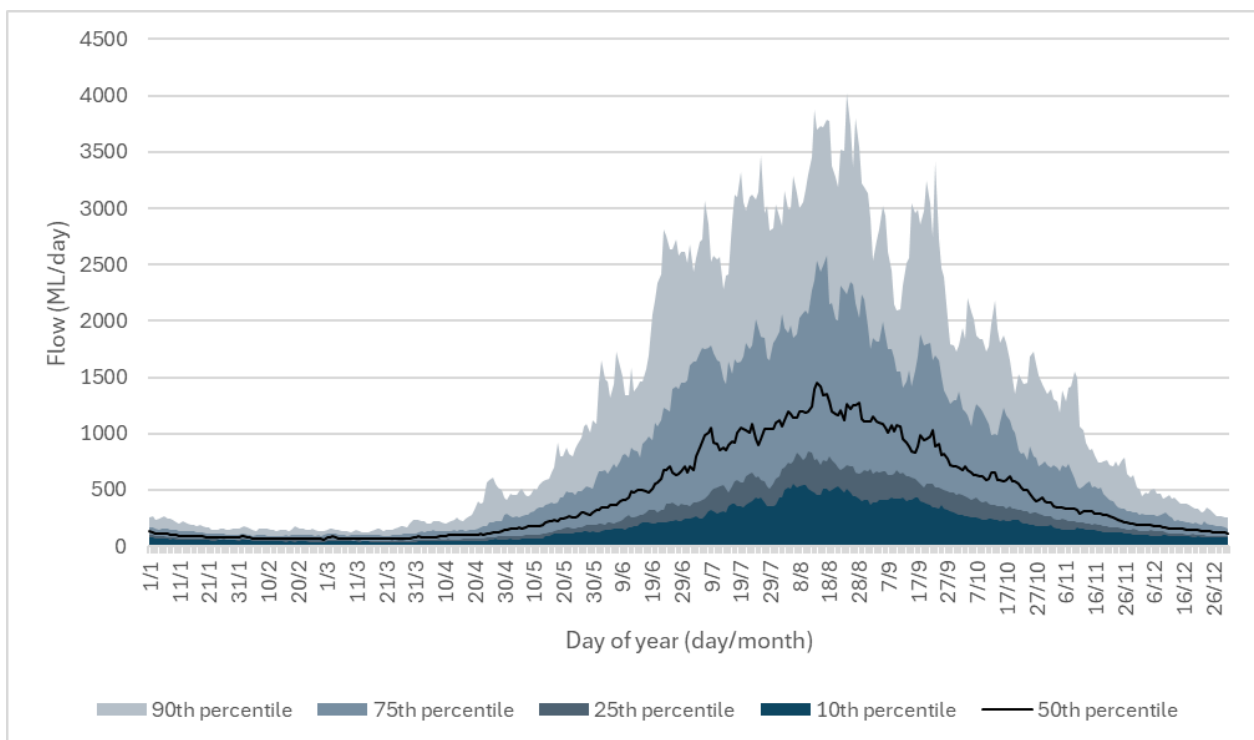


Figure 42. Day of year flow percentile plot for Reach 4, modelled current level of development, historic climate.

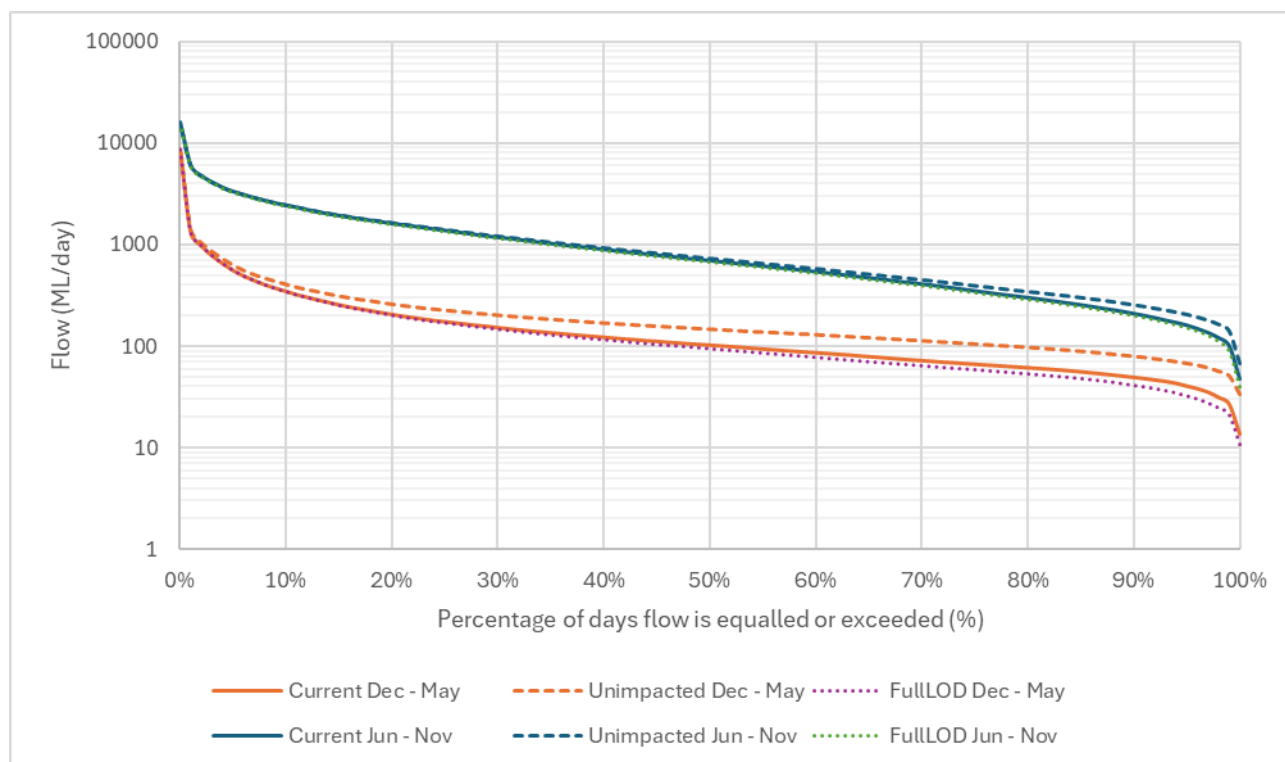


Figure 43. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 4

6.7.5 Notes on site selection for Reach 4

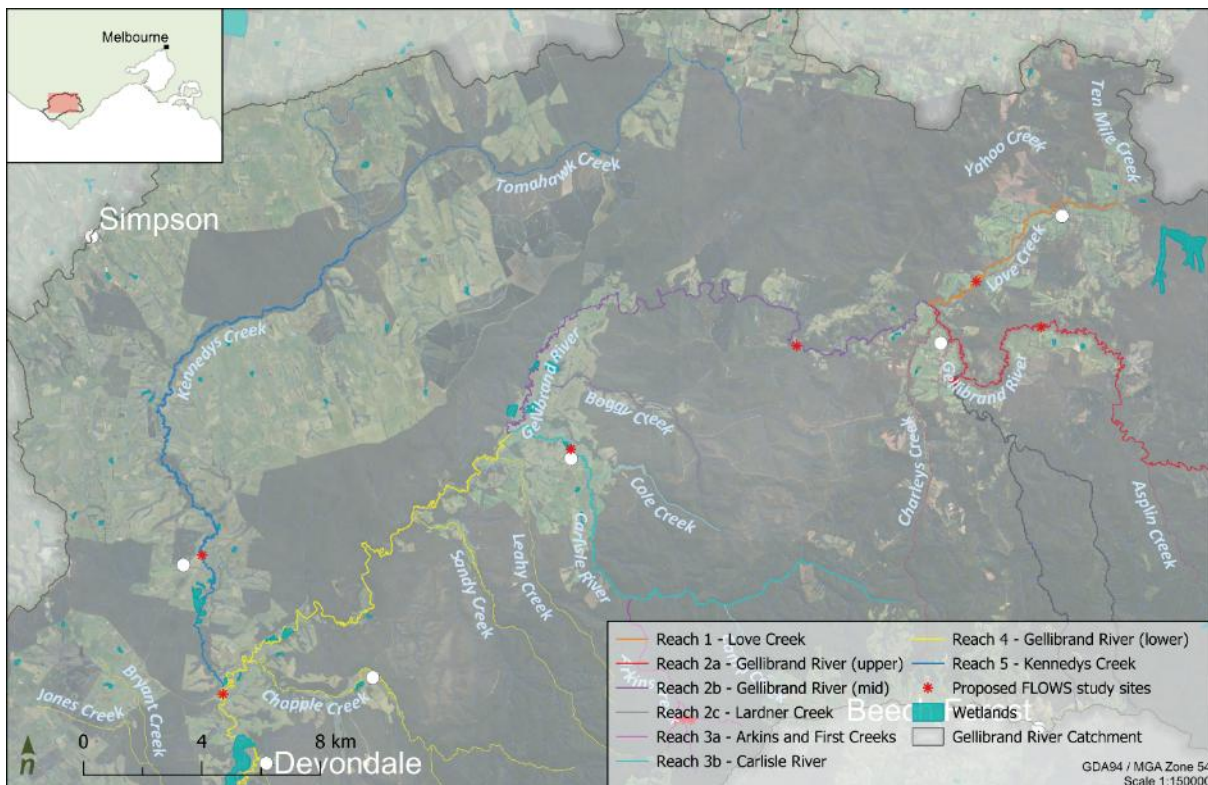
The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 4 - Gellibrand River	
Reach Boundaries	From confluence with Love Creek to confluence with Carlisle River
Major tributaries	• Leahy Creek • Sandy Creek • Chapple Creek • Jones Creek • Atkinson Creek
Proposed site	South Otway pump station, Deans Road <u>38°38'04.6"S 143°15'48.5"E</u>. Cattle grazing at South Otway pump site. Access to several meanders, upstream and downstream of pump station and up/downstream of Kennedys Creek confluence. Some physical features are present to aid the setting of flow recommendations. Wannon Water note that the site frequently floods.

Reach 4 - Gellibrand River	
Alternative sites	- King Track Bridge crossing: <u>38°36'33.7"S 143°17'55.6"E</u>. Forest cover upstream, agricultural activities downstream - Bone Track bridge crossing: <u>38°37'03.7"S 143°17'10.0"E</u>. Cattle grazing on both sides of the river 2006 FLOWS study Site 4: <u>38°38'52.7"S 143°16'07.4"E</u>. Cattle grazing on both sides of river. The channel width at Site 4 is different to other locations for Reach 4 and therefore not representative of the broader reach. The other three sites visited are consistent in their channel width and features.
Nearest flow gauge	Gauge 235258 is located at the pump station Note, gauge 235224 is located downstream at Burrupa
Assessment and survey requirements	A new site survey and hydraulic model are required.
Flow-dependent and instream values	- Diverse native fish assemblage - Spiny crayfish - Platypus - Algal biofilms on submerged surfaces - Instream vegetation, including diatoms - EVC 18 Riparian Forest <i>Instream wood and flow diversity (fast and slow flowing habitat niches)</i>
Threats	- Exotic vegetation (blackberries and pasture grasses) - Agricultural activity (cattle access to stream, and runoff) - Erosion - Regulated reach and subject to Bulk Entitlement (corresponding changes in hydrology) - Plantation forestry - Failing septic systems

Note, purple shaded values and threats were provided by the PAG

6.8 Reach 5 - Kennedys Creek



6.8.1 Geomorphology

Site 5 has not changed since 2006, and the site description in Earth Tech 2006a remains relevant. The representative site comprises an unconfined, alluvial, single channel, continuous stream, with a pool riffle stream bed profile (Earth Tech 2006a). The stream contains instream timber and the floodplain is cleared of vegetation and used for grazing operations (Figure 44).

6.8.2 Vegetation communities

Reach 5 waterways are located in EVC 18 Riparian Forest (Vulnerable in Warrnambool Plain bioregion), surrounded by terrestrial EVC 23 Herb-rich Foothill Forest. Instream vegetation, including *Vallisneria spp.*, was observed at Site 5, as well as fringing *Phragmites*, and algal biofilms on submerged surfaces.

6.8.3 Aquatic fauna

Data for fish species indicates that Kennedys Creek supports fewer native species than other reaches of the Gellibrand catchment (Table 4). There are no known fish barriers to prevent fish species from accessing the reach and preliminary site inspections to assess the habitat values of the reach suggest that there was suitable habitat to support a wide range of species similar to those recorded for reaches 2a, 2b, 2c, 3b and 4. There are no Waterbug Blitz survey sites in Kennedys Creek, however macroinvertebrates are presumed present.

Platypus and spiny crayfish have also been recorded in the reach and were not previously been considered in the 2006 FLOWS study.



Figure 44. Reach 5 existing (and proposed) site, looking downstream from Kennedys Creek Road bridge. Image taken 25 March 2025

6.8.4 Hydrology

Day of year flow percentile plots and flow duration curves were generated based on Source modelled flows at gauge 235211 in Reach 5. Day of year flow percentile plots are for modelled current level of development, historical climate (Figure 45). Flow duration curves are plotted for current, unimpacted and full levels of development, with a historical climate during summer / autumn (Dec – May) and winter / spring (June – November) (Figure 46). Please refer to Appendix B for a brief description of scenarios and flow duration curves.

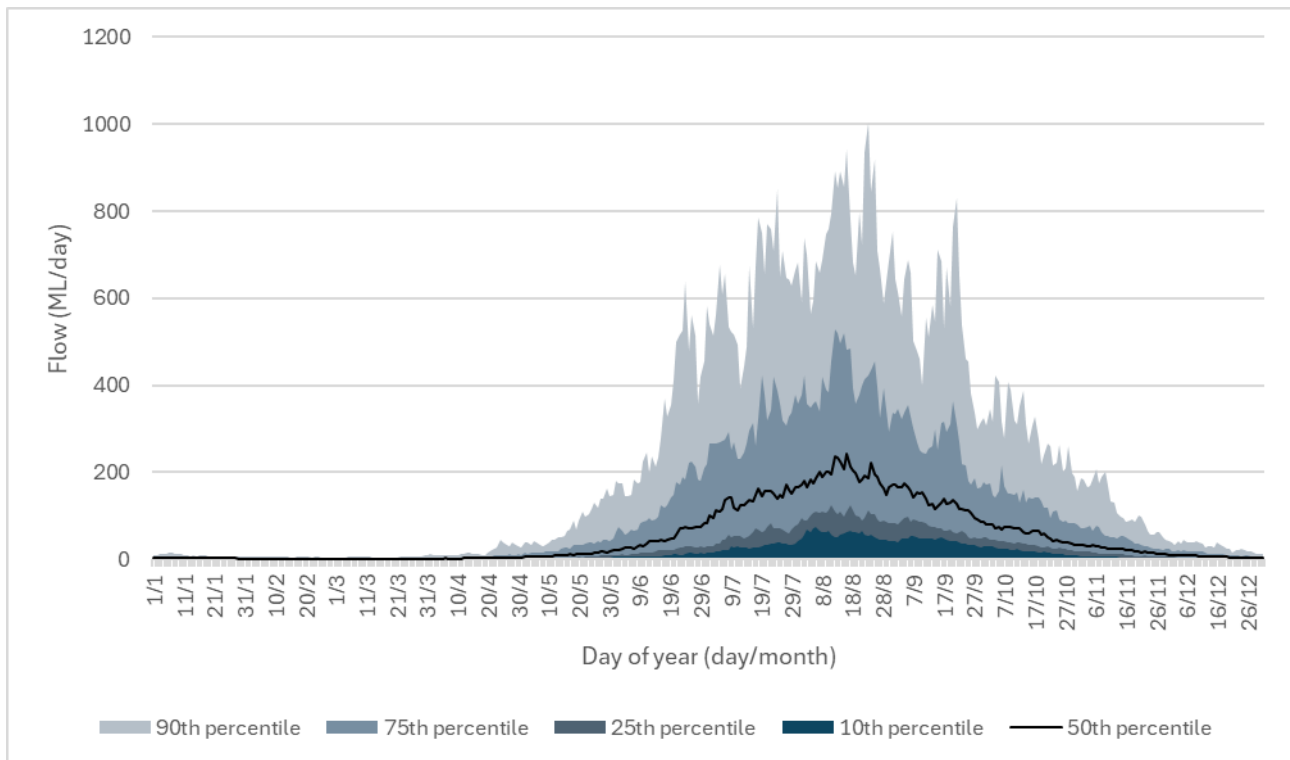


Figure 45. Day of year flow percentile plot for Reach 5, modelled current level of development, historic climate.

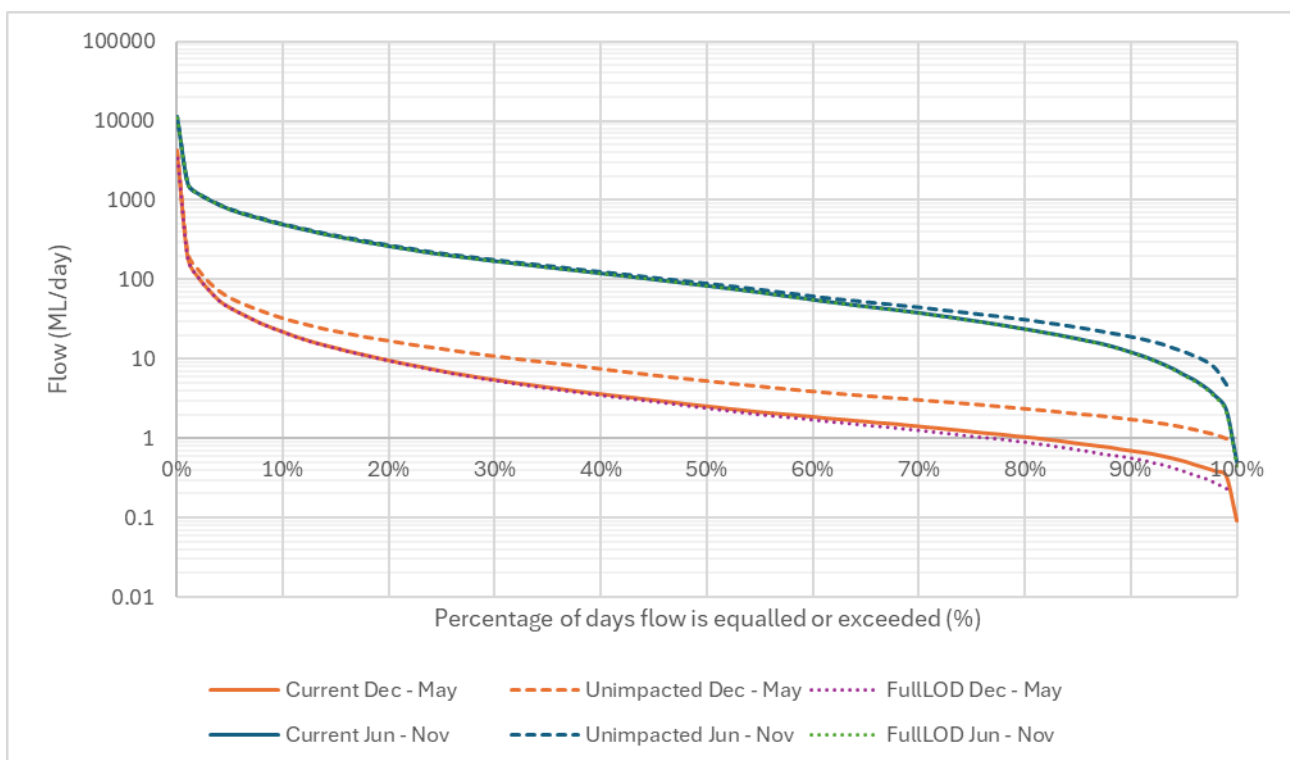


Figure 46. Flow duration curves for modelled current, unimpacted and full level of development scenarios, historic climate in Reach 5

6.8.5 Notes on site selection for Reach 5

The table below provides an overview of the reach and the proposed site for further investigation in the environmental flows study.

Reach 5 - Kennedys Creek	
Reach Boundaries	Upstream tributaries to the confluence of Kennedys Creek with the Gellibrand River
Major tributaries	• Tomahawk Creek • Muree Creek • Danger Creek
Proposed site	Original FLOWS study Site 5 location at the Kennedy's Creek Road bridge: <u>38°35'32.9"S 143°15'15.8"E</u>
Alternative sites	Nil. Conditions at Site 5 have not changed since the 2006 study
Nearest flow gauge	Gauge 235211
Assessment and survey requirements	The existing hydraulic model is of suitable length (180m), given the width of the channel, and is usable in its current state. Given the age of the model and the survey being relative to an arbitrary local datum it is strongly recommended that Site 5 be re-surveyed and a new hydraulic model developed.
Flow-dependent and instream values	• Diverse native fish assemblage • Platypus • Instream vegetation, including <i>Vallisneria spp</i>, • Fringing <i>Phragmites</i> • Algal biofilms on submerged surfaces • EVC 18 Riparian Forest • <i>Instream wood and flow diversity (fast and slow flowing habitat niches)</i>
Threats	• Exotic vegetation (willows, blackberries and pasture grasses) • Potential for salinity impacts • Land use change (expansion of, and new plantation operations) • <i>Effluent runoff from dairy farms</i>

Note, purple shaded values and threats were provided by the PAG

6.9 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, as receiving waters for Gellibrand freshwater flows, and for the ecosystems it supports.

6.9.1 Geomorphology

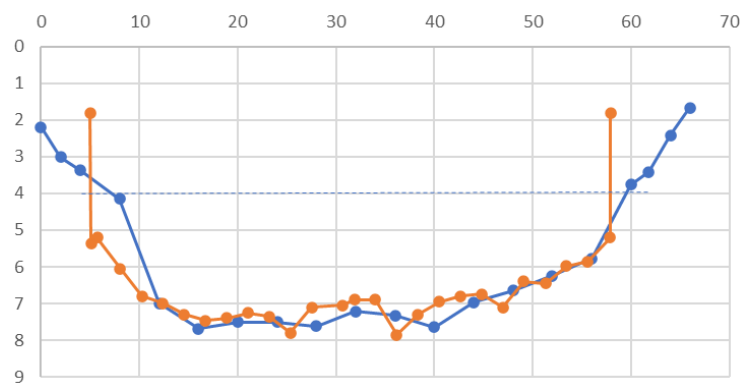
The Gellibrand estuary is a wave-dominated estuary. The estuary is intermittently open/closed to the sea, with opening and closing of the sand berm at the entrance controlled (under natural conditions) by coastal processes (waves, wind and tides) and freshwater inflows (Alluvium 2017).

As part of a preliminary visit in March 2025 estuarine geomorphology depth profiles were measured at four bridges that cross the estuary. The measured profiles were compared to those measured at the same sites in 1982 (Figure 47). 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.

(A) Bridge 1

This bridge is located 1.18km upstream of the estuary mouth and is a new structure replacing an older bridge in the same location.

There are some profile differences at the bank edges but these reflect changes to the abutments with the new bridge. Across most of the stream width there is little change in the depth profile.

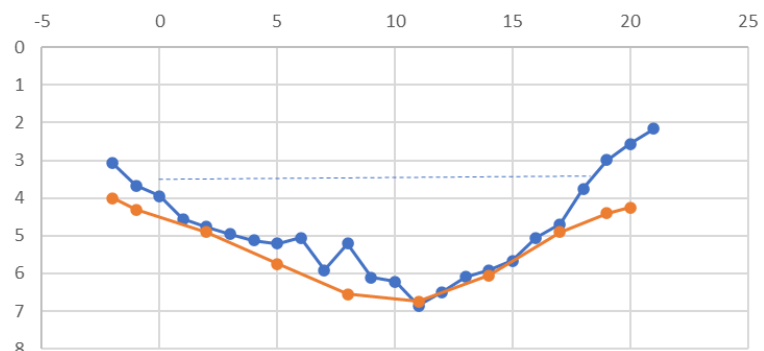


Comparison of 1982 (orange) and 2025 (blue) depth profiles. All measurements in metres. Dotted line shows the water level on 25 March 2025

(B) LaTrobe Creek Bridge

This bridge is on the Great Ocean Road where it crosses a tributary of the Gellibrand estuary. LaTrobe Creek enters the estuary just upstream of Bridge 1. The LaTrobe bridge is 1.71km upstream of the estuary mouth. The present bridge has replaced a bridge in the same location surveyed in 1982.

The two profiles are similar with differences at each bank probably linked to the structural differences between the old and new bridges.

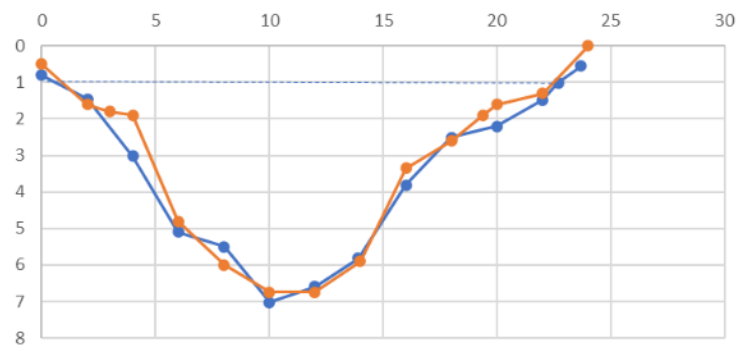


Comparison of 1982 (orange) and 2025 (blue) depth profiles. All measurements in metres. Dotted line shows the water level on 25 March 2025

(C) Bridge 2

This bridge is located in the more channelised upstream section of the estuary. It is 5.66km above the mouth. In 2025 it appeared little changed from the bridge surveyed in 1982.

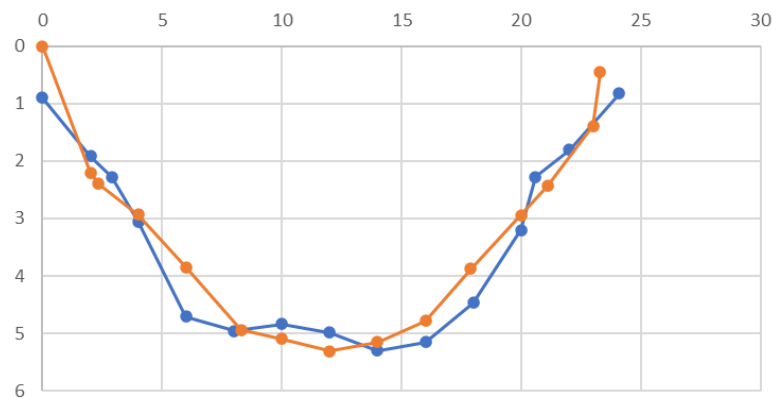
The 1982 and 2025 profiles are very similar.



Comparison of 1982(orange) and 2025 (blue) depth profiles. All measurements in metres. Dotted line shows the water level on 25 March 2025.

(D) Bridge 3

This bridge appeared to be little changed since the 1982 survey. It was the most upstream bridge sampled (8.79km from the mouth) and was also in the more channelised section of the estuary.



Comparison of 1982 (orange) and 2025 (blue) depth profiles. All measurements in metres.

Figure 47. Estuarine geomorphology depth profiles at four bridges

6.9.2 Vegetation communities

The Gellibrand estuary is one of 25 estuaries in western and central Victoria containing 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. Submerged vegetation (i.e. seagrasses) and extensive and floristically diverse non-woody, emergent, saline and semi-saline vegetation occurs on the floodplain of the lower estuary. Available evidence indicates that the most abundant emergent vegetation on the floodplain of the lower estuary is a mosaic of EVC 10 Estuarine Wetland and EVC 952 Estuarine Reedbed (Figure 48).



Figure 48. Vegetation of the floodplain of the lower Gellibrand estuary. Photograph taken by PI Boon March 2025.

6.9.3 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 (Table 4). 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, Mulloway.

Platypus have also been identified as being present in the estuarine reach of the Gellibrand River and are known 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.

6.9.4 Notes on Reach 6

Reach 6 - Gellibrand Estuary	
Reach Boundaries	Great Ocean Road Bridge to estuary mouth
Major tributaries	Latrobe Creek
Proposed site	N/A
Alternative sites	N/A
Nearest flow gauge	Gauge 235224 (at Burrupa, noting gauge is affected by estuary backups)
Assessment and survey requirements	N/A. New flow recommendations will not be developed for the estuary. EEFAM recommendations (Lloyd et al 2008) to be carried into the recommendations report.
Flow-dependent values	- Wetlands of national importance - Submerged seagrass bed - Extensive and floristically diverse non-woody, emergent, saline and semi-saline vegetation (floodplain of the lower estuary) - mosaic of EVC 10 Estuarine Wetland and EVC 952 Estuarine Reedbed - Diverse native fish assemblage - Platypus (likely foraging habitat) - Waterbirds (not typically considered in a FLOWS study)
Threats	- Artificial estuary openings - Upstream catchment impacts (receiving waters), including extractions under Bulk Entitlements - Grazing <i>Coastal acid sulfate soils</i> <i>Development on the floodplain impacting water quality and increasing pressure on artificial estuary openings</i> <i>Increased salinity - indicated by more salt tolerant species of vegetation</i> <i>Infrastructure associated with potential new resorts (raised roads acting as levee affecting flood flows, new bridge)</i> <i>Poor oxygen levels in the water (exacerbated when estuary is closed)</i>

7 Assumptions and limitations of applying the FLOWS method in the Gellibrand system

7.1 Limited instream physical features

The FLOWS method is 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 etc) that are targeted (inundated) to different extents by different flow components. Waterways in the Gellibrand system typically have trapezoidal cross sections with few, if any, physical features. This poses a significant 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 may need to 'lean' more heavily upon modelled hydrologic data to support the setting of 'reasonable' flow component magnitudes, in the absence of in-channel hydraulic features.

7.2 Physical form of Reach 3a is not conducive to hydraulic modelling

Arkins Creek (West and East) and First Creek are not amenable to the development of hydraulic models due to their steep, narrow and confined physical form. The EFTP will apply a hydrologic approach to the setting of low flow recommendations for these creeks, using the Source modelled flows. A single 'lumped' inflow to the diversion weirs was determined in the model (HARC 2025a) and we have estimated the inflows to each weir (First Creek, Arkins Creek West and Arkins Creek East) based on the proportion of catchment area.

7.3 Minimum flow recommendations

The FLOWS method is an eco-hydraulic 'building block' approach to the determination of environmental flows, based on the identification of the minimum flow rate required for identified flow components (summer base flows, summer freshes, winter base flows, winter freshes etc) to support environmental values. In rivers that had previously seen minimal and invariable flows through regulation, the method supports the delivery of greater flows with greater variability to support environmental values and improve river condition. Recommendations inform management decisions, may protect flows from future harvesting and help inform licencing of water take. For example, although some flow components such as overbank flows cannot be 'delivered' (due to operational 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 recommendations provided by an environmental flow study in Victoria are not legally binding or otherwise enforceable.

A potential unintended consequence of the application of the FLOWS method is that the resultant environmental flow recommendations could be less than the hydrologic regime operating within the waterway. While intended to support the return of water to a stream system, the application of the method could provide the opportunity to increase the harvesting of water from a system, and in particular waterways with a largely intact hydrologic regime. Reach 2c (Lardner Creek), despite being subject to a

Bulk Entitlement, has a relatively intact flow regime. The close to natural flows are anticipated to support diverse habitats in Reach 2c, and support natural flow seasonality in the Gellibrand River. The EFTP anticipate a need to employ additional precautionary measures to the setting of Reach 2c flow recommendations, to avoid setting an environmental flow 'floor'. Such precautionary measures could include stipulating a maximum allowable degree of alteration from mean annual natural flows, and requirements related to sediment transport dynamics.

7.4 Source of flows

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 agnostic to the 'source' of flows, which could come from rainfall/runoff processes, Bulk Entitlements, Environmental Entitlements, temporary trades, groundwater inflows or other sources. Likewise, the method is also agnostic to downstream losses.

The Project Advisory Group have strong interests in the impacts of groundwater extraction on flows. As noted in Section 4.4.1, groundwater inputs have been 'built into' the hydrologic model to help determine the modelled unimpacted flows (i.e. what the flows are likely to have been had the catchment not been developed and without all extractions).

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Appendix A Bulk Entitlements

A.1 Bulk Entitlement (Gellibrand) Conversion Order 1997.

Under Sections 43 and 47 of the *Water Act 1989*, the Gellibrand Bulk Entitlement was issued to Barwon Water, authorising the Authority to take the share of flow up to 60 ML from Lardner Creek (At the Lardner Creek pump station) in any year. This water is used for the Gellibrand Water supply system.

Passing flow rules are as follows:

When $F \leq 0.43$ ML/day, $E = F$

When $F > 0.43$ ML/day, $E = 0.43$ ML/day.

Where E = Barwon Waters entitlement, F = the flow past the Lardner Creek pump station):

i.e. When flows are at or below 0.43 ML/day, Barwon Water is authorised to take all the flow in the river. When flows are above 0.43 ML/day, Barwon Water can take a maximum of 0.43 ML/day.

Environmental obligations include management of impacts on the bed and banks, operational practices to remove silt from works, and operational practices to manage water quality in works on the waterway.

This bulk entitlement was issued before the publication of the first FLOWS method.

A.2 Bulk Entitlement (Otway System) Conversion Order 1998

Under Sections 43 and 47 of the *Water Act 1989*, the Bulk Entitlement authorises the South West Region Water Authority (Wannon Water) to take up to 12,580 ML at the system diversion points in any year, subject to flow sharing arrangements.

System diversion points include:

System diversion weirs: (1) Arkins Creek West (2) Arkins Creek East and (3) First Creek.

System pump stations: (1) North Otway pump station location on the Gellibrand River (FLOWS study Reach 4), and (2) South Otway pump station located on the Gellibrand River (FLOWS Study Reach 4).

The Authority may take up to a combined total of 22.5 ML/day from the waterways at the system diversion weirs and the North Otway pump station.

At the North Otway system:

When $F_N \geq 54.9$ ML/day, $E_N = 22.5$ ML/day

When $54.9 \geq F_N > 44.9$ ML/day, $E_N = 20.0$ ML/day

When $44.9 \geq F_N > 22.5$ ML/day, $E_N = 17.5$ ML/day

When $22.5 \geq F_N > 12.0$ ML/day, $E_N = 12.0$ ML/day

When $F_N \leq 12.0$ ML/day, $E_N = F_N$

Where E_N means the Authority's entitlement at the North Otway pump station, and F_N = North Otway System inflow.

At the South Otway system:

When $F_s \geq 41.2$ ML/day, $E_s = 21.5$ ML/day

When $41.2 \geq F_s > 32.7$ ML/day, $E_s = 19.0$ ML/day

When $32.7 \geq F_s > 22.0$ ML/day, $E_s = 17.0$ ML/day

When $22.0 \geq F_s > 12.0$ ML/day, $E_s = 12.0$ ML/day

When $F_s \leq 12.0$ ML/day, $E_s = F_s$

Where E_s means the Authority's entitlement at the South Otway pump station, and F_s = South Otway System inflow less any water not taken at the North Otway pump station to which the Authority is entitled.

This means that when flows are at or below 12 ML/day at either pump station, Wannon Water is entitled to take all flow from the river.

It is also noted that there are no passing flow rules at Arkins Creek East weir, Arkins Creek West weir and First Creek weir. The creeks cease to flow below the weirs if the weirs are not being overtopped by inflows.

Environmental obligations include management of impacts on the bed and banks, operational practices to remove silt from works, and operational practices to manage water quality in works on the waterway.

This Bulk Entitlement was issued before publication of the FLOWS method.

A.3 Bulk Entitlement (Colac) Amendment Order 2003

Under Sections 43 and 47 of the *Water Act 1989*, the Bulk Entitlement authorises Barwon Water to take up to 5400 ML from the system, in any given year, at a rate not exceeding:

5.0 ML/day from Olangolah weir

17.0 ML/day from the West Gellibrand Dam.

The share of flow is as follows:

At point A (immediately upstream of the weir pool on Olangolah Creek):

When $F \leq 1.0$ ML/day, $E = 0$ ML/day

When $F > 1.0$ ML/day, $E = F - 1.0$ ML/day

Where E means the Authority's entitlement, and F means flow past point A.

This is, in effect, as passing flow of 1 ML/day at the weir.

At point B (immediately upstream of the storage on the Gellibrand River west branch):

When $F \leq 5$ ML/day, $E = 0$ ML/day

When $F > 5$ ML/day, $E = F - 5.0$ ML/day

Where E means the Authority's entitlement, and F means flow past point A.

This is, in effect, a 5 ML/day passing flow in the west branch of the Gellibrand River.

It is noted that this Bulk Entitlement was issued after 2002 publication of the FLOWS method, but before the 2006 Gellibrand FLOWS study

A.4 Permissible Consumptive Volume Groundwater Order 2024

Under Section 22A of the *Water Act 1989* and under Section 27 of the *Interpretation of Legislation Act 1984*, the order lists permissible consumptive volumes for the Gellibrand Groundwater Management Area, the Newlingrook Groundwater Management Area and the Paaratte Groundwater Management Area.

Gellibrand Groundwater Management Area

The permitted consumptive volume for the Gellibrand Groundwater Management Area is 0 ML (all formations below the surface).

Newlingrook Groundwater Management Area

The permitted consumptive volume for the Newlingrook Groundwater Management Area is 1977 ML per year (all formations below the surface).

Paaratte Groundwater Management Area

The permitted consumptive volume for the Paaratte Groundwater Management Area is 4606 ML.

A.5 Groundwater Licence No. 9016487 (Wannon Water)

Groundwater Licence No. 9016487 authorises Wannon Water to take and use 1800 ML of water per year from Bore Numbers 142992 and 142993 for Urban purposes. This includes a maximum extraction rate of 6 ML / day.

A.6 Take and use licences in the Gellibrand System (Otway Coast Basin Local Management Plan, SRW 2014)

Southern Rural Water manages take and use licences within the Gellibrand system, in accordance with the Otway Coast Basin Local Management Plan, 2014 (SRW 2014, see attachment 2). For the management of direct pumping licenses, the Gellibrand River is divided into three zones: (1) Below North Otway Pump Station (2) Upstream of North Otway Pump Station (excluding Carlisle River) (3) Carlisle River. Each zone has its own five-stage roster and restrictions during periods of low flow (daily and 7-day rolling average).

Take and use licences in the Gellibrand System

Licence Type	Number of Licences	Volume (ML)
Irrigation - Direct pumping	32	1736.6
Irrigation - Winterfill	11	439.6
Registration	99	2354.7
Domestic and stock	29	66.8
Commercial / industrial	2	5.7
Dairy	36	169.3
Total	209	4772.7

Stage roster for each zone of the Gellibrand System (from SRW 2014).

Zone 1 (Below North Otway Pump Station)

Trigger level		Passing flow	Stage	Restriction
Daily (ML/day)	7-day average (ML/day)	Daily (ML/day)		
17.5	22.5	15	1	40mm/Ha/wk - 1/7 th per day
12.5	17.5	12.5	2	2 out of 3 days
10	15	10	3	Every second day
7.5	12.5	7.5	4	Every third day
5	10	5	5	Ban
Winterfill		350	5	Ban

Zone 2 (upstream of North Otway Pump Station, excluding Carlisle River)

Trigger level		Passing flow	Stage	Restriction
Daily (ML/day)	7-day average (ML/day)	Daily (ML/day)		
22.5	27.5	20	1	40mm/Ha/wk - 1/7 th per day
17.5	22.5	17.5	2	2 out of 3 days
15	20	15	3	Every second day
12.5	17.5	12.5	4	Every third day
5	15	5	5	Ban
Winterfill		350	5	Ban

Zone 3 (Carlisle River)

Trigger level		Passing flow	Stage	Restriction
Daily (ML/day)	7-day average (ML/day)	Daily (ML/day)		
6.6	8.1	5.6	1	40mm/Ha/wk - 1/7 th per day
5.6	6.6	5.6	2	2 out of 3 days
5.6	6.6	5.6	3	Every second day
5.6	6.6	5.6	4	Every third day
5.6	6.1	5.6	5	Ban
Winterfill		80	5	Ban



Appendix B Hydrology

B.1 Reach hydrology

Day of year flow percentile plots, and flow duration curves were generated, based on Source modelled flows at different gauge locations in the Gellibrand catchment (model outputs were provided to the Alluvium team by HARC). See appendices A.2 – A11. Data has been plotted for the following HARC development scenarios:

Scenario 1 – Modelled flows with a current level of development, in a historical climate

Scenario 2 – Modelled unimpacted flows (i.e. what the flows are likely to have been had the catchment not been developed and without all extractions) in a historical climate

Scenario 4 – Modelled flows with a full level of rural and urban development, in a historical climate (Full LOD)

Please refer to HARC 2025a for a full report on the harmonised Gellibrand catchment Source model.

B.1.1 Day of year plots

Day of year flow percentile plots provide an indication of the seasonality and variability of flows across the year, and aid in identifying 'seasons' (i.e. summer / autumn, and winter / spring) for the development of flow recommendations.

B.1.2 Flow duration curves and interpreting exceedance percentiles

Flow durations curves provide an indication of variability across the entire flow range within a given time period. The X^{th} exceedance percentile flow rate is defined as the flow rate that is equalled or exceeded on X percent of days. A given flow rate can be reframed as an exceedance percentile, to understand the percentage of days that the flow rate is equalled or exceeded.

The FLOWS method for determining environmental flows is a 'bottom-up', building-block type of approach. 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 check", whereby they are compared with natural hydrographs and flow-duration curves. 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: one is that low-flow recommendations are commonly of the order of the 80th exceedance percentile flow (that is, the flow rate that is exceeded on 80 percent of days in the period), and freshes are commonly of the order of the 20th percentile flow (that is, the flow rate that is exceeded on 20% of days in the period). Bankfull and overbank flows are rarer events and have low exceedance percentiles. Specific recommendations derived from application of the FLOWS approach that deviate greatly from these heuristics are often re-examined to determine why they differ from these common rules of thumb.

B.1.3 Inflow to Arkins Creek West Branch, Arkins Creek East Branch and First Creek diversion weirs

Total inflow to the diversion weirs (Arkins Creek West and East Branches, and First Creek) was calculated by HARC as follows:

Equation 1

Inflow to First Creek, Arkins Creek West and East Branch = 1.75 x Gauged flow at 235205

The estimated split for catchment inflow to the Arkins Creek West weir, Arkins Creek East weir and First Creek weirs, based on the proportion of catchment area estimated by spatial analysis, HARC, 2025a) is provided in Table 5.

Table 5. Split of catchment inflow across the Arkins Creek (west and east) and First Creek

Weir	Percentage of total inflow
Arkins Creek West Branch	57%
Arkins Creek East Branch	38%
First Creek	5%

