

Recommendations Report

Gellibrand River FLOWS study

Prepared for
Barwon Water
November 2026

alluvium consulting



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

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

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

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

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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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Foreword from Eastern Maar Aboriginal Corporation

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

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

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

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

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

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

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

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

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

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

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

Executive Summary

In December 2024, Alluvium Consulting Australia was engaged by Barwon Water and partner agencies DEECA, Wannon Water, Corangamite Catchment Management Authority and Eastern Maar Aboriginal Corporation, to update the environmental flow recommendations for the Gellibrand River and its major tributaries. This Recommendations Report is the third and final report of the Gellibrand River FLOWS study. It sets out new environmental flow recommendations, developed using the Victorian FLOWS method (Ed. 2), for eight freshwater reaches of the Gellibrand catchment, along with revised low flow objectives (but not a revised flow magnitude) for the Gellibrand estuary.

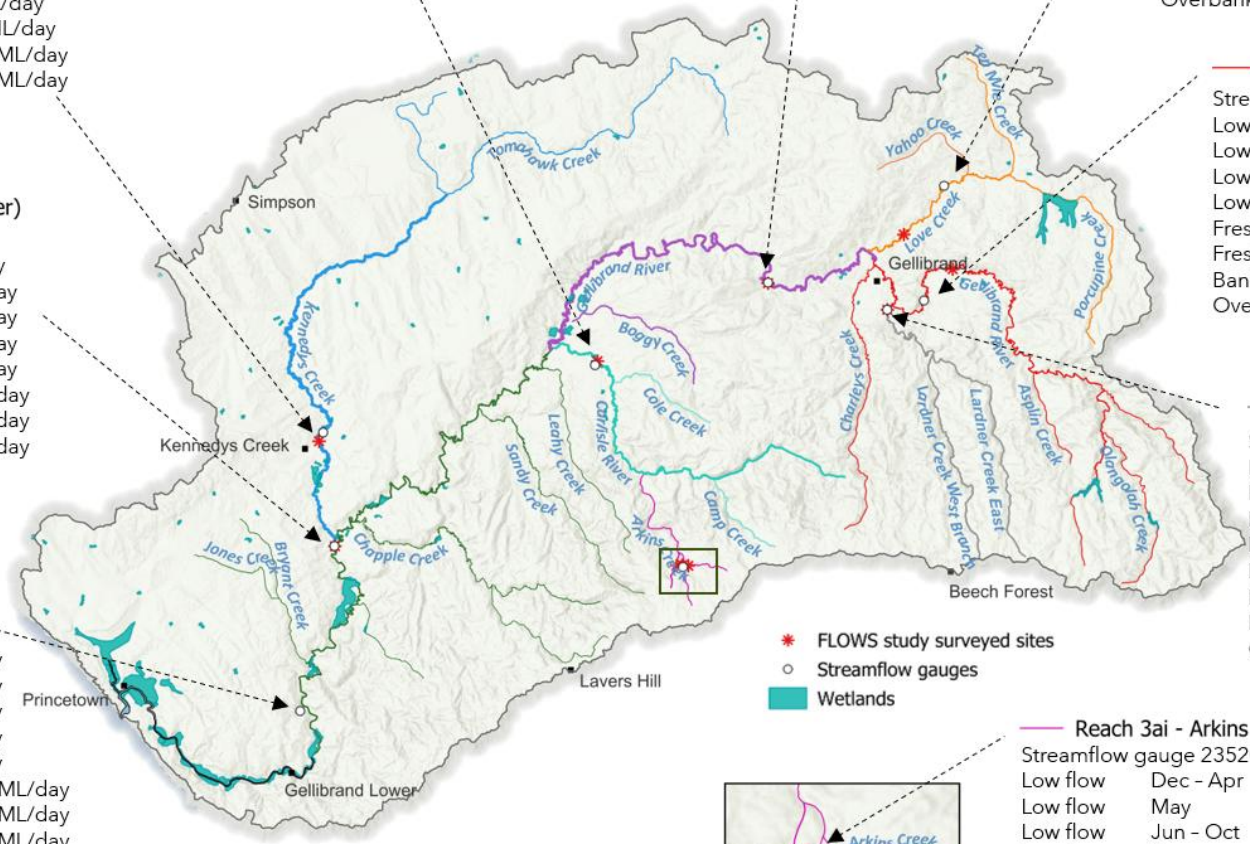
The recommendations update those set for the Gellibrand River, Love Creek, Kennedys Creek and Carlisle River in 2006 (Earth Tech 2006a-c), reflecting changes to the FLOWS method, an improved understanding of catchment values and threats, and greater inclusion of Traditional Owner knowledge and climate change considerations. Two new reaches – Lardner Creek and Arkins/First Creeks – have been added to this study. Flow recommendations for low flows, freshes, bankfull and (where applicable) overbank flows have been developed for the study reaches, informed by hydraulic modelling, a new Source hydrologic model, site assessments, literature review and extensive engagement with the agencies on the Project Steering Committee (PSC), as well as additional engagement with Eastern Maar Aboriginal Corporation and the Project Advisory Group (PAG). The study carries forward Gellibrand estuary flow recommendations set using the estuary environmental flows assessment method in 2008 (Lloyd et al. 2008).

Qualitative assessments of aquatic fauna, vegetation, geomorphology and hydrology values by the Environmental Flows Technical Panel (EFTP) suggest that reach condition across the catchment is variable. Lardner Creek (Reach 2c) retains a near-natural flow regime and has the best hydrologic condition of all freshwater reaches in this study, warranting a precautionary management approach to sustain the ecological values and hydrologic condition of this reach. The Gellibrand estuary is considered to be in good–moderate overall condition, reflecting its national ecological significance. By contrast, Love Creek (Reach 1), Gellibrand River (Reaches 2a, 2b and 4), Kennedys Creek (Reach 5) and Carlisle River (Reach 3b) show the substantial hydrologic impacts from water system development, particularly on the magnitudes of summer–autumn low flows.

The new flow recommendations are reasonable under a modelled unimpacted level of water system development (i.e. modelled natural flows) using a post 1975 climate. However, in a developed system (i.e. a modelled current and full uptake scenario) under post 1975 climate conditions, performance assessments indicate that in most reaches the recommendations are poorly achieved. The impacts of development on flow recommendation achievement are most obvious on low flows and freshes in December – April. When assessed against the impacts of modelled future climate change, achievement of the flow recommendations worsens, in all reaches and more broadly across all flow components.

The Gellibrand catchment experiences several threats to aquatic values that originate from land use, rather than flow, including high turbidity, direct stock access, and weed infestation. The report identifies complementary, non-flow management actions including stock exclusion and fencing, weed control, riparian revegetation, and supporting fish passage. Without these, improving flows may not lead to meaningful improvements to the ecological condition of the river.

Summary of flow recommendations



Reach 5 - Kennedys Creek

Streamflow gauge 235211

Low flow	Dec - Apr	3 ML/day
Low flow	May	9 ML/day
Low flow	Jun - Oct	40 ML/day
Low flow	Nov	17 ML/day
Fresh	Dec - Apr	30 ML/day
Fresh	May - Nov	150 ML/day
Bankfull	Jun - May	1650 ML/day
Overbank	Jun - May	2000 ML/day

Reach 4 - Gellibrand River (lower)

Streamflow gauge 235258

Low flow	Dec - Apr	90 ML/day
Low flow	May	130 ML/day
Low flow	Jun - Oct	300 ML/day
Low flow	Nov	205 ML/day
Fresh	Dec - Apr	260 ML/day
Fresh	May - Nov	1800 ML/day
Bankfull	Jun - May	3700 ML/day
Overbank	Jun - May	4700 ML/day

Reach 6 - Gellibrand estuary

Streamflow gauge 235224

Low flow	Sum - Aut	100 ML/day
Fresh	Sum - Aut	240 ML/day
Fresh	Mar - May	600 ML/day
Fresh	Win - Spr	300 ML/day
Fresh	May - Jul	900 ML/day
Fresh	Win - Spr	1500 / 500 ML/day
Fresh	Win - Spr	1800 / 200 ML/day
Fresh	Anytime	3900 / 200 ML/day
Overbank	Anytime	7000 ML/day

Reach 3b - Carlisle River

Streamflow gauge 235200C

Low flow	Dec - Apr	8 ML/day
Low flow	May	16 ML/day
Low flow	Jun - Oct	60 ML/day
Low flow	Nov	33 ML/day
Fresh	Dec - Apr	30-60 ML/day
Fresh	May - Nov	300 ML/day
Bankfull	Jun - May	1150 ML/day
Overbank	Jun - May	1300 ML/day

Reach 2b - Gellibrand River (mid)

Streamflow gauge 235227

Low flow	Dec - Apr	40 ML/day
Low flow	May	55 ML/day
Low flow	Jun - Oct	160 ML/day
Low flow	Nov	100 ML/day
Fresh	Dec - Apr	110 ML/day
Fresh	May - Nov	450 ML/day
Bankfull	Jun - May	900 ML/day
Overbank	Jun - May	1200 ML/day

Reach 1 - Love Creek

Streamflow gauge 235234

Low flow	Dec - Apr	3 ML/day
Low flow	May	3 ML/day
Low flow	Jun - Oct	10 ML/day
Low flow	Nov	7 ML/day
Fresh	Dec - Apr	8-10 ML/day
Fresh	May - Nov	60 ML/day
Bankfull	Jun - May	400-450 ML/day
Overbank	Jun - May	Not Set

Reach 2a - Gellibrand River (upper)

Streamflow gauge 235231

Low flow	Dec - Apr	20 ML/day
Low flow	May	26 ML/day
Low flow	Jun - Oct	60 ML/day
Low flow	Nov	45 ML/day
Fresh	Dec - Apr	60 ML/day
Fresh	May - Nov	220-250 ML/day
Bankfull	Jun - May	1000 ML/day
Overbank	Jun - May	1530 ML/day

Reach 2c - Lardner Creek

Streamflow gauge 235210

Low flow	Dec - Apr	10 ML/day
Low flow	May	17 ML/day
Low flow	Jun - Oct	50 ML/day
Low flow	Nov	31 ML/day
Fresh	Dec - Apr	30-50 ML/day
Fresh	May - Nov	180 ML/day
Bankfull	Jun - May	680 ML/day
Overbank	Jun - May	1200 ML/day

Reach 3aiii - First Creek

No streamflow gauge

Low flow	Dec - Apr	0.15 ML/day
Low flow	May	0.25 ML/day
Low flow	Jun - Oct	0.8 ML/day
Low flow	Nov	0.5 ML/day

Reach 3ai - Arkins Creek West Branch

Streamflow gauge 235205

Low flow	Dec - Apr	1.6 ML/day
Low flow	May	2.8 ML/day
Low flow	Jun - Oct	9 ML/day
Low flow	Nov	5.4 ML/day

Reach 3aii - Arkins Creek East Branch

No streamflow gauge

Low flow	Dec - Apr	1.1 ML/day
Low flow	May	1.9 ML/day
Low flow	Jun - Oct	6 ML/day
Low flow	Nov	3.6 ML/day

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1 Introduction

In December 2024, Alluvium Consulting Australia (Alluvium) was engaged by Barwon Water and partner agencies DEECA, Wannon Water, Corangamite Catchment Management Authority and Eastern Maar Aboriginal Corporation to update the environmental flow recommendations for freshwater reaches of the Gellibrand River and its major tributaries. The project was driven by concerns regarding the health and ongoing protection of the Gellibrand River system and the adequacy of the existing flow recommendations, given the age of the original FLOWS study (Earth Tech 2006a-c) and advances in understanding and management practices. Several factors have also changed since the 2006 study, which could also conceivably affect the determination of flow recommendations:

1. Changes in Victorian and regional water strategy and policy. This includes:
    a. Development of *Water is Life: Traditional Owner Access to Water Roadmap* (DELWP 2022a), and a partnership approach between DEECA and Traditional Owners for water management.
    b. An action led by Wannon Water to improve summer flows in the Gellibrand River (Western Region Sustainable Water Strategy 2011 and Central and Gippsland Region Sustainable Water Strategy, DELWP 2022b).
    c. Consideration and understanding of climate change and its impacts.
2. Improved understanding of the Gellibrand catchment and its values and threatening processes.
3. Changes to the FLOWS method itself, including seasonal adaptiveness of recommendations, and consideration of climate change.

The overarching objectives of the Gellibrand River FLOWS study are to:

- Use a transparent, science-based approach (FLOWS method Ed. 2, DEPI 2013), incorporating key elements from the 2024 method review to assess the flow requirements of the Gellibrand River and its major tributaries.
- Examine the flow-dependent environmental values and objectives of the system and determine the flow regime required to meet these objectives.
- Identify key system constraints and risks, including climate change risks.

1.1 Purpose of this report

This *Recommendations Report* is the third and final report for the FLOWS study and presents the new flow recommendations for Gellibrand FLOWS study reaches. The report further documents:

- Study assumptions and limitations.
- Expectations for the achievement of flows under different prevailing climate conditions.
- The extent to which the recommended flow regime may be achieved under modelled current and future climate conditions (i.e. performance assessment).
- Complementary management actions, which reduce threatening processes and enhance the ecological values of the river.
- The environmental flow recommendations and recommended next steps.

The report is informed by:

- Desktop review of available literature (findings are detailed in the study Site Paper and Issues Paper).
- Site visits and assessments (March 2025, July 2025, October 2025 and March 2026).
- Workshops with representatives from Eastern Maar Aboriginal Corporation (EMAC).
- Workshops with the Project Advisory Group (PAG).
- Meetings with the Project Steering Committee (PSC).
- Gellibrand estuary low flow objectives workshop (held November 2025).

This report is designed to be read in conjunction with the *Site Paper* (Alluvium 2025) and *Issues Paper* (Alluvium 2026), which document project governance arrangements, reach values, reach threats, and the environmental objective setting process.

1.2 Project governance

Alluvium Project Team

The investigation was co-ordinated by Alluvium Consulting (Amanda Wealands, Jessica Bolden and Gabby Vinyard). Responsibilities included coordination of the Environmental Flows Technical Panel (EFTP), project outputs, and working with the PSC and the PAG to ensure that outputs incorporate agency and community feedback. The Alluvium project team contributed expertise on the FLOWS methodology, catchment management, hydrology and hydrologic analysis, hydraulic modelling, community engagement and facilitation.

Environmental Flows Technical Panel

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

Honorary Associate Professor John Sherwood, Rebecca Sheldon and Dr Jon Fawcett provided technical advice on the Gellibrand estuary, aquatic fauna and groundwater, respectively.

Project Steering Committee

The Project Steering Committee (PSC) consisted 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 oversaw project implementation, direction and scope, and assisted with reviewing project deliverables. The PSC determined the spatial scope of the FLOWS study and received advice from the PAG.

Traditional Owners

The Gellibrand catchment is located on the border of three Maar language groups, Gadubanud, Gulidjan, and Kirrae Whurrong. This study seeks to recognise and reflect the unique relationship that First Peoples hold with their cultures, lands, and waters. All named waterways in the Gellibrand catchment (200 m

buffer either side of the waterway) are recognised Areas of Cultural Heritage sensitivity (ACHRIS 2025), as is the Great Otways National Park, through which many of the waterways flow.

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

The PAG also included First Peoples who are not represented by EMAC.

Project Advisory Group

The PAG consisted of 15 community members, each with a strong connection to the Gellibrand catchment. The PAG was selected through an open Expression of Interest process in January 2025. Six meetings/workshops were held with the PAG over the course of the project, as well as a site visit with the EFTP, and the group was invited to provide feedback on each of the FLOWS study outputs (site, issues, and final recommendations papers).

1.3 Spatial scope and study reaches

The Gellibrand catchment is located on the border of three Maar language groups, Gulidjan, Gadubanud, and Kirrae Whurrong on the western side of Cape Otway, Victoria. The headwaters of the Gellibrand River are in the northern slopes of the Otway ranges. The Gellibrand River and tributaries flow through the Otway Plains in the mid and lower catchment and meet the Southern Ocean in the Twelve Apostles Marine National Park, near Princetown (Dwyer and Lester 2021). The catchment covers an area of approximately 115,000 ha (Moss and Clifton 2018) and has a (high) mean annual rainfall of 1012 mm (Park and Roberts 2023).

The FLOWS study comprises eight freshwater reaches and the Gellibrand estuary (Figure 1). Reach boundaries and the locations of representative sites are summarised in Table 1.

Flow recommendations have been developed for all freshwater reaches. New *low-flow objectives* were developed for the Gellibrand estuary (Alluvium 2026), however new flow recommendations for the estuary have not been set due to a need for additional modelling and assessments (beyond the scope of the FLOWS study). Gellibrand estuary flow recommendations developed using the estuary environmental flows assessment method (Lloyd et al. 2008) have instead been carried into this study.

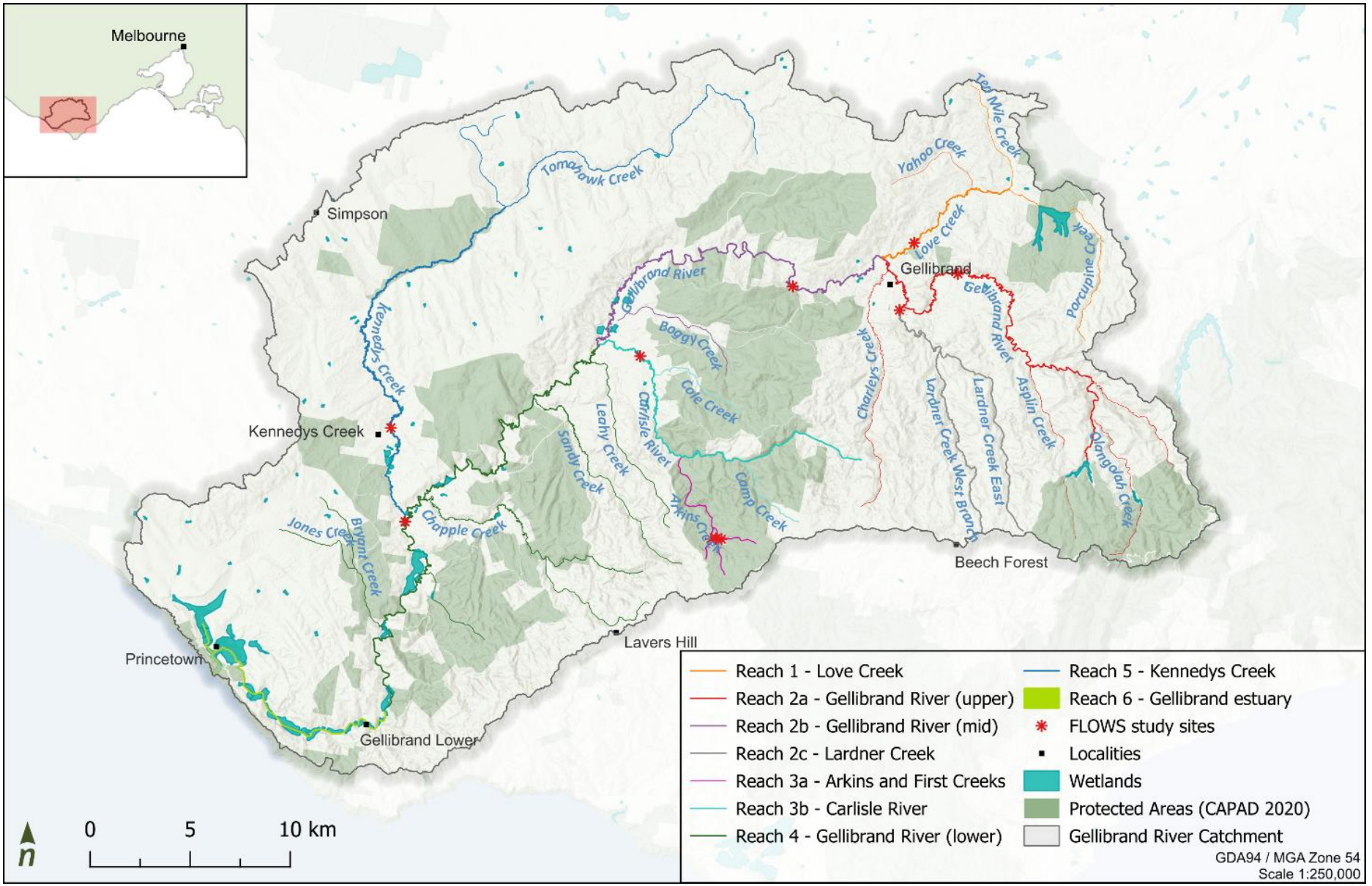

Figure 1. Gellibrand River FLOWS study reaches and sites

Table 1. Gellibrand FLOWS study reach boundaries, modelled site locations and performance streamflow gauges

Reach number	Waterway name	Reach boundaries	Site	Performance streamflow gauge
1	Love Creek	Love Creek and upstream tributaries to confluence with Gellibrand River	Wonga road crossing of Love Creek, downstream of bridge (38°30'12.0"S 143°33'06.3"E)	235234 (Love Creek @ Gellibrand)
2a	Gellibrand River (upper)	Downstream of West Gellibrand Dam, to confluence with Love Creek	End of Ashes Road, downstream (38°30'59.4"S 143°34'38.2"E)	235231 (Gellibrand River @ Raffertys Lane) Note – Streamflow data was modelled for Reach 2a at inactive gauge 235236 (Gellibrand River downstream dam site G5a i.e. James Access).
2b	Gellibrand River (mid)	Confluence with Love Creek to confluence with Carlisle River	Gellibrand Gauge 235227, off Gellibrand River Road (38°31'29.0"S 143°28'58.6"E)	235227 (Gellibrand River @ Bunkers Hill)
2c	Lardner Creek	Lardner Creek (including West and East branches) to confluence with the Gellibrand River	Opposite Yaugher Bushland Reserve (downstream Gellibrand East Road Bridge) (38°32'01.6"S 143°32'40.3"E)	235210 (Lardner Creek @ Gellibrand)
3a	Arkins and First Creeks	First Creek, Arkins Creek West and Arkins Creek East branches and Arkins Creek to confluence with Carlisle River	First Creek diversion weir (38°38'20.5"S 143°26'23.3"E) Arkins Creek West branch diversion weir (38°38'19.7"S 143°26'33.4"E) Arkins Creek East branch diversion weir (38°38'20.5"S 143°26'45.1"E)	235205 (Arkins Creek West Branch @ Wyelangta - at top of upstream weir). Arkins Creek East Branch and First Creek are ungauged
3b	Carlisle River	Carlisle River and upstream tributaries (excluding creeks of Reach 3a) to confluence with the Gellibrand River	Gauge 235200C, upstream of Gellibrand River Road bridge (38°33'27.3"S 143°23'47.5"E)	235200C (Carlisle River @ Carlisle River)
4	Gellibrand River (lower)	Between the confluence of Carlisle River and the upstream extent of the Gellibrand estuary (approximately the Great Ocean Road Bridge)	South Otways Pump Station, downstream of Kennedys Creek confluence (38°38'04.8"S 143°15'50.0"E)	235258 (Gellibrand River @ D/S South Otway pumps bridge)
5	Kennedys Creek	Kennedys Creek and upstream tributaries to confluence with Gellibrand River	Upstream of Kennedys Creek Road bridge crossing (38°35'32.1"S 143°15'15.4"E)	235211 (Kennedys Creek @ Kennedys Creek)
6	Gellibrand estuary	Great Ocean Road bridge to estuary mouth	N/A	235224 (Gellibrand River @ Burrupa)

1.4 Changes relative to the 2006 Gellibrand FLOWS study

Consideration of additional reaches

Lardner Creek (Reach 2c), Arkins Creek West Branch, Arkins Creek East Branch and First Creeks (Arkins and First Creeks, Reach 3a) were not considered as part of the 2006 FLOWS Study (Earth Tech 2006a-c) but have been included in this study at the request of the PSC. The spatial extent of 2006 FLOWS study reaches 1, 2a, 2b, 3 (now 3b), 4, 5 and 6 are as per the 2006 FLOWS study (Earth Tech 2006a-c).

Shifting of representative sites

Sites 1, 2a and 4 have shifted relative to the 2006 FLOWS study for improved accessibility, safety, physical features and representativeness of the broader reach. Site locations are included in Table 1 above. Sites 2b, 3b and 5 remain at the same general locations as the 2006 FLOWS study.

Consideration of the Gellibrand estuary

Gellibrand estuary flow recommendations have been carried from the 2008 estuary environmental flows study by Lloyd et al. (2008). New Gellibrand estuary low-flow objectives were developed by the EFTP as part of this 2026 Gellibrand River FLOWS study, however a revised low-flow recommendation (magnitude) has not been set, due to a need for additional modelling and assessments (beyond the scope of the FLOWS study).

Hydraulic models

The shifting of representative sites and the addition of new study reaches resulted in the need for new site surveys and the development of hydraulic models for Reaches 1, 2a, 2c and 4. A review of 2006 study hydraulic models by the EFTP found that the model for Site 2b was too short (given the width of the waterway) and did not adequately capture the rock riffles. Modelled cross sections for Site 3b did not correctly map to the waterway. New surveys and hydraulic models were therefore developed for Reaches 2b and 3b.

Reach 3a is not amenable to hydraulic modelling. A hydrologic approach was used to develop low flow recommendations, as described in Section 2.3. The 2006 hydraulic model for Reach 5 was deemed suitable for use in this 2026 FLOWS study.

Articulation of values and objectives

The 2006 FLOWS study approached environmental values from an 'Index of Stream Condition' (ISC) perspective with overarching objectives for macroinvertebrates, fish, water quality, physical form and vegetation. While the approach was appropriate at the time, the EFTP considered the approach no longer fit-for-purpose in 2026. A contemporary FLOWS study approach is applied here, including the articulation of nuanced objectives for specific vegetation types, aquatic fauna and geomorphology. Strategic and policy objectives developed since 2006 have been applied in this flows study [please refer to the Issues Paper (Alluvium 2026) for detailed information on study objective setting].

Implications for flow recommendations

Changes to site locations, reach delineation, hydraulic modelling, and the articulation of reach values and objectives have collectively led to the development of new flow recommendations in 2026. As a result,

the recommended flow magnitudes, timing, frequencies and durations differ from those developed in the 2006 assessment.

2 Approach to determining environmental flow recommendations

2.1 The Victorian FLOWS method

The FLOWS method is the Victorian Government's endorsed technical method for the development of environmental flow recommendations for rivers and streams. The FLOWS method was developed in 2002, updated in 2013 (FLOWS method Ed.2, DEPI 2013) and further reviewed in 2024 (Alluvium 2024a). At the time of writing, the FLOWS method was being updated (Ed. 3, anticipated 2026/2027). This study employs the FLOWS method Ed. 2 (DEPI 2013) and incorporates recommendations from Alluvium's 2024 method review such as greater inclusion of Traditional Owners and consideration of climate change. An overview of the method is provided in Figure 2.

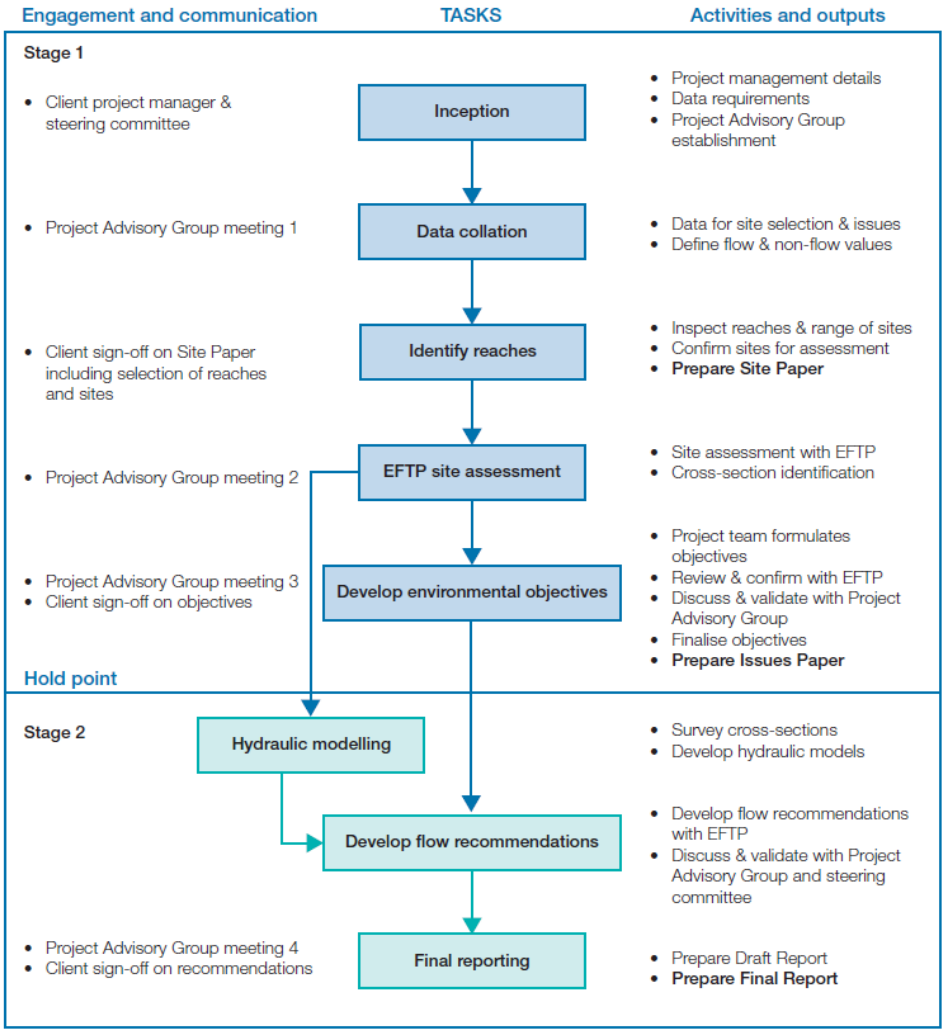

Figure 2. FLOWS method overview (source: DEPI 2013)

The FLOWS method is a hydraulic modelling and expert elicitation approach for the determination of flow recommendations at modelled sites that are deemed representative of the broader study reach. Flows are designed to satisfy hydraulic criteria (criteria for water in motion in the river) related to depth, velocity, shear stress, wetted width and other parameters at the modelled sites. The hydraulic criteria (identified by the EFTP) are intended to support physical processes, instream-, riparian- and floodplain- ecosystems, and life histories of flow-dependent flora and fauna.

2.2 Inputs to the FLOWS study

Key inputs to the study are described below. Assumptions and limitations are noted.

Desktop literature review

The EFTP and Alluvium team undertook a review of available literature to understand environmental values, threats and catchment operation. Findings of this review are documented in the Site Paper (Alluvium 2025) and Issues Paper (Alluvium 2026).

Assumptions and limitations:

The review was based on literature, models and datasets identified through targeted searches and/or provided by PSC representatives or the PAG. Despite efforts to conduct a comprehensive review, there is always the possibility that additional relevant information exists but was not identified and considered as part of this study.

Workshops with EMAC and the PAG

Throughout the course of the project, three meetings/workshops were held with EMAC representatives (in addition to their involvement on the PSC) and six meetings/workshops were held with the PAG. EMAC and PAG provide important local knowledge and perspectives on reach values, threats and environmental and strategic objectives.

Assumptions and limitations:

Outcomes were informed by the expertise and perspectives of attendees. As participation varied between sessions, the breadth of views captured was dependent on representation at each workshop. PAG members who did not attend were offered the opportunity to review workshop products and draft study reports.

Site assessments

Site visits and assessments to the Gellibrand catchment were undertaken by the EFTP and Alluvium team on 24-25 March 2025, 21 July 2025, and 28-31 October 2025.

The site visits enable ground-truthing of knowledge gained through desktop review and workshop input. Detailed site assessments (October 2025) supported identification of physical features and cross sections for survey, and confirmation of hydraulic criteria for the determination of flow recommendations.

The Alluvium team conducted a post-fire visit to Site 2b on 4 March 2026 to re-set survey markers following the January/February bushfires.

Alluvium acknowledges landholders who permitted access to private property for site assessments and surveys.

Assumptions and limitations:

While the EFTP endeavoured to visit several locations within each reach in March 2025 when selecting representative sites, the visits were constrained by time and site accessibility (e.g. public access, safety and road closure considerations).

Flows were high and exceptionally turbid in several reaches during the October 2025 visit which may have obscured submerged instream vegetation and low lying features.

Site survey and hydraulic models

Alluvium reviewed hydraulic models from the 2006 Gellibrand FLOWS study and determined that new models were required for all reaches except Reach 3a (Arkins and First Creeks) and Reach 5 (Kennedys Creek). This was due to:

- changes in site locations (reaches 1, 2a and 4),
- concerns about suitability of the existing hydraulic models (reaches 2b and 3b), or
- the lack of an existing hydraulic model (Reach 2c).

The existing (2006) hydraulic model for Kennedys Creek was deemed suitable for use in this 2026 FLOWS study. Reach 3a is not amenable to hydraulic modelling due to its steep, rocky and confined form.

Survey data was the primary input for hydraulic modelling. Approximately ten to twelve cross sections were selected for sites 1, 2a, 2b, 2c, 3b and 4 by the EFTP and Alluvium project team during the October 2025 site assessment. Surveys of these cross sections were subsequently undertaken by Smith Land Consulting during the period of 23 March 2026 – 24 April 2026.

One-dimensional steady flow hydraulic models were developed by Alluvium for each of the FLOWS study sites using HEC-RAS. Hydraulic models relate flow rates to other parameters of water in motion, such as depth, velocity, wetted width and shear stress, and are the primary input used by the EFTP to develop flow recommendations.

Assumptions and limitations:

The hydraulic modelling undertaken as part of this study is subject to several assumptions and limitations associated with the available data, modelling approach, and hydraulic representation of the study reaches.

Key assumptions adopted in the hydraulic modelling include:

- The surveyed cross-sections (approximately 10 to 12 cross sections per site) adequately represent channel and floodplain geometry within the study reaches.
- That Manning's roughness coefficients and blockages assigned within the models are representative of observed channel and overbank conditions.
- Boundary conditions applied at the upstream and downstream limits reasonably represent hydraulic conditions during the simulated flow scenarios.

- Flow is assumed to be predominantly aligned in the downstream direction within the river channel.

The primary limitations associated with the hydraulic assessment include:

- Limited observed flow and water level data available for calibration and validation at some sites, and the survey of cross sections at individual sites on multiple days.
- Simplification of complex hydraulic behaviour using a one-dimensional modelling approach.
- Potential localised variations in channel geometry and vegetation conditions not fully captured within the surveyed cross-sections.
- Bank and/or floodplain extent not fully captured at some of the surveyed cross sections in reaches 2a, 2b and 4.
- Uncertainty associated with roughness estimation and hydraulic assumptions.
- Hydraulic structures, debris, and transient flow conditions may not be fully represented within the model geometry.

Despite these limitations, the hydraulic models developed for this study are considered suitable for assessing general hydraulic behaviour, water surface profiles, and flow characteristics within the selected study reaches.

Source hydrologic model

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

1. Unimpacted flows (natural daily flows without development, diversions or storage of water).
2. Current level of development and demand (current daily flows).
3. Future demand – full use of licence volumes of sleeper licences.
4. Full demand (full uptake) – full use of licence volumes of sleeper licences including 1 GL of winterfill entitlement after the 2011 WRSWS[1] and urban demands at yield[2].

The two primary inputs to this model are gauged flow data and rainfall. Key model impacts on flows include urban demands (surface water and groundwater), rural demands, farm dam impacts, evaporation, impacts from former groundwater pumping activities at the Barwon Downs borefield, and losses (including to plantation forestry). The Source model captures the understanding of Gellibrand water

[1] In the WRSWS, the Gellibrand River has 1 GL of unallocated surface water remaining available for new winter fill (July – October) diversions under existing sustainable diversion limits (DSE 2011, p174).

[2] Yield is defined as the average annual demand that can be supplied at the preferred level of service. The preferred level of service for the Otway system is 95% annual reliability and no breach to the drought reserve volume (i.e. restrictions in no more than 1 in 20 years). The preferred level of service for Barwon Water systems is 95% monthly reliability and no breach to the drought reserve volume in Colac (i.e. restriction frequency does not exceed more than 5% of the modelled period) (HARC 2025).

system operations and demands at a given point in time (2025), based on best available data and water resource modelling guidance.

HARC modelled several current and future climate conditions for each development scenario:

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

Source model outputs have been used in several parts of the flow determination process:

1. Modelled unimpacted flows in a historical climate were used to understand monthly flow patterns and general flow seasonality.
2. Modelled unimpacted flows in a post 1975 climate were used to:
    - check the reasonableness of the flow recommendations in a current climate
    - set the frequency and duration of peak event-based flow components (i.e. freshes, bankfull and overbank flows).
    - understand expectations for the achievement of flow recommendations under different seasonal conditions.

3. Modelled flows under different development and climate scenarios were used to assess the potential for the recommendations to be achieved both now, and into the future.

The Gellibrand River Source model outputs are:

- the best quality controlled and gauge-calibrated flow dataset available for the Gellibrand catchment; and
- the only dataset for flows under different climate and development scenarios (including unimpacted flows).

Assumptions and limitations

Limitations for the Source model centre on the quality of streamflow data inputs, and how inflows and demands are represented in the model. These inputs and representations are described below:

Inflow derivation: Depending upon sub-catchment location, inflows are derived from (1) Water balance on storage, extended by rainfall runoff modelling (2) Reach balance, extended by rainfall runoff modelling (3) Gauged flow extended by rainfall runoff modelling (4) Transposed flow from gauge or neighbouring catchment.

[3] *Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria 2025* state the post 1975 climate reference period is recommended as being suitable for providing a representative sample of recent climate variability for the purpose of projecting future climate change.

Consideration of groundwater: The model includes specific representation of Barwon Water's historic groundwater pumping impacts associated with the Barwon Downs borefield on Yahoo Creek (Love Creek tributary) and Gellibrand River upstream of Bunkers Hill (as detailed by BlueSphere 2024), and the impacts associated with the operation of Wannon Water's Carlisle River bores (as detailed by GHD 2014). The model also assumes stock and domestic groundwater use in the lower reaches upstream of Burrupa. Impacts of groundwater pumping have been routed through downstream reaches. Broader groundwater-surface water interactions are indirectly reflected within the observed streamflow data used to develop and calibrate the Source model; however, the model does not identify which aquifers are involved in these interactions.

Farm Dam impacts: Farm dam impacts were derived using the current distribution of farm dams in the Boundary Creek and Gellibrand catchments, and their growth considered as part of future climate change scenarios.

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

Yahoo Creek streamflow data quality: HARC 2025 notes that streamflow data in Yahoo Creek at Kawarren is not well rated for flows above 100 ML/day. Data measures >100 ML/day were removed from the Source model analysis. Quality codes for the remaining data were also considered as part of the model development process. The PAG also note periodic errors and gaps in streamflow gauge data (for example gauged flows of 0 ML/day in Yahoo Creek on days where the PAG representatives have seen the creek flowing) that impact the reliability of very low flows (Gardiner 2025).

Water backups at the Burrupa streamflow gauge: When the Gellibrand estuary mouth is closed, freshwater inflows cause water to gradually accumulate in the estuary, increasing water levels. When estuary water levels are sufficiently high water backs up at the Burrupa streamflow gauge causing streamflow data quality issues.

Consideration of sea level rise: The Source model does not incorporate impacts of sea level rise in the Gellibrand estuary or lower Gellibrand River reach (Reach 4). Therefore, while sea level rise will impact the Gellibrand estuary and lower Gellibrand River, they could not be modelled or further considered within the FLOWS study.

Climate projections: HARC produced flow outputs for RCP8.5 2020, 2040 and 2065 low, medium and high climate projections, in accordance with the 2020 *Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria* (DELWP 2020, HARC 2025). 2040 High and 2065 High climate projections have been used for performance testing at the request of PAG and EMAC. Climate change effects are anticipated to continue beyond 2065, however as 2065 is the latest assessment year represented in the Source model, the 2065 high model is the furthest and most severe climate projection assessed in the FLOWS study.

Rural demands: Rural demands are represented in the current level of development, unimpacted level of development and at full uptake under future climate condition scenario modelling. The model assumes:

- Negligible direct irrigation usage

- Current take and use surface water licence volumes (stock and domestic, dairy, commercial and industrial licences)

Rural uptake in the Gellibrand system is typically for stock and domestic use, which is not subject to restrictions or level of service criteria.

Urban water demands: The model considers water extracted by Barwon Water and Wannon Water under current Bulk Entitlements and Licences. Future urban demand growth is based on estimated population growth and impacts of climate change. In the model, urban water demands are sensitive to 'level of service' criteria – i.e. restrictions on urban take may apply, depending on surface water availability. Current/future industrial demands (existing users and technologies) are represented in the model as urban water demands. Emerging technologies and novel industrial water demand, such as potential future water use by data centres and pumped hydro energy storage, is not represented in the Source model.

2.3 Assumptions and limitations of the FLOWS method

Regulated vs unregulated rivers

Regulated rivers are those with structures that regulate river discharge in order to provide storage of water for extractive uses (for example, potable use and irrigation) or for hydroelectric purposes. This usually results in a significant alteration of the downstream flow regime, through reductions in overall flow and changes in the seasonality and timing of flow. Under this definition, the Gellibrand River (reaches 2a, 2b, 4 and 6), Arkins Creek West Branch (Reach 3ai), Arkins Creek East Branch (Reach 3aii), First Creek (Reach 3aiii) and Carlisle River (Reach 3b), are regulated reaches.

Unregulated rivers do not have large structures that regulate river discharges. Based on this definition, Love Creek (Reach 1), Lardner Creek (Reach 2c) and Kennedys Creek (Reach 5) are unregulated reaches.

The FLOWS method was fundamentally designed to assist water managers to 'recover' water for the environment in overallocated, regulated river systems in poor condition. While the method is excellent for this purpose, it is being applied for a slightly different use case in this FLOWS study, where several reaches (Reaches 1, 2c, and 5) are effectively unregulated, and one reach (Reach 2c) has an almost natural flow regime. Several assumptions and limitations of the method are important for managers to consider when interpreting and implementing the flow recommendations, as detailed below.

Reach and site representativeness

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

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

Performance

Performance (i.e. assessment of achievement of the flow recommendations) is assessed at the nearest active streamflow gauge. While the EFTP aimed to have a stream gauge at or nearby the FLOWS study site, this was not possible in all reaches. Some streams are ungauged (Arkins Creek East Branch and First Creeks in Reach 3a), and some streamflow gauges are located several kilometres upstream (Reach 1) or downstream (Reach 2a) of the FLOWS study site. In reaches 1 and 2a, there are no major tributary inflows between the FLOWS study site and the streamflow gauge, and the nearest active streamflow gauge is assumed suitable for performance monitoring and assessment.

The diversity of instream features

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

Amenability to hydraulic modelling

The steep, bedrock-confined physical form of Arkins Creek West Branch, Arkins Creek East Branch and First Creek precludes the development of stable one-dimensional HEC-RAS hydraulic models, which are the standard tool used in the FLOWS method to relate flow rate to water depth and velocity at key habitat features. The confined channel form and absence of depositional instream features also limit the application of hydraulic criteria for higher magnitude flow components. Accordingly, the EFTP has applied a hydrologic approach to the setting of low flow recommendations for all three Reach 3a creeks, using Source modelled unimpacted inflow (post 1975 climate) to the weirs as the primary reference. This approach is a recognised adaptation of the FLOWS method where site conditions preclude hydraulic modelling (DEPI 2013).

Source of water to meet recommendations

Flow recommendations are set at a given location in a reach, based on known values in the reach, environmental objectives, flow-ecology relationships (hydraulic criteria) and the physical features captured in the hydraulic model. The flow recommendations are agnostic to the 'source' of water, which could come from rainfall/runoff processes, Bulk Entitlements, Environmental Entitlements, temporary

trades, groundwater inflows or other sources. However, the 'source' may be important in identifying the 'levers' that are available to water managers to work towards achieving the flow recommendations.

Minimum flow recommendations and enforceability

The hydraulic approach of the FLOWS method results in a set of minimum flow recommendations to inundate features or achieve hydraulic criteria and thereby support environmental values. These recommendations are not legally binding or otherwise enforceable and depending on the 'levers' available, may not be achievable. This is particularly true for systems where the ability to deliver additional water is not possible, or where climate conditions are not conducive to delivering certain flow components.

Application in regulated vs unregulated systems

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

The managed delivery of environmental flow recommendations in regulated systems is subject to operational and legal constraints. For example, in the Gellibrand catchment, the recommendations cannot currently be delivered as 'managed flows' in regulated reaches due to the capacity of storages and outlets (i.e. there are no outlets on Reach 3a weirs), operating rules (including those in bulk entitlements), and lack of an environmental entitlement. Even in regulated systems with sufficient storages and entitlements, large magnitude flow components such as overbank flows typically exceed the capacity of storage outlets and occur only when natural rainfall events cause spillage of reservoirs.

In unregulated rivers, where there are no storages and entitlements to support the 'managed delivery' of flows, managers use flow recommendations to aid the setting of diversion restrictions, passing flow rules and cease-to-pump rules. Recommendations may also protect flows from future harvesting and inform system licensing. For example, although the flow components cannot be 'delivered', the volumes required to achieve the recommendations could be protected from future allocation.

When applied to unregulated free-flowing rivers the FLOWS method 'conceptually' reduces the high variability of the natural flow regime to a 'minimum' flow regime comprising a set of distinct flow components. The potential unintended consequence is that minimum flow recommendations could be less than that currently received by an unregulated waterway. The EFTP note a strategic outcome to *improve riparian extent and condition, hydrological regime and water quality in Otway Coast priority waterways as defined in the Corangamite Waterway Strategy* and has been conscious of this when developing precautionary flow recommendations for Lardner Creek.

Scope of FLOWS study inputs and consideration of values

The FLOWS method focusses on identifying recommendations primarily for *flow-dependent*[4] values. While significant environmental and cultural values may be found at a site (for example Otway black snails and burrowing crayfish), if it is not flow-dependent it does not *directly* feature in the recommendations. However, recommendations can also support the broader conditions upon which significant environmental values depend, such as the maintenance of wet microclimates, and the continued presence of flows (and soil moisture) in the landscape.

Implementation of flow recommendations

This Recommendations Report is not a management plan and does not provide detailed information on how to manage rivers based on the flow recommendations. These recommendations are intended to inform decision-making, but the flow recommendations are exactly that: recommendations.

During the site assessment, the EFTP noted several catchment management challenges that will limit the potential to achieve environmental improvement through flows alone. The study makes recommendations for future work, including non-flow management actions such as stock exclusion and fencing, weed control, riparian revegetation, and supporting fish passage. Without these complementary actions, improving flows may not lead to meaningful improvements to the ecological condition of the river (see Section 4).

2.4 Flow components

Flow variability is a key driver of riverine ecosystem structure and function (Bice et al. 2014). The FLOWS method was designed to recover water for the environment in flow-stressed rivers, and to re-instate flow variability and ecologically important aspects of natural flow regimes. The flow regime can be broken down into key flow components, each of which performs specific ecological functions and physical processes. The flow components represent different phases of the river's hydrograph in terms of hydraulics (parameters related to water in motion), inundation extent (Figure 3), and biological processes (Bice et al. 2014). The EFTP has developed recommendations for the following flow components for FLOWS study reaches.

[4] A flow-dependent value in an environmental flow study refers to any specific biological species, physical habitat, ecological process, or ecosystem function whose health, viability, or persistence directly relies on particular characteristics of a river's flow regime—such as magnitude, timing, duration, and frequency.

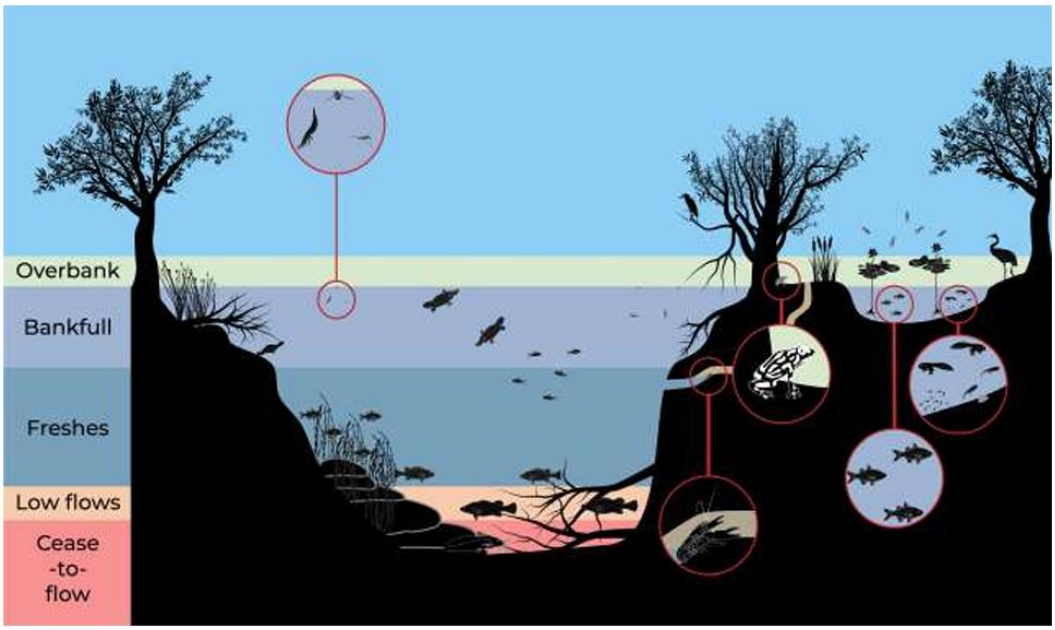

Figure 3. Flow components (from Wood et al. 2022)

Cease to flow: the frequency and duration with which the reach ceases to flow. The Gellibrand River and its tributaries do not typically cease to flow, therefore cease to flow recommendations were not made in this study.

Low flows: Low flows create pools of slow-moving water, continuous or near-continuous flow across the length of the waterway and wetted habitat for aquatic fauna. In the Gellibrand system low flows are to be provided year-round, ensuring that there is always water in the landscape to support flow-dependent flora and fauna and wet microclimates.

Hydrologic analyses of Source-modelled unimpacted flows (historical climate) identified a distinct seasonal flow pattern within the Gellibrand FLOWS study reaches (Alluvium 2026). Flows are typically highest from June to October and lowest from December to April (Figure 4). May and November are transition months that exhibit similar flow variability and do not align clearly with either period. For this reason, low flow recommendations were developed for the periods of December – April, May, June – October, and November.

Freshes: Freshes are peak flow events that are intended to mimic a pulse of flows after a rainfall event. In summer - autumn, freshes are small events that mimic short, localised rainfall events. In winter-spring freshes mimic sustained and heavy rainfall events. The magnitudes of freshes vary across the year, with the EFTP recommending different magnitude freshes for the periods of December – April and May – November (Figure 4). The frequencies and durations of freshes are determined based on spells analyses of modelled 'unimpacted' (i.e. without development), post 1975 climate flows during the period (December – April and May – November) in which the fresh applies.

Freshes contribute to flow variability, temporarily increase the depth of flow in pools and over riffles, increasing wetted area through the inundation of benches and other features, and improving vertical zonation of vegetation on banks. Freshes provide important migratory and spawning cues for aquatic fauna.

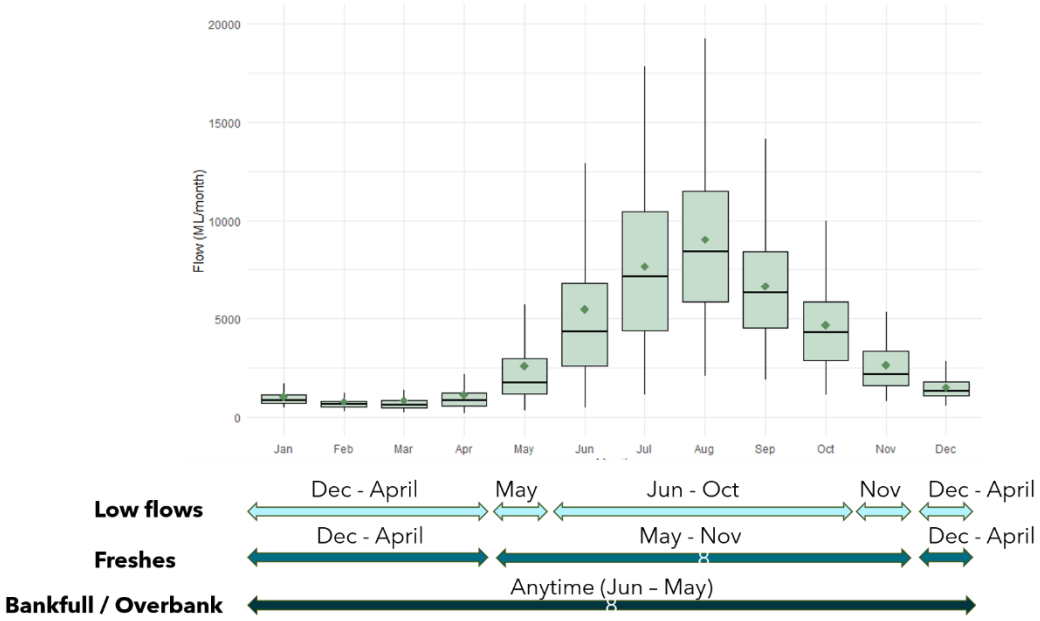

Figure 4. Timing of flow components in this FLOWS study [boxplots of monthly flows (Source-modelled unimpacted flows in a historical climate) in Reach 2a indicate monthly flow variability]

Bankfull flows: Bankfull flows are peak flow events that mimic flows after large rainfall events. They are of greater magnitude than freshes. Bankfull flows typically fill the channel to the top of the bank, but do not engage the floodplain. In deeply incised channels without floodplains, high flows do not completely fill the channel and are therefore not bankfull flows. Bankfull flows are considered 'channel-forming flows' that erode the toes of riverbanks, flush habitats and transport sediment through the system. In addition, they help to create vertical zonation of vegetation on banks, providing a range of habitats for aquatic and terrestrial species. Bankfull flows can occur at any time of the year (Figure 4).

Overbank flows: Overbank flows are high magnitude flows that exceed the capacity of the waterway channel, wetting the riparian zone, floodplains and engaging adjacent wetlands and billabongs. Wetland/billabong/floodplain vegetation provides important habitat for waterbirds, frogs, turtles and fish. Lateral flows from overbank events are important for maintaining soil moisture, for transporting sediment from the stream channel to the floodplain, and for entraining floodplain carbon into the water and transporting it across the system. Overbank flows are also 'channel forming flows', important for shaping the physical form of the waterway. Overbank flows can occur naturally at any time of the year (Figure 4), but in the Gellibrand system are more likely to occur in wetter years, than in drier years.

3 Summary of environmental objectives

Flow-dependent environmental values were detailed in the Site Paper (Alluvium 2025) and Issues Paper (Alluvium 2026). Key content on environmental values has been brought into Appendix A.1. Environmental objectives and flow objectives were presented in the Issues Paper (Alluvium 2026). They are summarised below, with flow objectives and hydraulic criteria provided for reference in Appendix A.2. Reach and catchment-scale threats were detailed in the Issues Paper (Alluvium 2026) and are provided for reference in Appendix A.3.

Environmental objectives and hierarchy in the FLOWS study

Environmental objectives have been developed under three umbrella subjects: aquatic fauna, vegetation, and geomorphology.

Aquatic fauna

Environmental objectives for aquatic fauna are designed to support specific and generic values associated with the Gellibrand catchment (Table 2). Generic values include broad fish groups and macroinvertebrates, while specific aquatic fauna values supported by objectives include River blackfish, Short-finned eels, Australian grayling, freshwater crayfish and Platypus. The specific values were identified as important to the community or ecosystem, and may be threatened (i.e. listed under Victorian or Commonwealth legislation) or widespread. Flow objectives focus on the flow components (i.e., magnitudes, timing, frequency and duration) that are required to support habitat, food web and life cycle requirements for aquatic fauna species (see Appendix A.2).

Table 2. Environmental objectives for aquatic fauna

F1	Maintain abundance and diversity of native fish assemblage
F2	Improve abundance of River blackfish
F3	Maintain self-sustaining populations of freshwater fish (Galaxias, Gudgeon, Pygmy perch, Blackfish)
F4	Maintain self-sustaining populations of migratory species (Australian grayling, Short-finned eel, Lamprey, Tupong)
F5*	Maintain self-sustaining populations of estuarine residents (Estuary perch, Black bream)
F6*	Maintain connection to the estuary and seasonal connection to the marine environment
F7*	Maintain estuary habitat
FC1	Maintain self-sustaining populations of freshwater crayfish species
P1	Improve condition and extent of Platypus population
R1	Maintain self-sustaining populations of Rakali
M1	Maintain self-sustaining populations of aquatic macroinvertebrates

* Objectives F5, F6 and F7 relate to estuary values. Flow objectives and recommendations for the estuary have been carried from Lloyd et al. 2008.

Vegetation

The environmental objectives for vegetation are designed to support the major functional types of Indigenous flow-dependent vegetation described for each reach (Table 3).

Table 3. Environmental objectives for vegetation

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

Water-dependent vegetation typically requires a suite of flow components in order to maintain adult plants, facilitate sexual recruitment, and facilitate the distribution of seed or stem fragments for asexual reproduction, and thus continuity of the population (See Appendix A.2 for vegetation flow objectives and hydraulic criteria). Plants in different parts of the waterway typically have different flow requirements, and in this context, it is customary to differentiate between different plant functional groups and settings (Brock & Casanova 1997, 2000; Casanova 2011; Roberts & Marston 2011; Tonkin et al. 2020). These different functional groups and settings generally have contrasting wetting and drying requirements, in keeping with their position in the landscape.

The freshwater reaches of the Gellibrand River system possess few water-dependent Indigenous vegetation values. In-stream submerged or floating-leaved vegetation, for example, is scarce and often restricted to a few specimens of Water ribbons. Similarly, the structurally and floristically diverse suite of reeds, rushes and sedges that typically occur along the shallow fringes of a waterway are largely absent, and a range of weeds (e.g. blackberry) have taken their place. A wide and well-vegetated riparian zone is also largely absent, and many non-hydrologic factors (e.g. land clearing, grazing / cattle damage, plantation forestry) have probably contributed to its current poor ecological condition (e.g. Jones et al. 2022). Therefore, while vegetation objectives have been developed to maintain and, where possible with complementary actions, improve flow-dependent Indigenous vegetation values, they are largely secondary to the objectives for aquatic fauna values in this study, and are generally satisfied by the hydraulic criteria set for aquatic fauna objectives.

Geomorphology

Geomorphic condition and processes rarely have inherent value. For the most part, the geomorphic conditions and processes in waterways support other waterway attributes and values of interest. This is the case for the Gellibrand River system. The geomorphic objectives set out in this study have been developed to support the vegetation condition and the aquatic fauna values of the system (Table 4).

Table 4. Geomorphic objectives

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

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

Maintain the area / volume of channel habitat for macroinvertebrates, fish, Platypus and Rakali. The volume of instream habitat can be attained and maintained by providing levels of sediment transport that match supply with transport capacity, preventing gross channel aggradation.

Maintain depth of pool habitat. Provision of suitable pool depth is necessary to prevent vegetation encroachment (and hence habitat loss) and is essential for fish, Platypus and Rakali. Pool depth can be maintained through the provision of flow events that regularly scour and mobilise sediment from the bed of the waterway.

Maintain the condition of gravel bar habitat. Algae is a primary food source for macroinvertebrates, which are in turn a primary food source for fish and Platypus. Algae production can be maintained by regularly scouring it from substrate material, including large wood and gravel bars.

Contribute to floodplain development and evolution. Waterways influence and are influenced by their adjoining floodplain. Overbank inundation is essential for the movement of sediment from the stream channel to the floodplain, contributing to the maintenance of the stream channel (for instream values) and the ongoing development of the floodplain for riparian values, including riparian vegetation.

4 Catchment management actions

The implementation of complementary catchment management actions is of fundamental importance to achieving the environmental objectives outlined in this study. Native flow-dependent plant and animal species need more than water availability and flow to thrive. Diverse riparian and instream habitat, invasive and exotic species management, and suitable water quality are all required to support flow-dependent environmental values. Many ecologically threatening processes in and beyond the Gellibrand catchment are related to land use (see Appendix A.3). For example, forestry operations, grazing and direct cattle access to streams all contribute to sediment or pollutant loads and turbidity in study waterways. Environmental water management cannot be expected to address impacts from inappropriate land management. Land-use-related threats must be mitigated at their source via complementary management actions. Key actions in the Gellibrand catchment are detailed below.

Stock exclusion – fencing and off-stream watering of stock

Livestock grazing and unrestricted access to waterways damages riparian vegetation, reduces ground cover and degrades soils through feeding, trampling and nutrient and microbe deposition (Jones et al. 2022). Livestock access further drives bank erosion, sediment delivery to streams and instream turbidity through physical pugging and disturbance of streamside zones. Beyond direct contribution of nutrients to streams through defecation, nutrients such as phosphorus are readily carried on suspended sediments, with potential to contribute to algal growth.

Stock exclusion is a key complementary management action required in the Gellibrand catchment to manage turbidity and nutrient sources and improve riparian zones. Beyond improvements to sediment and nutrient loads, stock exclusion enables planted revegetation works to be successful, as plants are no longer trampled or consumed by stock. Furthermore, stock exclusion enables the recruitment of Indigenous vegetation through supporting the germination of blown in seeds, and survival of seedlings (i.e. germinants are no longer trampled or consumed).

Management of erosion and sedimentation

Agriculture, forestry, and other uses can generate excessive amounts of sediment within the catchment which can move into waterways. Land management should aim to retain sediment within the managed area by maintaining soil cover, and installing and maintaining appropriate mechanisms (e.g. design of roading, sediment capture).

Fuel reduction, wildfire events, fire suppression, and post-fire rehabilitation can dramatically reduce ground cover and alter water movement. Management of erosion and sedimentation and the protection of waterways should be a high priority when planning and implementing works.

Weed removal and ongoing maintenance

All freshwater FLOWS study reaches, except for Arkins and First Creeks (Reach 3a), had highly weedy riparian zones (e.g. blackberries, willows, flag irises, etc.), compromising riparian ecosystem diversity, productivity and function. Weed infestations are rarely a result of an inappropriate watering regime. Instead, they are more often caused by changes in land use and significant disturbance.

Jones et al. (2022) note that stock exclusion from waterways can lead to the invasion and/or dominance of exotic species through the lack of control by herbivores. This was observed at the James Access bridge in Reach 2a (Gellibrand River upper), where a change in land use from grazing to plantation forestry appeared associated with the current dominance of blackberry in the riparian zone.

Weed removal is an important complementary management action required to support establishment of an effective riparian zone. Weed management should be an ongoing activity following stock exclusion and revegetation works. Weed management is also an important activity following large scale ecological disturbance, such as bushfires.

Pest animal management

Feral deer, rabbits, and pigs can all contribute to erosion and sedimentation in the catchment, and around waterways. They can also damage riparian vegetation and may prevent the natural regeneration of native plants or graze/browse revegetation efforts.

Pest animal management is an important complementary action to allow establishment of an effective riparian zone.

Establishment of an effective riparian zone

In many locations, the Gellibrand River and tributaries are bordered by plantations or agricultural operations, and the waterways lack an effective riparian zone. Previous riparian revegetation works undertaken in the catchment (sometimes following willow removal) consist of a single row of canopy trees, mostly eucalypts, which are now falling into the waterways as a result of erosion and/or wind effects. It is noted that some reaches with areas of previously intact riparian zones (reaches 2b, 3b and 4) were impacted by the January 2026 bushfires.

Victorian Planning Provision 14.02-1S Catchment Planning and management requires the retention of natural drainage corridors with vegetated buffer zones of at least 50 m wide, along both sides of a waterway (DTP 2026a). Policy guidelines for Victorian Planning Provision 12.03-1S (River and riparian corridors, waterways, lakes, wetlands and billabongs, DTP 2026b) include locating earthworks a minimum of 50 m from waterway systems. Development should be located a minimum of 50 m from the banks of waterway systems. Both provisions apply to all waterways across Victoria, and are designed to ensure that waterway corridors are of adequate width to allow for natural systems and functions of the environment and landscape to occur, protect ecological values, encourage biodiversity, and recognise the connectedness of systems.

An effective riparian zone requires multi-storey vegetation, including ground, shrub and canopy layers and an intact organic ground layer including bryophytes, soil crust, and litter. Key functions performed by an effective riparian zone include:

- Minimising erosion of stream banks and verges,
- Nutrient and pollutant interception and uptake – the riparian zone filters runoff, prevents sediments and nutrients from entering the waterway,
- Shading of the waterway, which:
    - Decreases light and water temperature to limit algal growth and provide thermal buffering,

    - Moderates predation by species that rely on sight of prey (mottled light),
- Providing stable banks for construction of burrows by Platypus, Rakali, and freshwater crayfish
- Providing habitat for terrestrial species,
- Supporting animal passage (i.e. fauna corridor, protected access to drinking/bathing water),
- Providing large wood, coarse woody debris and leaf fall, to provide instream habitats and support food webs,
- Supporting slow, gradual channel movement and change,
- Impeding livestock access to the waterway.

As noted above, riparian corridors should be fenced to exclude livestock. Weed removal, pest animal management, and ongoing maintenance of riparian zones is also required.

Support fish passage

Constructed anthropogenic fish barriers (i.e. dams, road crossings, weirs etc.) are limited in Gellibrand catchment. The biggest natural barrier is Stevensons Falls, with the West Gellibrand and Olangolah weirs located upstream of the falls. The diversion weirs in Arkins Creek West Branch, Arkins Creek East Branch and First Creek likely impede movement at low flows (noting that the lack of flows below these weirs when the weirs are not overtopped by flows also results in the disconnection of these reaches for fish passage). Gauging weirs and other constructed waterway features have the potential to act as temporary barriers during periods of low flow for some species. Constructed barriers should be reviewed and addressed to support fish passage. The maintenance of minimum flow requirements at critical times is also important for maintaining fish passage and will need to be supported via other water management actions such as flow demand management and a review of passing flow rules (see also Section 6).

Acid sulfate soils

Acid sulfate soils are present within the Gellibrand Catchment. While naturally occurring, these can be activated by climate and/or anthropogenic activities and in severe circumstances, result in the mobilisation of acidity and metals to receiving waterways. The identification and management of acid sulfate soils is an important complementary action to maintain water quality.

Community awareness

The effectiveness of many catchment management actions depends on community awareness and participation. Engagement programs can build understanding of waterway values, foster relationships with private landholders, and increase uptake of voluntary actions such as fencing, revegetation and weed management. Citizen science initiatives, including Waterwatch and EstuaryWatch, also provide valuable information on waterway condition while strengthening community connection to and stewardship of local waterways.

5 Environmental flow recommendations – by reach

The environmental flow recommendations are presented herein on a reach-by-reach basis. The technical approach to the determination of flow recommendations is detailed in Appendix A.4. The appendix includes methods for:

- determination of flow recommendations for Reaches 1, 2a, 2b, 2c, 3b, 4 and 5 (Appendix A.4.1),
- determination of flow recommendations for Reach 3a (Appendix A.4.2),
- seasonal expectations and the determination of climate condition for spells analysis (Appendix A.4.3),
- performance assessment and interpretation of performance scores (Appendix A.4.4).

For each reach, this section provides an overview of reach condition, including management directions and the condition of aquatic fauna, vegetation, geomorphology and hydrology values. Readers are referred to the Site Paper (Alluvium 2025) and Issues Paper (Alluvium 2026) for detailed information on reach values. As values are generally consistent across reaches, a catchment-scale description of reach values is provided for reference in Appendix A.1. Hydraulic model cross sections and photos are provided in Appendix A.5.

Readers are referred to the Issues Paper (Alluvium 2026) for the qualitative descriptions of reach condition for each study reach. **These qualitative descriptions are based on EFTP field observations, existing data, and reach descriptions in the literature. They are not formally calibrated against the Index of Stream Condition or an equivalent index.**

Environmental flow recommendations are presented for each flow component, including the recommended magnitude, timing, frequency and duration, and the environmental objectives the flow component supports.

Seasonal expectations are described to assist flow managers in understanding how to interpret recommendations under different (very dry, dry, wet, and very wet) climatic conditions. The classification of Source modelled data (unimpacted, post 1975 flow) years as very dry, dry, wet and very wet is shown in Table 5. Please refer to Appendix A.4.3 for further information on the classification approach.

Table 5. Classification of each year of Source modelled data according to climate condition

Climate Condition	Annual flow percentile	Interpretation
Very dry	0% < f ≤ 20%	Very dry years are the driest 20% of years in the modelled record
Dry	20% < f ≤ 50%	Dry years comprise the next 30% of years (below median, 20th–50th percentile annual flows)
Wet	50% < f ≤ 80%	Wet years comprise the next 30% of years (above median, 50th–80th percentile annual flows)
Very wet	80% < f ≤ 100%	Very wet years are the wettest 20% of years in the record (80th–100th percentile annual flows)

Where *f* is the annual flow percentile.

Seasonal expectations are informed by additional spells analyses of modelled flows under the unimpacted level of development and post 1975 climate conditions, focusing on the mean annual frequency and duration of peak flow events during very dry, dry, wet and very wet years. Recommended frequencies and durations together with the mean annual frequencies and durations are presented alongside the climate conditions for reference.

The performance of the recommended flow regime was assessed using eFlow Predictor v3.0.10.0 (Marsh et al. 2009). Performance testing evaluated the extent to which the recommended flow regime could be achieved under a range of Source-modelled water system development and climate scenarios (Table 6). The modelled development and climate scenarios used for performance testing were selected by the PAG and EMAC. Mean annual performance (summarising 122 years of modelled flow data) is provided for each reach in this section. Annual performance scores for each recommended flow component, reach and modelled scenario are provided as heat maps in Appendix A.6.

Table 6. Source modelled development and climate scenarios for performance testing.

Level of development	Climate	Description
Unimpacted	Post 1975	Assessment of the reasonableness of the recommendations had the system never been developed (i.e. natural flows with no diversions or water storages), in a current climate.
Current	Post 1975	The extent to which the recommendations are achieved under the current level of development and climate.
Current	2040 High	Performance at/near the end of the lifetime of the recommendations, with the current level of development.
Full urban and rural uptake[1]	Post 1975	Performance should all water users access their maximum entitlement each year, in a current climate.
Full urban and rural uptake[1]	2040 High	Performance should all water users access their maximum entitlement each year, under a 2040 high climate change scenario (i.e. worst case scenario).
Full urban and rural uptake[1]	2065 High	Performance should all water users access their maximum entitlement each year, under a 2065 high climate change scenario (i.e. worst case scenario).

[1] In the model, full urban and rural uptake is subject to existing operating rules including restrictions and bans. This means that users may not be able to access their maximum take limits in every year.

All flows are biocultural

The Eastern Maar *Water is Life* Nation statement describes Parreeyt as 'bio-cultural in its entirety' (EMAC 2022). EMAC reiterate that all existing flows are part of the broader biocultural flow regime of Parreeyt and should be protected, not just the technical minimum flow recommendations developed in this study using the FLOWS method.

5.1 Reach 1 – Love Creek

The overall condition of Reach 1 is moderate–poor. The management direction is to **maintain and improve flow-dependent values**, conditional on complementary non-flow related actions to reduce stock access, extend riparian fencing and revegetation, and continue to facilitate recovery of the Lower Tertiary Aquifer.

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 1.

Aquatic fauna values are moderate, with a reasonably diverse native fish assemblage (River blackfish, Southern pygmy perch, Common galaxias, Ornate galaxias, Spotted galaxias, Climbing galaxias, Southern short-finned eel, Tupong and Shorthead lamprey), very high macroinvertebrate diversity (28 taxa), and Spiny crayfish present. Platypus have been recorded once in Love Creek (Atlas of Living Australia) and suitable Platypus habitat exists and possible burrows were observed on the site assessment. Rakali are assumed present.

The riparian zone is in poor to moderate condition – narrow, fragmented, largely limited to the canopy layer, highly weedy in the shrub and ground layers, and only partly fenced. Algal biofilms occur on submerged surfaces. Instream vegetation is sparse, with few observations of fringing emergent macrophytes and submerged and floating leaved plants. No floating plants were observed during the site assessment. Parts of the Love Creek catchment have a wet microclimate. Geomorphic condition is moderate: the channel is partially confined, large wood is present, but bank undercutting and slumping were observed in October 2025 and instream geomorphic complexity is limited.

Hydrologic condition is poor, with the most severe flow impacts from development of any freshwater reach – a 61% reduction in the magnitude of 80th exceedance percentile (low) flows, and a 26% reduction in the magnitude of 20th exceedance percentile (fresh) flows during December–May (unimpacted development, historical climate compared to current development, historical climate (Alluvium 2026)). Further climate-driven reductions in flows are projected into the future. Water quality is generally good, but periodically poor, with low dissolved oxygen concentrations in low flow periods, nutrient spikes (related to livestock), and pesticides detected. Love Creek has elevated salinity compared to other study reaches, particularly during low flows (CCMA 2020), potentially due to groundwater contributions.

Reach 1 flow recommendations

The environmental flow recommendations for Reach 1 are provided in Table 7. The performance assessment point for Reach 1 is streamflow gauge 235234 (Love Creek @ Gellibrand).

Table 7. Reach 1 flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported**
Low flow	Dec – Apr	3 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6
	May	3 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported**
	Jun – Oct	10 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6, Geo2
	Nov	7 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6
Fresh	Dec - Apr	8-10 ML/day	2 events per season exceeding 8 ML/day, 1 of which should exceed 10 ML/day	5 days for 8 ML/day events 4 days for 10 ML/day event	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, Geo3
	May - Nov	60 ML/day	8 events per season	2 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, V2, Geo1, Geo3
Bankfull	Anytime	400-450 ML/day	1 per year	1 day	Geo1
Overbank	Anytime	Not set*	N/A	N/A	N/A

* Reach 1 is incised. According to the hydraulic model, no reasonable flow rate (examining partial flood series for flow rates up to an Average Recurrence Interval of 25 years) could be set that would achieve an overbank flow in Reach 1. An overbank flow recommendation was not set.

**Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish (P) Platypus (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 1 seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet and very wet conditions are provided in Table 8. Conditions where the recommended frequencies or durations are not met are coloured grey. These data suggest that, on average, the recommended number of Dec – Apr freshes may be expected to be delivered in all but very dry years. May – Nov freshes are more likely to occur in wet and very wet years. The bankfull recommendations are expected to be achieved in very wet years. Additional and longer duration freshes may be expected in very wet years.

Table 8. Reach 1 mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		Dec - Apr		May - Nov		Anytime		Anytime	
Flow component	**Fresh 8 ML/day**		**Fresh 10 ML/day**		**Fresh 60 ML/day**		**Bankfull 400 ML/day**		**Bankfull 450 ML/day**	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	5	1	4	8	2	1	1	1	1
Very Dry	1.0	5.4	0.8	3.3	2.9	2.2	0.0	N/A	0.0	N/A
Dry	2.1	6.0	1.4	4.5	6.7	2.6	0.5	1.4	0.3	1.2
Wet	2.8	6.5	2.1	4.5	9.1	3.3	0.9	1.3	0.6	1.2
Very Wet	3.6	9.2	3.0	5.8	11.4	4.2	2.5	1.4	1.6	1.5

Reach 1 environmental flow performance

The Reach 1 recommendations perform reasonably under unimpacted conditions (post 1975 climate), with low flows achieved on average 70–80% of days per applicable season per year across the 122 years of data (Figure 5). December - April freshes (8 and 10 ML/day) show lower performance even under unimpacted conditions, however as the frequencies and durations of freshes were based on annual (seasonal) medians, performance scores in the region of 40-60% for unimpacted flows are expected.

Water system development substantially reduces achievement of summer-autumn and transitional low flow recommendations, particularly the 3 ML/day December - April low flow. The May – November fresh recommendation (60 ML/day) performs consistently across development scenarios, suggesting it is less affected by development than low flows.

Climate change has a marked effect on performance, with all flow components showing lower achievement under the 2040 and 2065 climate scenarios.

Development (current and full uptake) does not impact the achievement of Bankfull events (400-450 ML/day), however, performance declines substantially under future climate scenarios.

Performance assessment indicates that current water resource development already limits achievement of the Reach 1 recommendations, particularly December - April low flows, and that climate change is expected to further reduce performance across all flow components.

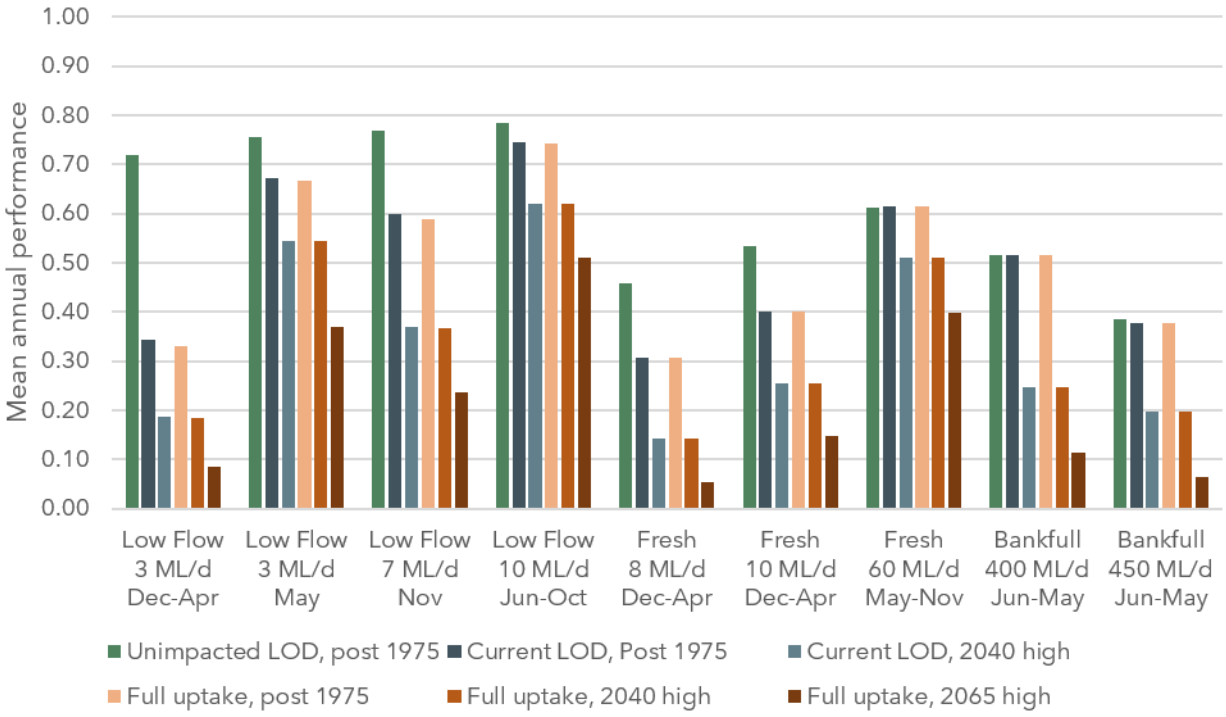

Figure 5. Reach 1 mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios.

5.2 Reach 2a – Gellibrand River (upper)

Overall condition in Reach 2a is moderate. The management direction is to **maintain and improve flow-dependent values**, conditional on complementary non-flow related actions to improve riparian fencing and weed management, and continue to facilitate recovery of the Lower Tertiary Aquifer.

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 2a.

Aquatic fauna condition in Reach 2a is moderate, with a diverse native fish assemblage including migratory species (Australian grayling, Short-finned eel, Tupong, Pouched lamprey, Shorthead lamprey, Common galaxias, Climbing galaxias) and freshwater species (River blackfish, Ornate galaxias, Southern pygmy perch, Australian smelt). Platypus and Spiny crayfish have been recorded, and Rakali are presumed present. Stevensons Falls provides partial refuge from Brown trout predation. The riparian zone is in poor to moderate condition – narrow, revegetated but only one to two trees wide, with a depauperate shrub and ground layer and significant weed presence. Instream submerged and floating-leafed plants and fringing emergent vegetation are scarce. Algal biofilms are present on submergent surfaces. No floating-leafed plants were observed. No wetlands were observed at the assessed site, however billabong soaks are present in the broader reach. Upper reach 2a has a wet microclimate. Geomorphic condition is moderate: the channel is partially confined with large wood and log jams present, though bank slumping was observed and sand deposition is increasing in the mainstem.

Hydrologic condition is moderate–poor, with development reducing the magnitude of summer-autumn 80th exceedance percentile flows by 17% and the magnitude of 20th exceedance percentile flows by 28% (modelled unimpacted development in an historic climate, compared to modelled current development in an historical climate). Hydrology in Reach 2a is compounded by operation of West Gellibrand Reservoir and reductions in groundwater contributions associated with Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield and climate-driven reductions across all months. Spot water quality data is available for this reach.

Reach 2a flow recommendations

The environmental flow recommendations for Reach 2a are provided in Table 9. The performance assessment point for Reach 2a is active streamflow gauge 235231 (Gellibrand River @ Raffertys Lane).

Table 9. Reach 2a flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	20 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V5, V6
	May	26 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V5, V6
	Jun – Oct	60 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V5, V6, Geo2
	Nov	45 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V5, V6

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Fresh	Dec - Apr	60 ML/day	2 per season	4 days	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, Geo3
	May - Nov	220-250 ML/day	8 events of 220 ML/day per season, 7 of which should exceed 250 ML/day	4 days for 220 ML/day events 3 days for events exceeding 250 ML/day	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, V2, Geo1, Geo3
Bankfull	Anytime	1000 ML/day	1 event per year	1 day	Geo1
Overbank	Anytime	1530 ML/day	1 event per 5 years	1 day	F3, M1, Geo1, Geo4

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 2a seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet and very wet conditions are provided in Table 10. Climate conditions under which the recommended frequencies or durations are not expected to be met are coloured grey.

These data suggest that in an unimpacted, post 1975 flow regime, the recommended number of freshes are expected to occur in wet and very wet conditions, with fewer fresh events expected on average in dry and very dry years. When the freshes do occur in dry and very dry years, they are expected (on average) to be of the recommended duration. Bankfull and overbank events are expected to occur under wet and very wet conditions, and are unlikely to occur in very dry years. Additional and longer duration freshes may be expected in very wet years.

Table 10. Reach 2a mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		May - Nov		May - Nov		Anytime		Anytime	
Flow component	Fresh 60 ML/day		Fresh 220 ML/day		Fresh 250 ML/day		Bankfull 1000 ML/day		Overbank 1530 ML/day	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	4	8	4	7	3	1	1	1 in 5	1
Very Dry	0.8	4.2	4.3	3.1	3.5	3.1	0.2	1.7	0.0	1.0
Dry	1.4	4.4	7.5	4.0	6.7	3.5	0.5	1.5	0.1	1.0
Wet	2.1	5.8	8.7	4.7	8.1	4.2	1.0	1.6	0.2	1.3
Very Wet	3.2	6.0	10.2	5.7	9.8	4.9	1.8	1.8	0.4	1.6

Reach 2a environmental flow performance

The Reach 2a recommendations perform reasonably under unimpacted conditions (post 1975 climate), with low flows achieved on average 65–82% of days per applicable season per year across the 122 years. December – April freshes (37%) and 220 ML/day May – November freshes (43%) have lower performance even under unimpacted levels of development. As noted in Appendix A.4.1, the frequency of December – April freshes in Reach 2a was increased from the calculated median of 1 event to 2 events per season (without adjustment of the magnitude or duration), which helps to explain the low performance score for this flow component. The frequencies and durations of the May – November freshes and bankfull and overbank flows were based on annual (seasonal) medians, thus performance scores in the region of 40-60% for unimpacted flows are expected.

Water system development substantially reduces the achievement of December - April and transitional month low flows. Limited impacts of water system development on performance are predicted on June – October low flows and freshes. The achievement of bankfull and overbank flows is not appreciably affected by water system development. The difference between current development and full uptake is relatively small, indicating that most development-related impacts are already reflected under current conditions.

Climate change has a strong and consistent effect across all flow components, with performance declining under both the 2040 high and 2065 high scenarios. Lowest performance is observed under the full uptake, 2065 high climate scenario.

Overall, performance assessment indicates that the current level of water system development reduces achievement of the Reach 2a low flow and fresh recommendations, and climate change is expected to further reduce performance of all flow recommendations over time.

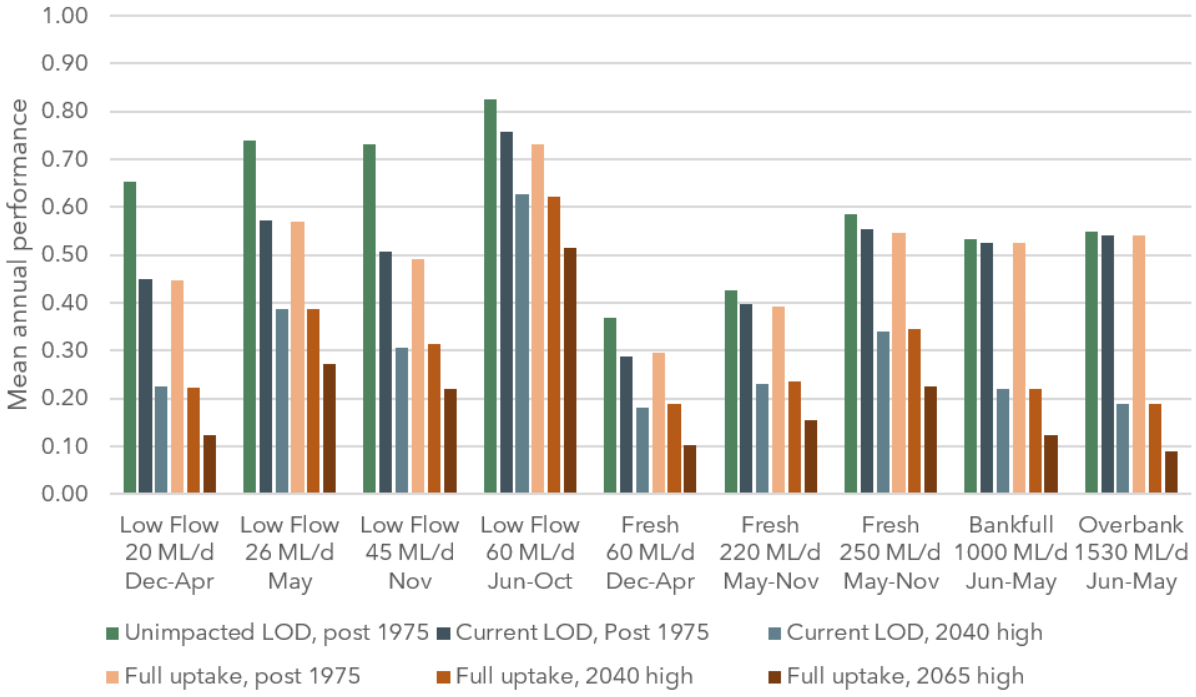

Figure 6. Reach 2a mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios

5.3 Reach 2b – Gellibrand River (mid)

Overall condition in Reach 2b is moderate. The management direction is to **maintain and improve flow-dependent values**. Relatively intact riparian and instream condition means this reach is best placed to respond to improved flow delivery in the study, but post-fire recovery monitoring and complementary sediment management will be important.

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 2b.

Aquatic fauna condition is moderate: nine native fish species were recorded including Australian grayling and River blackfish. River blackfish recruitment appears low. Platypus and Spiny crayfish are present, and the presence of Rakali is assumed. The reach supports high instream habitat diversity including boulders, cobbles, rock bars, pools, and abundant large woody debris. However, macroinvertebrate data are limited, and while the conservation-listed Otway stonefly (*Eusthenia nothofagi*) has been reported in this reach its distribution is unknown. Vegetation condition is moderate: at the October site assessment the riparian zone in the mid-reach was the most intact in the study, with continuous native forest cover extending from the stream, however this reach was directly impacted by a bushfire in January 2026. Riparian vegetation is weedy in places and submerged and floating leafed plants and fringing instream vegetation is sparse. Billabong soaks are present in the broader reach, however no directly connected wetlands were present at the assessment site. Geomorphic condition is good–moderate: the reach appears stable with an exposed rock bar, depositional benches, and large wood intact; post-fire sedimentation from January 2026 has since delivered sand to drainage lines and represents a near-term geomorphic risk.

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

Reach 2b flow recommendations

The environmental flow recommendations for Reach 2b are provided in Table 11. The performance assessment point for Reach 2b is streamflow gauge 235227 (Gellibrand River @ Bunkers Hill).

Table 11. Reach 2b flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	40 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V5, V6
	May	55 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V5, V6
	Jun – Oct	160 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V5, V6, Geo2

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
	Nov	100 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V5, V6
Fresh	Dec - Apr	110 ML/day	2 per season	7 days	F1, F2, F3, F4, FC1, P1, R1, M1, V1, Geo3
	May - Nov	450 ML/day	8 per season	5 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, Geo1, Geo3
Bankfull	Anytime	900 ML/day	5 per year	3 days	Geo1
Overbank	Anytime	1200 ML/day	4 per year	2 days	F3, M1, Geo1, Geo4

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 2b seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet, and very wet conditions are provided in Table 12. Conditions where the recommended frequencies or durations are not met are coloured grey.

These data suggest that in an unimpacted, post 1975 flow regime, peak flow events are expected to occur at the recommended frequency in wet and very wet years. When they occur in dry and very dry years, May – Nov freshes and Bankfull events are expected to be of shorter than recommended duration. Overbank events are more likely to occur in wet and very wet years. On average, overbank events are expected to occur for the recommended duration irrespective of prevailing conditions. Additional and longer duration peak flow events may be expected in very wet years.

Table 12. Reach 2b mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		May - Nov		Anytime		Anytime	
Flow component	Fresh 110 ML/day		Fresh 450 ML/day		Bankfull 900 ML/day		Overbank 1200 ML/day	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	7	8	5	5	3	4	2
Very Dry	1.0	5.5	4.7	3.8	2.4	2.7	1.4	2.5
Dry	1.9	7.3	7.8	5.0	4.8	2.7	2.8	2.5
Wet	2.3	9.0	8.9	6.4	6.0	3.3	4.2	2.8
Very Wet	3.4	10.8	10.0	7.8	7.2	4.0	6.0	3.2

Reach 2b environmental flow performance

Mean annual performance is presented in Figure 7. The Reach 2b recommendations perform reasonably under unimpacted conditions (post 1975 climate), with low flows achieved on 71-79% of days per applicable season per year. Freshes, bankfull and overbank recommendations show lower performance, even under unimpacted conditions (40% - 60%). However, as the frequencies and durations of event-based flow components were based on annual (seasonal) medians, performance in the region of 40% - 60% are expected.

In Reach 2b, the negative effect of water system development is most evident in low flow performance during December – April, May and November. Performance of December – April freshes is also reduced by water system development. The achievement of May – November freshes, bankfull and overbank events remain comparatively similar under unimpacted, current and full uptake scenarios in the post 1975 climate. The differences between current development and full uptake scenarios are relatively small, indicating that most development-related impacts are already reflected under current conditions.

Future climate scenarios have a marked effect on performance of all flow components, with poorest achievement of the recommendations projected for the 2065 high climate scenario.

Overall, performance assessment indicates that the current level of water system development reduces achievement of the Reach 2b December – April, May and November low flow recommendations and December - April fresh recommendations, and that climate change is expected to further reduce performance of all flow recommendations over time.

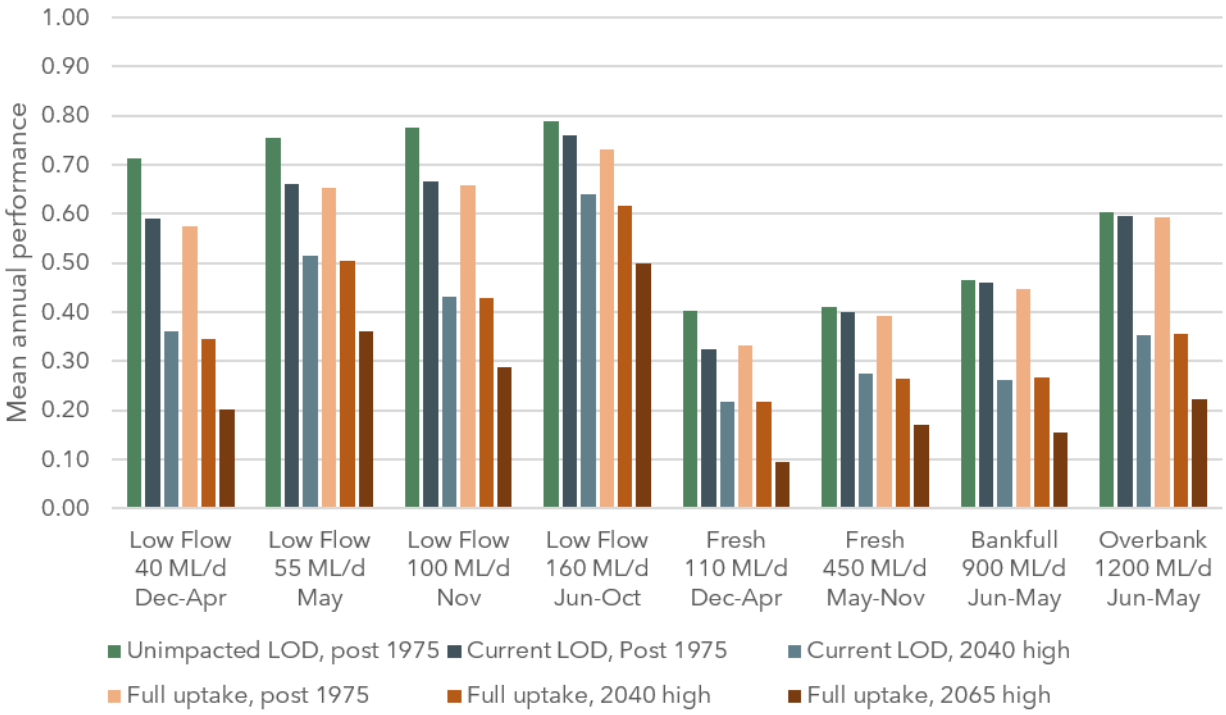

Figure 7. Reach 2b mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios

5.4 Reach 2c – Lardner Creek

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

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 2c.

Aquatic fauna condition in Reach 2c is moderate: historic records of 7 native fish species, including Short-finned eel, Tupong, Lamprey and Common galaxias. Australian grayling and River blackfish are predicted to be present (although not formally recorded), and the near-natural flow regime likely supports a diverse fauna community not fully captured in available records. Platypus and Rakali are assumed present. Vegetation condition is moderate–poor: the riparian zone is narrow, revegetated with limited fencing, and the shrub and ground layers are highly depauperate and weedy; this reflects non-flow threats more than hydrologic impacts. Very few fringing emergent macrophytes and submerged and floating leafed plants were observed. No floating plants were observed. Algae were observed on exposed coarse wood and is assumed present on submerged surfaces. Geomorphic condition is moderate: the reach is a partially confined, meandering sand bed stream with active bank erosion; significant recent bank slumping with revegetated trees falling into the stream was observed in October 2025. Salinity and turbidity in Reach 2c are typically low.

Hydrologic condition is good: Lardner Creek retains a near-natural flow regime with negligible modelled impacts of current water system development, making it the least hydrologically impacted freshwater reach in the study. Climate change is projected to reduce median flows in all months.

Reach 2c flow recommendations

The environmental flow recommendations for Reach 2c are provided in Table 13. The performance assessment point for Reach 2c is streamflow gauge 235210 (Lardner Creek @ Gellibrand).

Note: The EFTP was deliberately conservative when setting low flow recommendations for this reach, setting higher flow magnitudes, resulting in lower exceedance percentiles for low flow recommendations than for other study reaches (deviating from the 80% exceedance percentile 'rule of thumb' for low flows). This was done to preserve a greater proportion of low flows in the creek.

Table 13. Reach 2c flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	10 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6
	May	17 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
	Jun – Oct	50 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6, Geo2
	Nov	31 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V6
Fresh	Dec - Apr	30 - 50 ML/day	2 events exceeding 30 ML/day per season, 1 of which should exceed 50 ML/day	4 days for 30 ML/day events. 2 days for 50 ML/day events	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, Geo3
	May - Nov	180 ML/day	6 per season	2 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, V2, Geo1, Geo3
Bankfull	Anytime	680 ML/day	1 per year	1 day	Geo1
Overbank	Anytime	1200 ML/day	1 per 5 years	1 day	F3, M1, Geo1, Geo4

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 2c seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet, and very wet conditions are provided in Table 14. Conditions where the recommended frequencies or durations are not met are coloured grey.

The recommended number of Dec – Apr freshes are expected to occur in all but very dry years. The recommended number of freshes are expected to occur in wet and very wet conditions. Fewer freshes are expected in very dry and dry years. While bankfull and overbank events can be expected to occur under any climate conditions, they are more likely to occur in wet and very wet years. Additional and longer duration freshes may be expected in very wet years.

Table 14. Reach 2c mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		Dec - Apr		May - Nov		Anytime		Anytime	
Flow component	**Fresh 30 ML/day**		**Fresh 50 ML/day**		**Fresh 180 ML/day**		**Bankfull 680 ML/day**		**Overbank 1200 ML/day**	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	4	1	2	6	2	1	1	1 in 5	1
Very Dry	1.3	4.2	0.8	2.3	2.3	2.5	0.3	1.5	0.1	1.0
Dry	2.4	4.1	1.1	3.2	5.5	2.6	0.6	1.2	0.1	1.0
Wet	3.1	5.6	1.8	3.2	7.3	2.9	1.1	1.5	0.3	1.2

Timing	Dec - Apr		Dec - Apr		May - Nov		Anytime		Anytime	
Very Wet	4.1	8.3	3.3	4.0	8.8	3.8	1.8	1.3	0.3	1.2

Reach 2c environmental flow performance

As noted above, the EFTP were deliberately conservative when setting low flow magnitudes for Lardner Creek, deviating from the 80% rule of thumb. Consequently, the performance of low flow recommendations is lower than that observed in other study reaches, ranging from 55% - 68%. The moderate performance of freshes, bankfull and overbank flows (i.e. 44% - 64%) under unimpacted level of development (post 1975 climate) is expected, given that the recommended frequencies and durations of event-based flow components were based on annual (seasonal) medians.

Consistent with hydrologic analysis, which suggested that Lardner Creek has a largely natural flow regime, performance assessment (Figure 8) shows that water system development does not appreciably impact the achievement of flow recommendations in a current (post 1975) climate. There is no difference between the performance of the current level of development and full uptake level of development (post 1975 climate) scenarios.

Climate change is projected to decrease achievement of all flow components, with greatest declines in performance observed on overbank flows.

In summary, the precautionary approach to the setting of low flow recommendations in Lardner Creek is reflected in the lower performance score under unimpacted conditions. The current level of water system development and full uptake does not appreciably affect performance. Climate change is projected to significantly impact the achievement of the flow recommendations, particularly overbank flows.

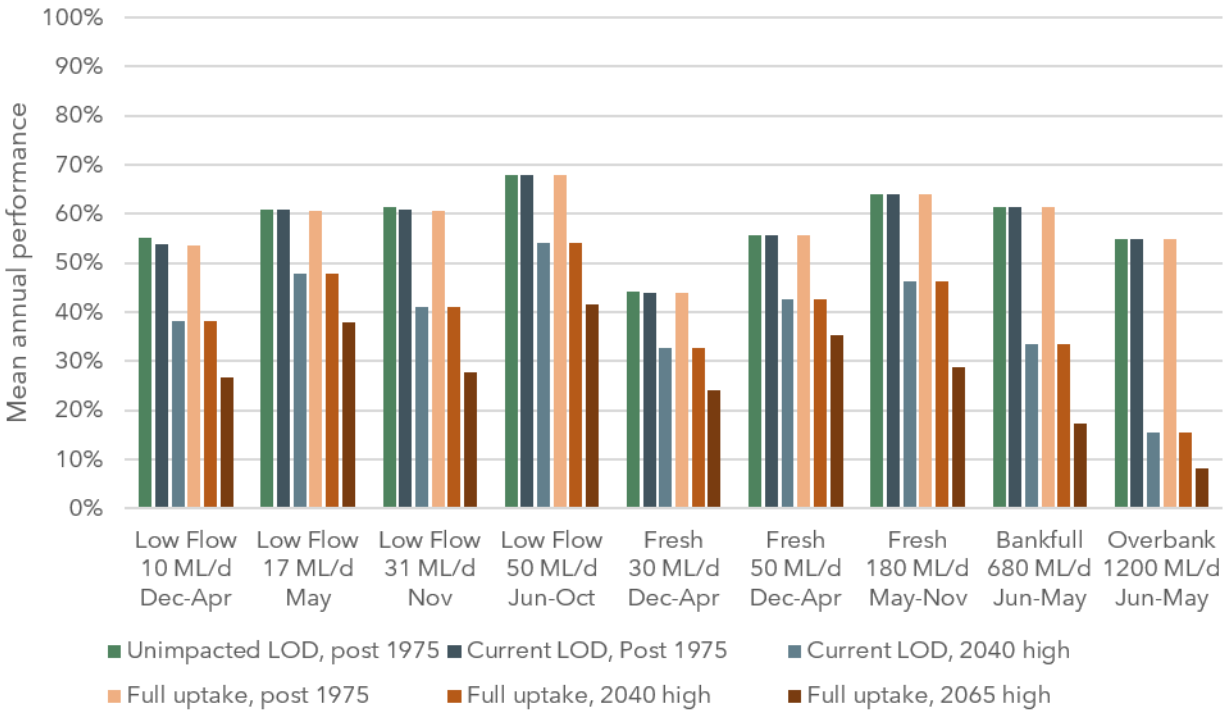

Figure 8. Reach 2c mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios.

Additional precautionary considerations for Lardner Creek

Lardner Creek has a largely natural flow regime, despite being subject to a Bulk Entitlement. This is because the annual extraction of 60 ML from Lardner Creek under the bulk entitlement is a fraction of the creek's average annual flows of 25 GL. Lardner Creek is particularly important headwater stream in the context of the Gellibrand system, providing natural seasonal flows, the potential to act as refuge for aquatic fauna, particularly during drier months (Dec – Apr), and in dry years. This importance will only increase with climate change.

Given the natural variability of flows, verbatim implementation of recommendations as a minimum flow regime, will negatively impact on the hydrology of the catchment, in contravention to the Corangamite Regional Catchment Strategy's regional water outcome: "*By 2027 there is an improvement in riparian extent and condition, hydrological regime and water quality compared to 2022 baselines in priority waterways defined in the Corangamite Waterway Strategy*" (CCMA 2021). Lardner Creek is identified as a priority waterway for economic reasons.

As noted above, the EFTP was deliberately conservative when setting low flow recommendations for this reach, resulting in lower exceedance percentiles (55%-68%) for low flow recommendations than for other study reaches. This was done to preserve a greater proportion of low flows in the creek, but has implications for the 'achievability' of low flow recommendations.

The FLOWS method is a 'building block method' for the determination of environmental flows, where flows are 'added back' to the system to protect the environment. Others have approached the setting of environmental flows through identification of the degree to which flows can deviate from the natural flow regime while still supporting river processes and ecological function. Conceptually, the greater the degree of deviation, the lower the confidence that river processes and ecological functions will be maintained. Tennant (1976) suggested that the optimum retention of mean annual natural flows (MANF) for supporting environmental values ranged from 60-100% of MANF. Richter et al. (2012) proposed a 'cumulative allowable depletion' approach to environmental flow determination and suggested that a high level of ecological protection is provided when daily flow alterations were less than 10% of the natural regime. A moderate level of protection was provided when flows were altered by 11-20% from natural flows. Daily flow alterations >20% were likely to result in moderate to major changes in structure and ecosystem function (Richter et al. 2012). Resource managers should be cognisant of daily flow alterations and implications for ecosystem function when developing rules for water allocation, take and use in Lardner Creek.

5.5 Reach 3a – Arkins Creek West Branch, Arkins Creek East Branch and First Creek

Overall condition is moderate upstream of weirs and poor downstream. The management direction is **maintain upstream values; improve values downstream of weirs**. The primary focus for flows is to maintain longitudinal hydrologic connectivity in the reach for the benefit of all flow-dependent values i.e. when there are inflows to the weirs, there should be outflows below the weirs. Environmental flow

recommendations for these creeks may inform any potential future review of the Bulk Entitlement (Otway System) Conversion Order 1997, including the introduction of passing flow obligations.

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 3a.

Aquatic fauna condition upstream of the weirs is moderate–good: crayfish burrows observed, Spiny crayfish and Climbing galaxias are anticipated, and Platypus habitat is present in both Arkins Creek branches. Downstream of the weirs, aquatic fauna condition is effectively poor during periods when weirs are not overtopped and the creeks cease to flow entirely. Vegetation condition upstream of the weirs is good: the surrounding Wet Forest (EVC 30) and Cool Temperate Rainforest (EVC 31) are largely intact, the wet microclimate is maintained by continuous stream flow, and water-dependent mosses, ferns and algal biofilms are well developed. Fringing aquatic vegetation and wetlands are absent, consistent with the steep, bedrock-confined geomorphic setting. Geomorphic condition is good: the creeks are steep, bedrock-confined systems with natural sediment throughput.

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

A note on seasonal expectations: as peak-based flow components were not set for Reach 3ai, Reach 3aii and Reach 3aiii, seasonal expectations are not provided for these reaches.

A note on performance assessment: Sub-catchment (split) flow data for inflows under unimpacted post 1975 climate were used to derive the low flow recommendations for Arkins Creek West Branch, Arkins Creek East Branch and First Creek. Sub-catchment (split) flow data for inflows under different climate scenarios (unimpacted level of development in 2040 high and 2065 high climates) were used to assess performance under climate change.

Flow recommendation performance under different levels of development could not be assessed because modelled outflows below the Reach 3a weirs were only available as a pooled dataset, and there was no appropriate basis for apportioning these outflows between Reach 3ai, Reach 3aii and Reach 3aiii.

Reach 3ai Arkins Creek West Branch flow recommendations

The environmental flow recommendations for Reach 3ai are provided in Table 15. The performance assessment point for Reach 3ai is streamflow gauge 235205 (Arkins Creek West Branch @ Wyelangta), which is located downstream of the Arkins Creek West Branch weir. There are no flow gauges upstream of the weir.

Table 15. Reach 3ai flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	1.6 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	May	2.8 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Jun – Oct	9 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Nov	5.4 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 3ai environmental flow performance

Low flow recommendations are assessed to have good mean annual achievement in Arkins Creek West Branch (77% - 80%) based on modelled unimpacted inflow to the weir, in a current (post 1975) climate (Figure 9). These performance scores are expected, given the hydrologic approach taken to develop the low flow recommendations. The achievement of low flow recommendations decreases with climate change (2040 high and 2065 high climate projections), with greatest impacts observed on the achievement of the November low flow recommendation.

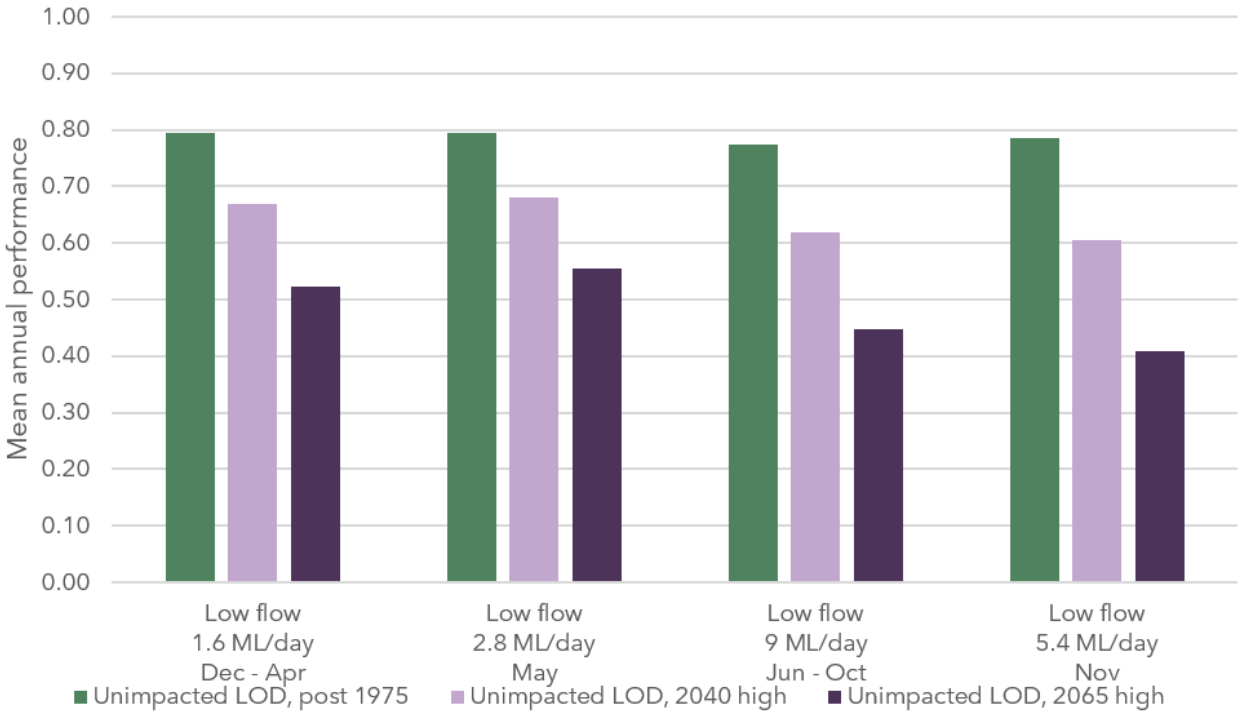

Figure 9. Reach 3ai mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under climate scenarios.

Reach 3aii Arkins Creek East Branch flow recommendations

The environmental flow recommendations for Reach 3aii are provided in Table 16. Arkins Creek East Branch is currently ungauged. A relationship with streamflow gauge 235 205 (Arkins Creek West Branch @ Wyelangta) could be developed to monitor performance in Reach 3aii.

Table 16. Reach 3aii flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	1.1 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	May	1.9 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Jun – Oct	6 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Nov	3.6 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 3aii environmental flow performance

As for Reach 3ai, good achievement of low flow recommendations is conceivably possible under unimpacted flows in a post 1975 climate (77% - 79%, Figure 10). Climate change (2040 high and 2065 high projections) impacts the achievement of low flow recommendations in all seasons. Note: Similar performance patterns are seen for all Reach 3a sub-reaches due to splitting of modelled inflow data based on sub-catchment area, and the application of a hydrologic approach to the determination of low flow recommendations.

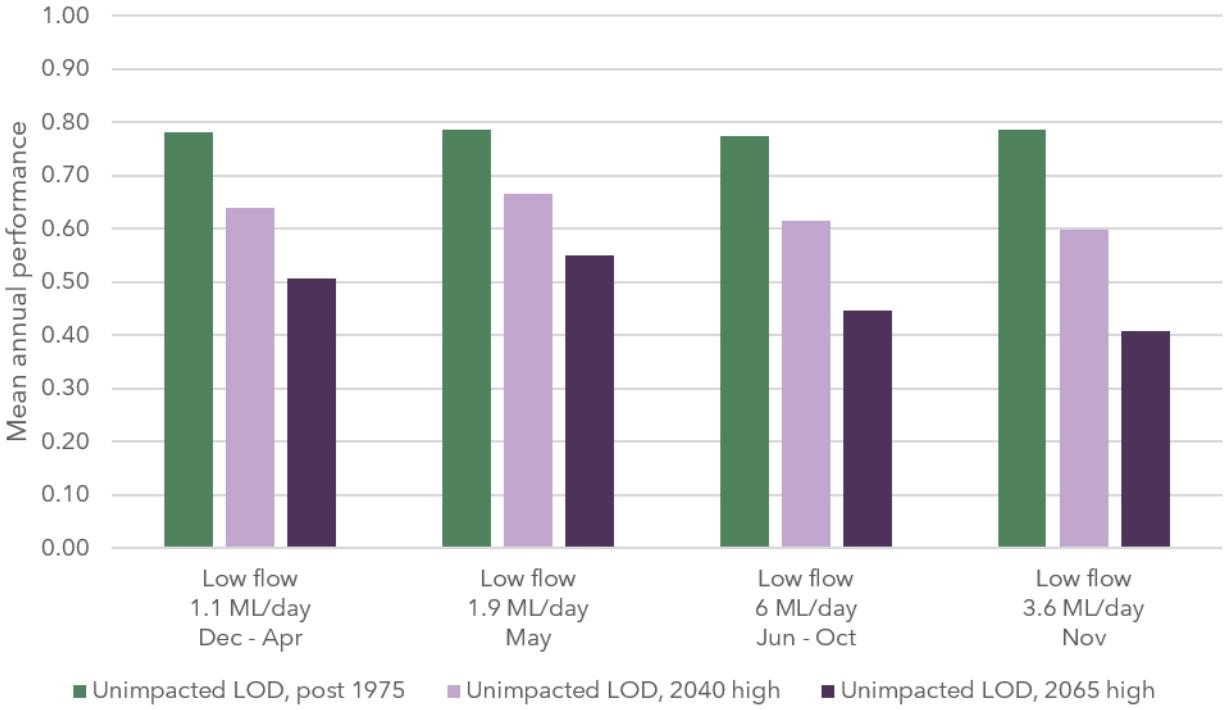

Figure 10. Reach 3aii mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under climate scenarios

Reach 3aiii First Creek flow recommendations

The environmental flow recommendations for Reach 3aiii are provided in Table 17. First Creek is currently ungauged. A relationship with streamflow gauge 235 205 (Arkins Creek West Branch @ Wyelangta) could be developed to monitor performance in Reach 3aiii.

Table 17. Reach 3aiii flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	0.15 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	May	0.25 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Jun – Oct	0.8 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6
	Nov	0.5 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V4, V6

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 3aiii environmental flow performance

As for Reaches 3ai and 3aiii, good performance of low flow recommendations in Reach 3aiii under an unimpacted level of development and post 1975 climate (76% - 79%, Figure 11). These performance

scores are expected, given the hydrologic approach taken to develop the low flow recommendations. Poor achievement is expected with climate change, with greatest reductions in performance predicted under the 2065 high climate scenario. As noted previously for Reach 3aii, similar performance patterns are seen for all Reach 3a sub-reaches due to splitting of modelled inflow data based on sub-catchment area.

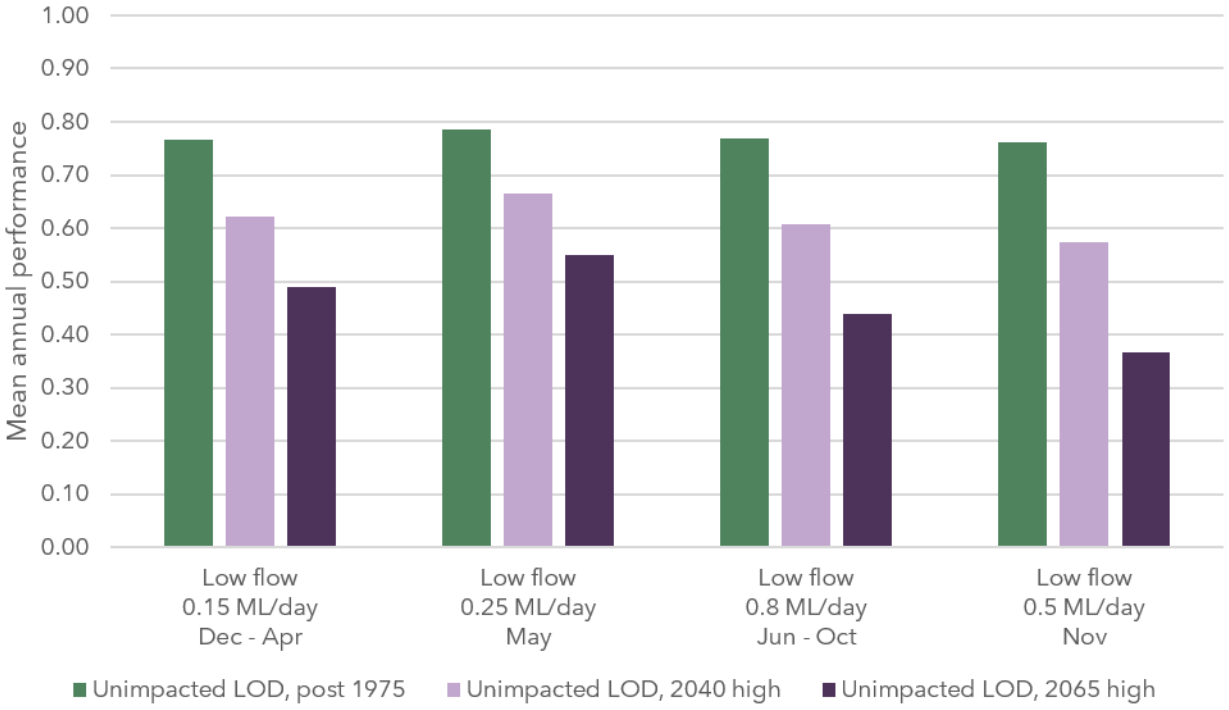

Figure 11. Reach 3aiii mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under climate scenarios

5.6 Reach 3b – Carlisle River

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

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 3b.

Aquatic fauna condition is moderate: River blackfish and Southern short-finned eel are among the seven native fish species recorded in the reach. Platypus are present, and Rakali are assumed. Macroinvertebrate condition assessed by the Waterbug Blitz showed a SIGNAL score of 4.2, indicating impacted conditions. Large woody debris and flow habitat diversity are notable positive features. Vegetation condition is moderate–poor: the riparian zone is mostly cleared in the lower sections, the narrow strips of EVC 18 Riparian Forest and EVC 17 Riparian Scrub/Swampy Riparian Woodland Complex that remain are unfenced. No floating plants, submerged and floating-leafed plants or algae were observed, however conditions may be suitable for these elsewhere in the reach. Few water-dependent mosses and small ferns were observed on exposed coarse woody debris and along lower banks Geomorphic condition is moderate–poor: the channel is incised with a low width–depth ratio, limited active depositional features, and active erosion including bank slumping that is taking revegetated plants into the stream.

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

Reach 3b flow recommendations

The environmental flow recommendations for Reach 3b are provided in Table 18. The performance assessment point for Reach 3b is streamflow gauge 235200C (Carlisle River @ Carlisle River).

Table 18. Reach 3b flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	8 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V6
	May	16 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V6
	Jun – Oct	60 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V6, Geo2
	Nov	33 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V3, V6

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Fresh	Dec - Apr	30-40, 60 ML/day	3 events exceeding 30 ML/day per season, 2 of which should exceed 40 ML/day, and 1 of which should exceed 60 ML/day	9 days for 30 ML/day events 4 days for 40 ML/day events 3 days for 60 ML/day events	F1, F2, F3, F4, FC1, P1, R1, M1, V1, Geo3
	May - Nov	300 ML/day	5 events per season	3 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, Geo1, Geo3
Bankfull	Anytime	1150 ML/day	1 per 5 years	1 day	Geo1
Overbank	Anytime	1300 ML/day	1 per 9 years	1 day	F3, M1, Geo1, Geo4

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 3b seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet, and very wet conditions are provided in Table 19. Conditions where the recommended frequencies or durations are not met are coloured grey.

The recommended number and duration of Dec – Apr 30 ML/day freshes are expected to occur in wet and very wet years. If these freshes occur in dry and very dry years, their durations are expected to shorter than recommended duration. The recommended Dec – Apr 40 ML/day and 60 ML/day freshes are expected to occur in all but very dry conditions, with the potential for additional and longer duration events to occur in very wet years. The recommended number and duration of May – Nov freshes are expected to be met in wet and very wet years, with potential for additional and longer duration events to occur. Bankfull and overbank recommendations are expected to occur in all but very dry years, with events in very wet conditions having a longer than recommended duration.

Table 19. Reach 3b mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		Dec - Apr		Dec – Apr		May - Nov		Anytime		Anytime	
Flow component	**Fresh 30 ML/day**		**Fresh 40 ML/day**		**Fresh 60 ML/day**		**Fresh 300 ML/day**		**Bankfull 1150 ML/day**		**Overbank 1300 ML/day**	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	3	9	2	4	1	3	5	3	1 in 5	1	1 in 9	1
Very Dry	1.9	6.5	1.3	4.9	0.8	3.3	1.7	2.2	0.0	1.0	0.0	1.0
Dry	2.9	9.1	2.3	4.6	1.2	3.7	4.1	3.3	0.2	1.0	0.1	1.0
Wet	3.1	10.3	2.5	5.7	1.6	4.0	6.3	4.0	0.2	1.3	0.1	1.2
Very Wet	3.1	19.5	2.8	11.9	2.6	8.0	7.6	4.7	0.5	2.1	0.2	2.5

Reach 3b environmental flow performance

The reach 3b recommendation perform well under unimpacted conditions (post 1975 climate), with low flows achieved on average 78% - 81% of days per season per year across the 122 years of modelled data (Figure 12). Low performance is observed for the achievement of December – April 30 ML/day freshes under unimpacted, post 1975 climate scenario. The reason for this low performance score is currently unclear, however we note that Reach 3b is the only study reach requiring 3 fresh events during the December – April period, which when combined with a median 9-day duration requirement may set a particularly high bar for achievement of this recommendation. The performance scores observed for higher magnitude December – April freshes, May – November freshes, bankfull and overbank flows (47% - 58%), are expected, given that the frequencies and durations of these recommendations were based on annual (seasonal) medians.

In Reach 3b, performance analyses (Figure 12) suggest that water system development (current level of development and full uptake) is expected to decrease achievement of all low flows and December – April freshes. Development has only minor negative impacts on May - November freshes, bankfull and overbank events. Performance scores for modelled current level of water system development and full uptake level of development are similar for all flow components, thus full uptake is not predicted to further worsen achievement of flows beyond that of current development.

Climate change is expected to decrease achievement of the recommended flows for all flow components, with a particularly marked effect on bankfull events (12% achievement and 4% achievement under the 2040 and 2065 high climate scenarios, respectively).

In summary, the flow recommendations are considered reasonable under unimpacted, post 1975 climate. The performance of low flows and December – April freshes decline with water system development, and further worsens with climate change.

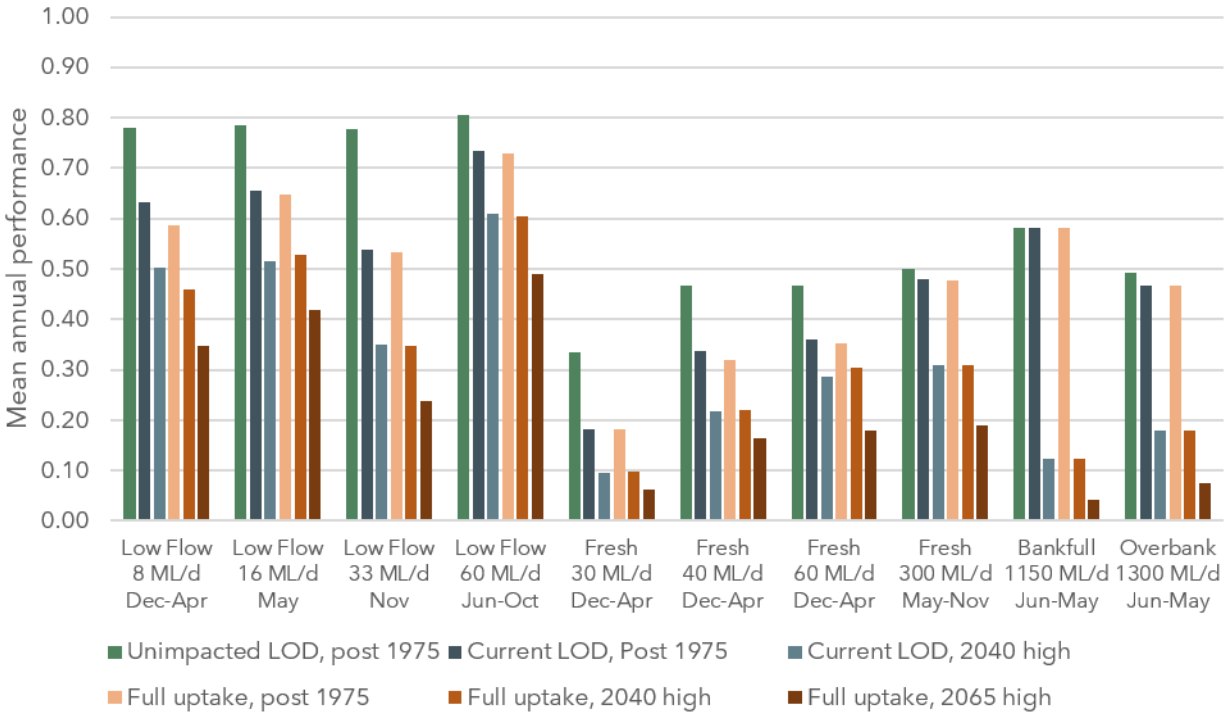

Figure 12. Reach 3b mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios.

5.7 Reach 4 – Gellibrand River Lower

Overall condition of Reach 4 is poor–moderate. The management direction is to **maintain and improve**. Significant improvement is possible with flow delivery, but the near-complete absence of riparian fencing and the extent of stock degradation mean that complementary non-flow related land management actions are required to deliver meaningful ecological gains. The floodplain wetland and billabong adjacent to the site represent a priority inundation target.

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 4.

Aquatic fauna condition is moderate: River blackfish, Australian grayling and Short-finned eel are among the 12 native fish species recorded in Reach 4. Spiny crayfish are also present. Platypus have been recorded and were directly sighted by the EFTP in October 2025. Rakali are assumed present. The reach is heavily degraded by stock access. Vegetation condition is poor: the site is largely cleared and used for cattle grazing; the riparian zone is discontinuous almost non-existent except for isolated Manna Gum; Common Reed dominates channel margins; and the reach is highly weedy and completely unfenced. Geomorphic condition is moderate: the reach is alluvial and unconfined with depositional bars and benches, a functional floodplain, and a flood runner wetland adjacent to the right bank – these are important physical assets. However, active pugging and erosion from stock access were observed, and the channel was highly turbid during the October 2025 site visit.

Hydrologic condition is poor: water system development reduces the magnitudes of summer-autumn 80th exceedance percentile (low) flows by 36%, and 20th exceedance percentile summer-autumn flows by 20%.

Climate change is projected to reduce median low-flow period flows by 13–25% and high-flow period flows by 19–22% by 2040.

Further information on the values and threats in Reach 4 is provided in the Issues Paper (Alluvium 2026).

Reach 4 flow recommendations

The environmental flow recommendations for Reach 4 are provided in Table 20. The performance assessment point for Reach 4 is streamflow gauge 235258 (Gellibrand River downstream South Otway pumps bridge). Please note that an update of the rating table for streamflow gauge 235258 is required to enable gauging of high magnitude flows at this location.

Table 20. Gellibrand River Lower (Reach 4) environmental flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported[#] *
Low flow	Dec – Apr	90 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
	May	130 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
	Jun – Oct	300 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6, Geo2
	Nov	205 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
Fresh	Dec - Apr	260 ML/day	2 per season	7 days	F1, F2, F3, F4, FC1, P1, R1, M1, V1, Geo3
	May - Nov	1800 ML/day	4 per season	4 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, Geo1, Geo3
Bankfull	Anytime	3700 ML/day	1 per year	3 days	Geo1
Overbank	Anytime	4700 ML/day	1 per year	2 days	F3, M1, V7, Geo1, Geo4

[#]Note, aquatic fauna objectives F5, F6 and F7 relate to estuarine resident fish, estuary connection to the marine environment and estuary habitat, respectively. These objectives are supported by the Reach 4 recommendations and the Gellibrand estuary flow recommendations set by Lloyd et al. 2008.

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 4 seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet, and very wet conditions are provided in Table 21. Conditions where the recommended frequencies or durations are not met are coloured grey.

The recommended number and duration of freshes are expected to occur in wet and very wet years. Fewer than the recommended number of freshes are expected in dry and very dry years. When freshes occur in very dry years, on average they are expected to be of shorter than recommended duration. While

bankfull and overbank events can occur under any climate condition, they are more likely to occur at the recommended frequency under wet and very wet conditions. Additional and longer duration peak flow events may be expected in very wet years.

Table 21. Reach 4 mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		May - Nov		Anytime		Anytime	
Flow component	Fresh 260 ML/day		Fresh 1800 ML/day		Bankfull 3700 ML/day		Overbank 4700 ML/day	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	7	4	4	1	3	1	2
Very Dry	1.3	5.4	1.3	3.7	0.2	4.3	0.1	1.3
Dry	1.7	7.8	3.5	4.4	0.8	3.1	0.5	2.7
Wet	2.6	8.1	5.3	5.8	1.8	3.1	1.2	2.2
Very Wet	3.0	12.1	6.8	7.2	3.2	3.9	2.0	3.0

Reach 4 environmental flow performance

Mean annual performance for Reach 4 recommendations is presented in Figure 13. Good performance of low flow recommendation (80% - 87%) is expected under modelled unimpacted, post 1975 climate conditions. Consistent with observations in other reaches, the lowest performance is observed for December – April freshes (39%). Performance scores in the region of 40-60% are expected for freshes, bankfull and overbank flow components (39% - 59% observed), as the frequencies and durations of these events are based on annual (seasonal) medians.

Current water system development substantially reduces the achievement of low flow recommendations, particularly in December – April, May and November, while the June-October low flow recommendation remains comparatively well achieved. Full uptake under the post 1975 climate produces only a small additional reduction in performance relative to current development. Freshes, bankfull and overbank flows are less affected by development than low flows.

Climate change is projected to cause a broad decline in performance across all flow components with substantial climate-related reductions projected for December – April low flows, May – November freshes, bankfull and overbank events.

Overall, the assessment indicates that development already constrains low flow achievement in Reach 4. Climate change is expected to further reduce achievement of all flow components, in all seasons, at the end of the recommendations' lifetime (2040) and beyond.

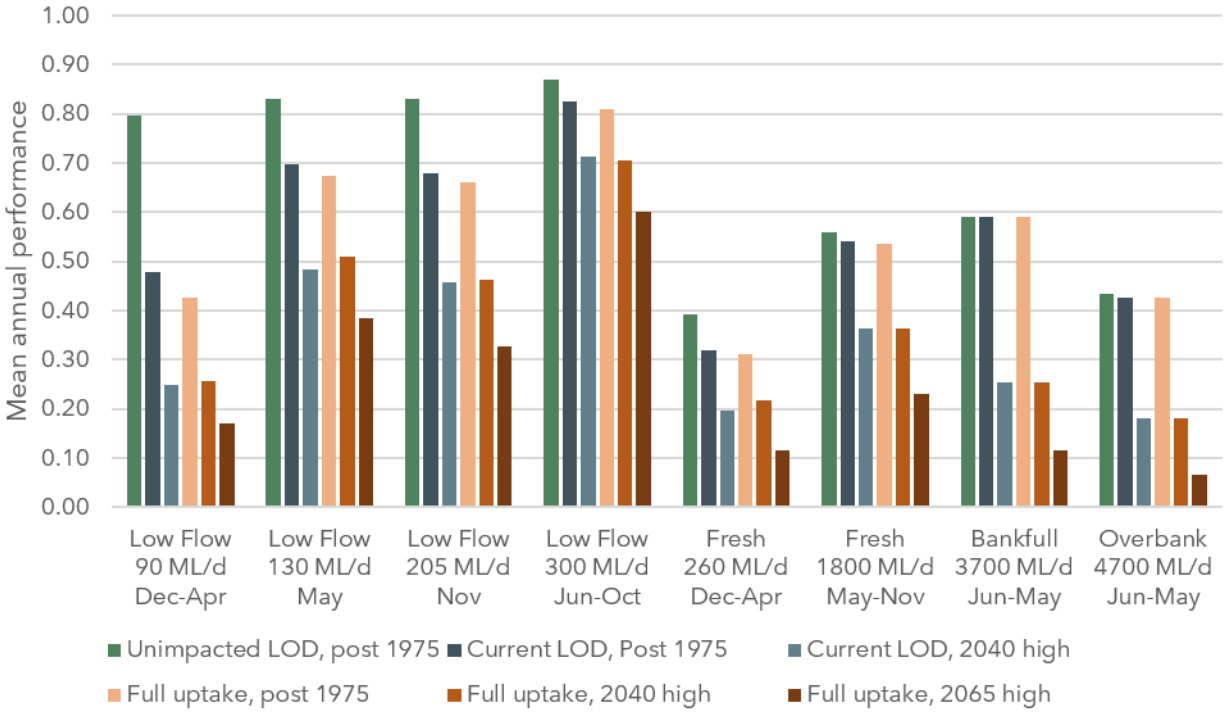

Figure 13. Reach 4 mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios.

5.8 Reach 5 – Kennedys Creek

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

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 5.

Aquatic fauna condition is moderate: Platypus and Spiny crayfish are recorded, suitable fish habitat exists and there are no known fish barriers, but the species assemblage (consisting of four native species: Southern pygmy perch, Common galaxias, Southern short-finned eel and Spotted galaxias) is sparser than other reaches. Macroinvertebrate data are absent. Vegetation condition is poor: the sub-catchment is largely cleared for agriculture, the riparian zone is highly variable in condition with some sections entirely lacking native vegetation. Common Reed dominates channel margins, and the reach is unfenced at the FLOWS study site. Geomorphic condition is moderate: the channel is unconfined with pool–riffle morphology, instream timber, and a billabong depression present at the site – positive physical features.

Hydrologic condition is poor: the most severely impacted unregulated reach in the study, with a 57% reduction in summer-autumn 80th exceedance percentile (low) flows and 44% reduction in moderate (20th exceedance percentile) summer-autumn flows, despite Kennedys Creek not being subject to surface water Bulk Entitlement extractions. The drivers behind these reductions are not fully resolved but may include take-and-use licences, pumping for domestic and stock use or potentially, farm dams. Climate

change is projected to reduce low-flow period flows by 27–37% and high-flow period flows by 11–23% by 2040. Water quality in October 2025 was very poor (highly turbid, chocolate-brown). Spot water quality data indicate times of poor water quality (including 22 out of 431 months with dissolved oxygen concentrations below 3 mg/L, including a minimum reading of 0.8 mg/L which would not support fish viability).

Reach 5 flow recommendations

The environmental flow recommendations for Reach 5 are provided in Table 22. The performance assessment point for Reach 5 is streamflow gauge 235211 (Kennedys Creek @ Kennedys Creek).

Table 22. Reach 5 flow recommendations

Flow component	Timing	Magnitude	Frequency	Duration	Environmental objectives supported*
Low flow	Dec – Apr	3 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
	May	9 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
	Jun – Oct	40 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6, Geo2
	Nov	17 ML/day	All days	N/A	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V5, V6
Fresh	Dec - Apr	30 ML/day	2 per season	4 days	F1, F2, F3, F4, FC1, P1, R1, M1, V1, Geo3
	May - Nov	150 ML/day	8 per season	5 days	F3, F4 (early winter for galaxiids and grayling movement, late autumn to winter for grayling spawning), V1, Geo1, Geo3
Bankfull	Anytime	1650 ML/day	1 per year	1 day	Geo1
Overbank	Anytime	2000 ML/day	1 per 2 years	1 day	F3, M1, V7, Geo1, Geo4

*Environmental objectives codes are provided in Appendix A.2. (F) Fish, (FC) Freshwater crayfish, (P) Platypus, (R) Rakali, (M) Macroinvertebrates (V) Vegetation, (Geo) Geomorphology.

Reach 5 seasonal expectations

The mean annual frequency and durations of peak flow components in very dry, dry, wet, and very wet conditions are provided in Table 23. Conditions where the recommended frequencies or durations are not met are coloured grey.

The recommended number of Dec – Apr freshes are expected to occur in wet and very wet years. May – Nov freshes are expected to occur at the recommended frequency under all but very dry conditions. When freshes (Dec – Apr and May – Nov) occur in very dry conditions they are expected to be of shorter than recommended duration. Bankfull and overbank events are expected to occur in wet years, with potential for more frequent events in very wet conditions.

Table 23. Reach 5 mean annual frequency (number) and duration (days) of peak events under different climate conditions (unimpacted level of development, post 1975 climate)

Timing	Dec - Apr		May - Nov		Anytime		Anytime	
Flow component	Fresh 30 ML/day		Fresh 150 ML/day		Bankfull 1650 ML/day		Overbank 2000 ML/day	
	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.	Freq.	Dur.
Recommendation	2	4	8	5	1	1	1 in 2	1
Very Dry	0.8	2.8	5.1	3.4	0.0	1.0	0.0	1.0
Dry	1.5	4.7	8.4	5.0	0.5	1.4	0.4	1.1
Wet	2.5	5.5	8.6	7.1	1.2	1.5	0.7	1.4
Very Wet	3.5	6.6	9.8	9.2	2.1	1.4	1.4	1.4

Reach 5 environmental flow performance

Mean annual performance is presented in Figure 14. The reach 5 recommendations perform reasonably under unimpacted conditions (post 1975 climate). Low flows are achieved on average 76% - 77% of days per applicable season per year across the 122 years of modelled data. Freshes (December – April, and May – November) have the lowest performance of all flow components, with moderate to good performance observed for bankfull and overbank flow recommendations. As noted in Appendix 4.1, the frequency of December – April freshes in Reach 5 was increased from the calculated median of 1 event to 2 events per season (without adjustment of the magnitude or duration), which helps to explain the low performance score for this flow component. As noted previously, performance scores in the region of 40% - 60% are expected for freshes, bankfull and overbank flow components (40% - 66% observed in Reach 5), as the frequencies and durations of event-based flow components were based on annual (seasonal) medians.

Water system development reduces achievement of low flows, with particularly marked impacts during December – April and May. Declines in performance due to development are also projected for November low flows and December – April Freshes. Water system development is modelled to have minor to negligible negative impacts on the mean annual achievement of June – October low flows, May – November freshes and channel forming flows (bankfull and overbank).

Climate change is modelled to decrease performance of all flow components, with large reductions in performance projected for December – April low flows, and bankfull and overbank events.

In summary, performance assessments indicate that while reasonable under an unimpacted development post 1975 climate scenario, some recommendations are poorly achieved under current water system development, particularly December – April low flows. Achievement of the flow recommendations is projected to further worsen in a modelled 2040 and 2065 climate.

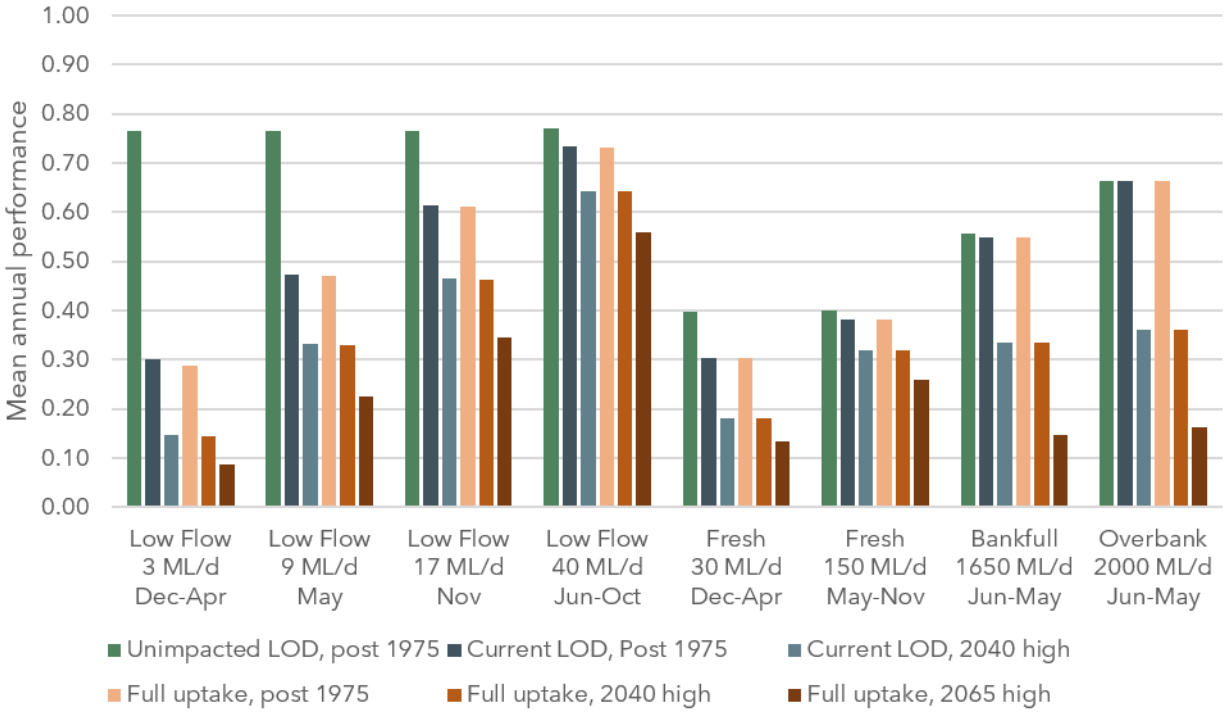

Figure 14. Reach 5 mean annual performance of flow recommendations (summarising the annual performance scores from 122 years of modelled flow data) under six development and climate scenarios.

5.9 Reach 6 – Gellibrand estuary

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

Please refer to the Gellibrand FLOWS Study Issues Paper (Alluvium 2026) for further detail on this qualitative condition summary and the condition descriptions provided below for Reach 6.

Aquatic fauna condition is good–moderate (Alluvium 2026): the estuary supports up to 29 fish species, is nationally important for waterbird diversity (48 species, 1,406 individuals recorded in 2010), and Platypus have been observed in the estuarine reach. The estuarine community is broadly intact but subject to periodic fish kill risk during mouth-closure events and artificial opening drawdowns. Vegetation condition is good–moderate: the estuary contains a diverse and floristically rich assemblage of estuarine EVCs, the estuarine community is listed as an endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999*. There is unrestricted livestock access to parts of the Gellibrand estuary and floodplain that has significant potential to impact vegetation. Geomorphic condition is good: estuarine depth profiles measured in March 2025 showed little change since 1982, and estuary hydrodynamics appear largely unaltered since the 2008 EEFAM study.

Hydrologic condition is moderate (Alluvium 2026): freshwater inflows from the catchment (modelled unimpacted level of development, historical climate vs current level of development, historical climate)

are subject to a 32% reduction in the magnitude of summer-autumn 80th exceedance percentile (low) flows at the Burrupa gauge. Moderate climate-driven reductions are predicted across all months projected to 2040; the estuary remains an intermittently open and closed system broadly consistent with its natural behaviour. Water quality is generally fair across the estuary, with improvements in dissolved oxygen in recent years. Water quality is periodically poor following estuary openings (Alluvium 2026).

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

Note: As the recommendations have been carried from Lloyd et al. (2008), seasonal expectation analyses and performance assessment were not undertaken for the estuary
Instead, the implications of the Reach 4 freshwater recommendations for the estuary are discussed

Estuary flow recommendations

Gellibrand estuary flow recommendations, as set by Lloyd et al. (2008) for flows at the Burrupa streamflow gauge (235224) are provided in Table 24. The EFTP note uncertainty regarding the magnitude of the summer-autumn low flow recommendation. New estuary low flow objectives have been developed in this FLOWS study however there is insufficient information to revise the magnitude at this time. Further work is required (outside of the FLOWS study) to inform the setting of revised low flow magnitudes (see Section 6). The performance assessment point for freshwater inflows to Reach 6 is streamflow gauge 235224 (Gellibrand River @ Burrupa). Please note that water backups (caused by high water levels in Gellibrand estuary when the estuary mouth is closed) affect water quality at streamflow gauge 235224.

Table 24. Reach 6 flow recommendations (carried from Lloyd et al. 2008).

Flow component / condition	Magnitude	Frequency	Duration	Season	Mouth status
Summer - autumn					
Cease to flow	Not recommended				-
Low flow	100 ML/day	All days	N/A	Summer - autumn	-
Fresh (fish migration)	240 ML/day	At least 4 per season	3 days	Summer - autumn	-
Fresh (galaxiid spawning)	600 ML/day	2 per season	3 days	Autumn (March – May)	-
Winter - spring					
Low flow	No specific requirement				-
Fresh (estuarine conditions)	300 ML/day	3 per season	11 days	Winter - spring	-
Fresh (seagrass)	900 ML/day	4 per season	4 days	May – July	-
Fresh (salt flushing)	1500 / 500 ML/day	1-2 per season	4-6 days	Winter - spring	Open
Fresh (*Phragmites*)	1800 ML/day	7-8 per season	3 days	Winter - spring	Open
	200 ML/day				Closed

Flow component / condition	Magnitude	Frequency	Duration	Season	Mouth status
Fresh (*Gahnia*)	3900 ML/day	4 per year	2 days	Any month	Open
	200 ML/day				Closed
Moderate overbank	7000 ML/day	1 per year	1 day	Any month	Open

Note, aquatic fauna objectives F5, F6 and F7 relate to estuarine resident fish, estuary connection to the marine environment and estuary habitat, respectively. These objectives are supported by the estuary environmental flow recommendation and the recommendations for Reach 4.

Implications of the freshwater flow recommendations for the Gellibrand estuary

Reach 4 is located immediately upstream of the Gellibrand estuary, thus the environmental flow recommendations for Reach 4 are of direct relevance for the estuary. Note that reach 4 recommendations are set for streamflow gauge 235258, downstream of the South Otway Pumps bridge, whereas the estuary recommendations were set at the Burrupa gauge (235224). As an approximation, flows at gauge 235258 are ~90% of flows at the Burrupa gauge (235224).

Side-by-side comparison of the Reach 4 and estuary recommendations are provided in Table 25.

Table 25. Comparison of Reach 4 and Gellibrand estuary recommendations

Flow component	Reach 4 (235258)	Estuary (235224)	Comment
Summer – autumn (Dec – Apr)			
Low flow	90 ML/day	100 ML/day	The reach 4 recommendation is consistent with the estuary recommendation, noting EFTP uncertainty regarding the suitability of the estuary recommendation to meet the estuary low flow objectives
Fresh	260 ML/day (2 events, 7 day)	240 ML/day (4 events, 3 days)	The magnitude of the Reach 4 recommendation is consistent with the estuary recommendation, noting differences in the frequencies and durations.
Fresh (galaxiid spawning)	N/A	600 ML/day (2 events, 3 days)	A higher magnitude autumn (March – May) fresh recommendation was set by Lloyd et al. 2008 to support galaxiid spawning. This is equivalent to a 3% exceedance event at Burrupa in December – April (infrequent). The EFTP could not justify setting a higher magnitude autumn fresh using the FLOWS method. This estuary recommendation is not met by the Reach 4 recommendations. An equivalent reach 4 recommendation would be unachievable based on limited analysis of Source-modelled unimpacted post 1975 flow data.
Winter – Spring (Jun – Oct + Transition months)			
Low flow	300 ML/day (Jun – Oct)	N/A	Lloyd et al. 2008 set a 300 ML/day fresh, whereas in Reach 4, the EFTP has set a June – October fresh of the same magnitude. The Reach 4 low flow recommendation satisfies the estuary 300 ML/day fresh requirement to support estuarine condition.
Fresh (estuarine condition)	N/A	300 ML/day, 3 times, 11 days	
Fresh (seagrass)	1800 ML/day, 4 events 4 days	900 ML/day, 4 events 4 days	Lloyd et al. 2008 set several freshes of different magnitudes. In this FLOWS study, the magnitude of the Reach 4 recommendation (1800 ML/day) aligns with the fresh for *Phragmites*, however the frequency and durations for Reach 4 (4 events, 4 days) differ to those of the estuary recommendation (7-8 events, 3 days). The frequency and duration of freshes in Reach 4 are based on the median frequency and durations of 1800 ML/day events in spells analysis. The estuary winter-spring fresh recommendation for *Phragmites* is therefore partially met. The Reach 4 recommendation satisfies the estuary fresh requirements for seagrass and salt flushing.
Fresh (salt flushing)		1500 / 500 ML/day (1-2 events, 4-6 days)	
Fresh (*Phragmites*)		1800 ML/day (7-8 events, 3 days)	
Fresh (*Gahnia*)	N/A	3900 ML/day (4 events, 2 days)	The magnitude of the Reach 4 bankfull event is similar to that of the estuary fresh recommendation, however Lloyd et al. 2008 recommend 4 events. The frequency and duration of bankfull events was determined by spells analysis. The estuary fresh to support *Gahnia* is partially met by the Reach 4 overbank flow recommendations.
Bankfull	3700 ML/day (1 event, 3 day)	N/A	
Overbank	4700 ML/day (1 event, 2 days)	7000 ML/day (1 event, 1 day)	The Reach 4 overbank is of lower magnitude than the estuary recommendation. The EFTP could not justify setting higher magnitude overbank events based on hydraulic criteria, but note that the recommendations are minimum recommendations that occur naturally, rather than via 'managed delivery'.

The Reach 4 flow recommendations are generally consistent with the existing estuary flow recommendations, particularly for summer-autumn low flows and the magnitude of key freshes. The Reach 4 recommendations are sufficient to meet several estuary flow requirements, including those related to estuarine condition, seagrass and salt flushing. However, some estuary-specific flow requirements, including higher-frequency winter-spring freshes and certain fish migration and floodplain inundation objectives, are not fully supported by the Reach 4 recommendations. The EFTP determined that these estuary higher flow requirements could not be supported by flow recommendations based on hydraulic criteria and modelling for Reach 4, and are unlikely to be achievable based on Source-modelling data for the estuary reach.

5.10 Summary of the flow recommendations

The flow recommendations are summarised in Figure 15.

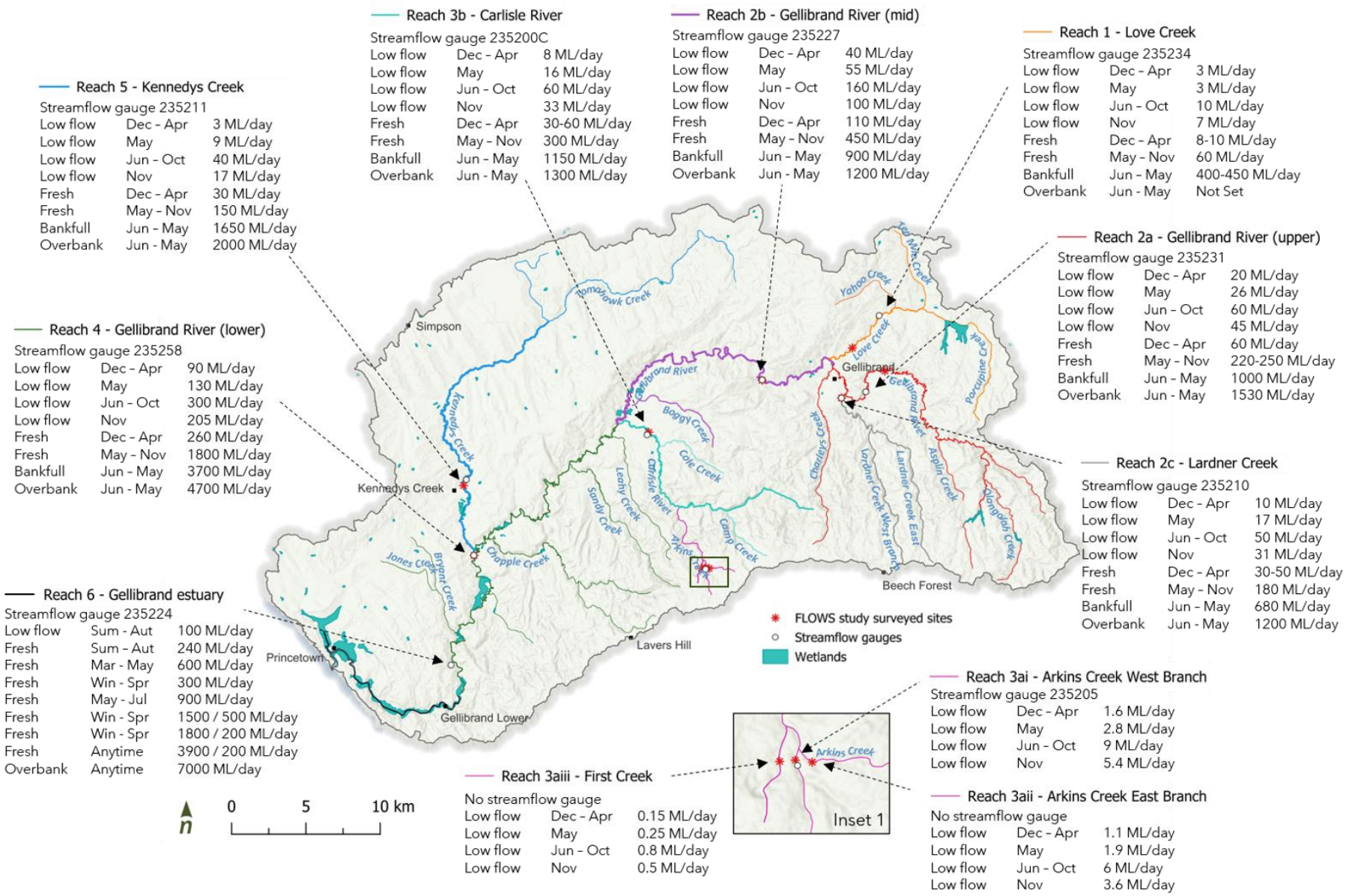

Figure 15. Summary of flow recommendations

5.11 Seasonal expectations summary and management objectives for very dry, dry, wet and very wet conditions

In regulated rivers with environmental entitlements, flow recommendations are used to inform Seasonal Watering Proposals (SWPs), in which water managers articulate how environmental flows will be delivered across the coming year. The SWPs are adjusted annually based on the volume of the environmental entitlement, previous climatic conditions, and forecasts of the upcoming year's climatic conditions. There is no current environmental entitlement or mechanism to deliver managed flows in the Gellibrand River, thus the recommendations have been framed to articulate what may be expected to occur under different climatic conditions, as opposed to what should be delivered under different climatic conditions. This helps to illustrate how achievement of the flow recommendations is expected to vary with prevailing conditions. Moreover, as water availability varies with prevailing conditions, so do the key management objectives.

A catchment level summary of seasonal expectations and potential management objectives are shown in Table 26. Please note that the seasonal expectations for each reach were presented earlier in Section 5 and are based on an unimpacted level of development and post 1975 climate.

Table 26. Flow component expectations in very dry, dry, wet and very wet years and management objectives

Climate condition	Expectations (unimpacted level of development, post 1975 climate) and management objectives
Very Dry [driest 20% of years]	**Expectations:** The recommended flow regime is unlikely to be achieved in a very dry year. Freshes are expected to occur less frequently than recommended. When they do occur, freshes are expected to be of similar duration to the recommended duration. While bankfull and overbank events can occur in very dry years, they are unlikely to occur. If they do occur, bankfull and overbank events are expected to be of similar duration to that recommended. **Management Objective: 'Protect'** Maintain refuges and critical habitats, such as critical deep pools and flow over riffles. Lardner Creek may be a particularly important refuge, given the near-natural flows in the reach. Avoid critical loss and catastrophic events (algal blooms, hypoxic water)
Dry [the next 30% of years]	**Expectations:** The recommended flow regime is expected to be partially achieved in some reaches and unlikely to be achieved in others in a dry year. Freshes may be less frequent than recommended, but have similar average durations to the recommended durations. While bankfull and overbank events can occur under any climate condition, they are less likely to occur in dry years. **Management objective: 'Maintain'** Pass through low flows and critical freshes to support life histories of aquatic fauna - preserve freshes at key migratory times. Maintain connectivity of the system.

Climate condition	Expectations (unimpacted level of development, post 1975 climate) and management objectives
	Support continued freshwater inflows to the estuary to maintain water quality and support natural mouth opening
Wet [the next 30% of years]	**Expectations:** The recommended flow regime is expected to be achieved in all reaches in a wet year. Freshes and bankfull events are more likely to occur at the recommended frequencies and durations. While overbank events may occur under any climate condition, they are more likely to occur in above-median annual flow years than in below median annual flow years. **Management Objective: 'Recover'** Improve ecological health and resilience. Improve recruitment opportunities for Indigenous flora and fauna
Very wet [the wettest 20% of years]	**Expectations:** The recommended flow regime is expected to be achieved in all reaches in a very wet year. Freshes may be more numerous and have longer durations than the recommended regime Bankfull events may be more numerous and have longer durations than the recommended regime. While overbank events may occur under any climate condition, they are more likely to occur in very wet years and to be of recommended duration **Management Objective: 'Enhance'** Restore lateral connections to wetlands, billabongs and floodplains. Maximise recruitment opportunities for vegetation and fauna.

How will managers know what type of climate condition they are experiencing, or likely to experience in coming months?

The Australian Bureau of Meteorology (BOM) provides long range forecasts (monthly and seasonal predictions) for rainfall that are consistent with the percentile climate classifications used above.

1. The BOM provides a long-range forecast for the *chance of above median rainfall*, which corresponds to the chance of climate condition being classified as wet or very wet (the climate conditions with above-median flows).

2. The BOM provides a long-range forecast for the *chance of extremes* – that is, the chance of monthly/seasonal rainfall being in the lowest 20% of the historical range, and the chance of being in the highest 20% of the historical range, for the forecast period. This forecast therefore provides an indication of whether the climate condition of upcoming months is likely to be very dry or very wet.

Taken together, these long-range forecasts provide an indication of what the expected flow regime might be compared to flow recommendations (above/below median, and on the extreme ends of the range), within the forecast period.

5.12 Rates of rise and fall

Rates of rise and fall describe how quickly flows increase or decrease between consecutive days. Excessive changes in flow can cause negative ecological impacts, including fish stranding and bank instability. In the context of environmental flows, rates of rise and fall are used by managers to avoid causing excessive changes in flow rates when transitioning between low flows and peak flow events. To minimise ecological risks from rapid, large-magnitude changes in flow rates, maximum recommended rates of rise and fall have been developed for each reach. These rates are most relevant to reaches downstream of storages (Reaches 2a, 2b and 4), where flows could be managed in the future, but are also provided for unregulated reaches should future operational arrangements change.

Recommended rates (ratios) of rise and fall are presented in Table 27 and represent the maximum day-to-day changes in flow considered consistent with the natural hydrology of each reach. For example, if the flow on day 1 is 100 ML/day and the flow on day 2 is 70 ML/day, the rate of fall is 70/100 = 0.7. If the flow on day 1 were 70 ML/day and the flow on day 2 were 100 ML/day the rate of rise would be 100/70 = 1.4.

Rates were calculated from Source modelled unimpacted daily flow data (post 1975 climate) for the period 1 July 1900 to 30 June 2022. The maximum rate of rise was defined as the 90th percentile rise ratio, while the maximum rate of fall was defined as the 10th percentile fall ratio, noting that these do not consider future climate conditions.

Table 27. Rates (ratio) of rise and fall of flows that exceed the seasonal low flow magnitude

Reach	Season	Rise	Fall
1	Dec - Apr	1.6	0.9
	May	2.2	0.8
	Jun - Oct	3.1	0.5
	Nov	3.1	0.6
2a	Dec - Apr	1.5	0.9
	May	1.8	0.7
	Jun - Oct	2.0	0.7
	Nov	1.8	0.8
2b	Dec - Apr	1.4	0.9
	May	1.7	0.8
	Jun - Oct	2.0	0.7
	Nov	1.8	0.8
2c	Dec - Apr	2.2	0.8
	May	2.7	0.7
	Jun - Oct	2.7	0.6
	Nov	2.5	0.7
3b	Dec - Apr	1.6	0.8
	May	1.8	0.8
	Jun - Oct	1.8	0.7

Reach	Season	Rise	Fall
	Nov	1.7	0.8
4	Dec - Apr	1.3	0.9
	May	1.4	0.8
	Jun - Oct	1.7	0.8
	Nov	1.6	0.8
5	Dec - Apr	2.1	0.8
	May	2.1	0.7
	Jun - Oct	3.2	0.6
	Nov	3.2	0.6

* Rates of rise and fall were not calculated for Reach 3ai, 3aii and 3aii as no peak flow recommendations were made. ** Rates of rise and fall were not calculated for Reach 6, as recommendations have been carried from the 2008 EEFAM study by Lloyd et al. 2008.

6 Recommended next steps

The new environmental flow recommendations are considered reasonable under a modelled unimpacted level of water system development, post 1975 (current) climate. However, performance assessments indicate that in most reaches, the recommendations are poorly achieved under modelled water system development scenarios (both current level of development and full uptake scenarios). The impacts of development on the achievement of flow recommendations are most obvious on low flows and freshes in December – April. Projected achievement of the flow recommendations worsens, in all reaches and more broadly across all flow components, under modelled future climate change.

Pragmatic recommendations are provided to support managers to improve achievement through integrated management of the catchment, improved coordination, and incorporation of the flow recommendations into relevant planning, policy and management instruments.

Recommendation 1. Adopt an integrated and landscape approach to management of the Gellibrand catchment

(a) Furthering collaborative relationships in the catchment

Agencies should explore options to achieve an integrated, catchment-scale approach to planning and decision-making across the Gellibrand system. This includes considering the catchment-scale implications of management decisions, recognising the authority, rights and responsibilities of Traditional Owners and ensuring they are actively involved in decisions regarding the management, allocation and protection of water, as well as strengthening the relationships developed through this FLOWS study to support ongoing collaboration.

Such an approach can improve the protection of environmental and cultural values, enhance catchment resilience, and support more effective and sustainable management of the Gellibrand River system.

(b) Embed the environmental flow recommendations into policy instruments and strategy

Agencies should explore opportunities to carry the new recommendations into revised strategy and policy instruments and to seek funds to improve achievement of the flow recommendations. Examples of relevant instruments include the Western Region Sustainable Water Strategies, the Corangamite Regional Catchment Strategy, the Corangamite Regional Waterway Strategy, Urban Water strategies, price submissions, water resource modelling, and other studies and assessments. Any limitations associated with the recommendations, including the need for further modelling and assessment (such as sea level rise modelling in the estuary), should be documented alongside the recommendations in relevant planning and management instruments. This will ensure that knowledge gaps and areas requiring further work remain visible and can be addressed through future strategies and planning processes.

Embedding the recommendations within policy and strategy instruments will support coordinated decision-making, improve alignment across agencies, guide future investment priorities, and improve the long-term protection and restoration of environmental and cultural values in the Gellibrand catchment.

Recommendation 2. Explore management levers to implement the environmental flow recommendations

At present, there are limited management levers available to support improved achievement of the recommended flows in study reaches. While the Gellibrand River proper does have upstream storages (West Gellibrand Reservoir and Olangolah Reservoir), there is no environmental entitlement to support the delivery of managed flows to Gellibrand River reaches (2a, 2b, 4 and estuary).

The environmental flow recommendations should be considered in water system operations including Bulk Entitlements and passing flow rules, Sustainable Diversion Limits, Permissible Consumptive Volumes, take and use licensing, restrictions and rostering, to consider opportunities to improve achievement of environmental flow recommendations, particularly the improvement of December - April low flows. This will become of even greater importance in a drying climate, where the recommended flows are predicted to be poorly achieved. It is recognised that infrastructure upgrades may be required to enable the passage of recommended flows downstream of existing storages and weirs. It is also understood that restrictions and bans do not apply to extractions for stock and domestic use.

Some options are available to support the achievement of recommended flows in an unregulated system. These levers are outlined further below, with relevance to the Gellibrand system. It is recommended that these options be explored further.

(a) Consider need for review of Permissible Consumptive Volumes (PCVs)

Managers should consider the FLOWS study findings, monitoring outcomes and future groundwater assessments to identify the need to review groundwater management arrangements, including PCVs, through established groundwater resource assessment, sustainable yield and local management planning processes. It is noted that development of the PCVs is also driven by monitoring of groundwater and surface water availability (see also Recommendation 3, which informs sustainable yield assessments.

(b) Explore opportunities in the application of "cease to pump" restrictions

Managers can explore opportunities to enhance rostering and implement restrictions and bans outlined in the relevant Local Management Plans (namely the Gellibrand or Newlingrook Groundwater Management Area Local Management Plans and the Otway Coast Basin Local Management Plan). The Gellibrand River surface water catchment also extends into the Paaratte and South West Limestone Groundwater Management Areas, so these may also require some further consideration. Opportunities could include:

- **Graded restrictions and bans on licensed pumping** at the recommended low flow magnitude, to ensure the passage of low flows through the system.
- **Unimpeded passage of the recommended number of freshes without extraction**. While all peak flow events perform important functions, some flows are of particular importance to waterway health – i.e. the first fresh following an extended dry period (i.e. a May fresh with break of season) to flush habitats and promote natural estuary opening, while other freshes support migration and spawning of native fish. Freshes should be allowed to pass throughout the season. Reaches typically have 4 to 8 recommended freshes in May – Nov, which equates to approximately one fresh every 1 to 2 months. Two freshes are recommended per December – April period, one of which should be passed in late summer/autumn (the Eastern Maar season of Kooyang) to support migration of Short-finned eels.

More broadly, seasonal flows are an important part of Eastern Maar's cultural connections to Parreeyt and extend beyond the ecological functions identified here.

- **Seasonally adaptive application of rules** in very dry, dry, wet and very wet conditions.
- **Multi-year application of rules** – for example, exploration of how rules should be applied in the first wet year following prolonged drought, and/or if a critical flow event is missed (for example, a fresh for to cue migration or spawning) or after wildfire event.

(c) Review adequacy of passing flow rules

Managers should explore opportunities to review and update passing flow rules to improve achievement of the flow recommendations. In reaches where passing flow rules don't currently exist, exploring mechanisms to pass flows is critical in maintaining the condition of downstream environments, noting that under the Section 46E (3) of the Victorian *Water Act 1989*, changes to Bulk Entitlements cannot be made where these directly impact water security and may be dependent on other sources coming online.

Bulk Entitlements requiring review include:

- **Bulk Entitlement (Otway system) Conversion Order 1998**, which allows extraction of up to 22.5 ML/day when flows are above 54.9 ML/day, a proportion of flows when flows are below 54.9 ML/day, and all flows when flows are less than12 ML/day. No passing flow rules currently apply to Arkins Creek and First Creek weirs.
- **Bulk Entitlement (Gellibrand) Conversion Order 1997**, which allows a maximum take of 0.43 ML/day at the Lardner Creek pump station, and all flows when the flow rate is below 0.43 ML/day.
- **Bulk Entitlement (Colac) Amendment Order 2003**, which includes (in effect) passing flows of 5 ML/day in the west branch of the Gellibrand River and 1 ML/day on Olangolah Creek at the weir.

(d) Assess the net environmental effects of potential low-flow augmentation options

Action 8-9 of the *Central and Gippsland Region Sustainable Water Strategy* (DELWP 2022b) has the Victorian Government, Wannon Water, Eastern Maar Aboriginal Corporation and Corangamite CMA working together to investigate water supply augmentation options to improve critical low flows in the Gellibrand River through the summer low flow period. As part of the SWS action, managers should assess the net environmental effects of potential low-flow augmentation options, including both reduced surface-water extraction and any changes in groundwater extraction, having regard to groundwater-surface water interaction, timing of impacts, cumulative effects and long-term system behaviour.

(e) Protect flow volumes and unallocated flows

Volumes required to achieve the recommendations should be protected from future consumptive allocation/extraction. The flow recommendations, along with the interconnectedness of surface water and groundwater systems and the role these play in sustaining flows in the Gellibrand River, should be considered as part of licencing decisions.

(f) Limit interception of flows in headwater streams (farm dams and diversions)

Managers should limit interception of flows in headwater streams (including the management of licensed and domestic and stock private dams) to maintain hydrologic connectivity and biodiversity values of the broader Gellibrand system. Headwater streams play important roles in maintaining hydrologic connectivity and supporting catchment biodiversity and riparian networks (Meyer et al. 2007, Colvin et al.

2019). Their relatively small catchment sizes make headwater streams more sensitive to changes in local conditions (Meyer et al. 2007).

In the Gellibrand catchment, flows in headwater streams are intercepted by large storages (e.g. West Gellibrand Dam), by diversions (Arkins Creek West Branch, Arkins Creek East Branch and First Creek) and by farm dams. The impacts of major water storages on biodiversity and downstream flows are well understood by managers. While individual farm dams may have small individual capacity, their abundance and widespread distribution in headwater catchments can have significant cumulative impacts on instream biodiversity and hydrology (Morden et al. 2022). Indeed, water system development is modelled to have significant impacts on hydrology in all reaches except for Reach 2c (Lardner Creek), with the greatest impacts occurring in Reaches 1 and 5, where farms dams are prevalent and there are no extractions under Bulk Entitlements.

(g) Limit additional take and use licences

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

Given the importance of groundwater discharge to some reaches of the Gellibrand River system, a precautionary approach should be taken to ensure that any future licencing decisions consider groundwater-surface water connectivity, environmental flow objectives and recommendations, groundwater-dependent ecosystems, cultural values and sustainable resource management objectives. Applications by Eastern Maar Aboriginal Corporation for unallocated surface water and groundwater in the Gellibrand River system should be supported, as per Action 6-15 of the Central and Gippsland Region Sustainable Water Strategy (DELWP 2022b), and Water is Life (DELWP 2022a).

(h) Explore ways to reduce water demand

Water managers should continue to explore ways to reduce demand on drinking water supplies from the Gellibrand catchment in the short- and long-term. This could include:

- Exploring ways managers can help improve water literacy and help communities understand where their water comes from
- Community education campaigns, such as the Make Every Drop Count campaign
- Incorporating Water Sensitive Urban Design initiatives into future developments
- Exploring opportunities to integrate alternative water sources, such as rainwater or stormwater harvesting, or recycled water schemes for non-potable uses
- Consider the potential to incentivise water conservation behaviour
- Continuing to review service levels and the role of restrictions, and monitoring whether these are achieving their intended purpose
- Detecting and fixing network leaks and optimising network maintenance to minimise water wastage.

(i) Undertake system optimisation analysis

Water managers should work together to manage flows as an integrated system. Managers should consider undertaking system optimisations analysis to identify solutions to improve the achievement of flow recommendations that consider the Gellibrand system as a whole. This would need to ensure that environmental water is protected and not just extracted further downstream.

Recommendation 3. Undertake monitoring

The following monitoring is proposed to help managers validate the flow recommendations and monitor the effectiveness of management interventions and complementary management actions. Further work is required to review existing monitoring, identify and prioritise monitoring gaps that are important to flow recommendations.

(a) Monitoring to validate the flow recommendations

Flow recommendations have been made based on hydraulic and hydrologic models. The monitoring of stream flows and depths over features at study sites is required to confirm that the hydraulic criteria are being met by the recommended flow rates. Flow recommendations should be refined where required to reflect on-ground outcomes and new evidence, as part of adaptive management of the system. Improvements to streamflow gauging are required in Reach 4 as part of this validation. These include improvements to the ratings table for streamflow gauge 235258 to enable gauging at higher flow rates, and quality control changes to enable estimates of flow at streamflow gauge 234224 when the estuary is flooded.

(b) Monitoring of estuary entrance condition

Estuary entrance conditions, water level and water quality should continue to be monitored in response to freshwater inflows, particularly low flows, to better understand the inter-relationship between flow rates, sea state, mouth condition (open / closed), water levels and water quality. EstuaryWatch citizen scientists undertake monthly monitoring in the Gellibrand estuary.

(c) Monitoring of instream and riparian vegetation in upper tributaries

Monitoring should be undertaken in upper tributaries (Arkins Creek West and East branches and First Creeks, Love Creek and Kennedys Creek) to ensure that the waterways are remaining open (i.e. are not being colonised by terrestrial vegetation) at the recommended low flow rates, and that stream values are benefitting from passing flows and other management interventions.

(d) Monitoring of groundwater-surface water interaction

Targeted, risk-based monitoring of groundwater-surface water interaction should be undertaken in areas of significant existing or proposed extraction, to better understand the area of influence, as well as gradients and fluxes over time. This will also help managers understand the 'levers' specific to this water source to support improvements in achievement of the flow recommendations.

Monitoring of different aquifer systems and the interconnectivity between groundwater and surface water systems in the Gellibrand catchment, will help inform future resource assessments and understand how these are being impacted by a changing climate. This could also help identify when additional controls

are required to protect groundwater-dependent ecosystems and surface water-dependent ecosystems in the Gellibrand catchment.

(e) Continued long-term water quality monitoring

Long term water quality monitoring across the Gellibrand River system helps managers understand trends in water quality over time and can be used to identify anomalies or changes (either improvement or decline) that may be driven by water harvesting practices, catchment management activities, land-use changes or natural disasters (e.g. floods or fires etc.). Two main types of water quality monitoring that are recommended in the Gellibrand catchment, as described below.

1) **Physicochemical parameters.** Monitoring of physical parameters such as water level, flow, temperature, electrical conductivity, dissolved oxygen, pH, turbidity are important in understanding whether conditions are suitable to support the identified environmental values. These can also be used to identify where interventions are required to sustain these values.
2) **Analytical parameters.** Laboratory analysis plays an important role in gaining a deeper understanding of what is in the water (i.e. metals, pesticides, nutrients, and organic carbon). This helps understand the drivers behind poor water quality or ecological condition and plays an important role in monitoring the effectiveness of management interventions.

Monitoring (continuous and spot) occurs at several locations in the catchment by agencies and citizen science groups (WaterWatch and EstuaryWatch), and this should be continued.

(f) Continued monitoring of environmental values

Monitoring should be undertaken to better understand plant and animal community dynamics. Long-term monitoring of plant and animal populations allows the tracking of condition and trends over time. While monitoring might not identify the cause of changes in condition, it does play an important role in identifying potential correlations/associations between ecological condition, flow, climate and management interventions in the catchment. Specific intervention monitoring and scientific research play important roles in establishing causation and answering specific ecological questions. Community involvement in ecological monitoring builds community understanding of values and their condition and supports continued community stewardship of Gellibrand waterways. Examples of monitoring that should continue in the Gellibrand system include native fish report cards (Arthur Rylah Institute) and citizen science programs such as WaterWatch, Water Bug Blitz and EstuaryWatch.

Recommendation 4. Undertake assessments and modelling to inform the update of Gellibrand estuary low flow magnitudes

Assessments and modelling should include:

(a) Estuary open state modelling

Findings of the Commonwealth Estuarine Risk Hazard Mitigation Project (once the study has been completed and the finding made available) should be reviewed to understand the relationship between freshwater inflows, sea state and Gellibrand mouth state.

(b) Estuary water quality response modelling

A water balance/water quality response model is recommended for the Gellibrand estuary that incorporates freshwater inflows, losses, and impacts on water quality (dissolved oxygen and salinity concentrations). This should also include (1) review and/or update of the 2008 EEFAM salt wedge model to understand flows required to maintain maximum extent of the salt wedge. (2) Review literature on the depth of freshwater layer / lens that is required to support ecological values in intermittently open and closed estuaries. This modelling will support managers to understand the impacts of inflows on estuary water quality to enable risks of estuary opening to be understood and mitigated.

(c) Estuary vegetation response modelling

Estuary vegetation response monitoring is recommended to understand impacts of freshwater inflow on dissolved oxygen and salinity concentrations, and the implications for estuary vegetation. This includes (1) review of the estuary vegetation assessment undertaken by Osler & Cook (2010) to understand and map the distribution and elevation of estuary EVCs, and (2) development of an estuary vegetation response model to predict vegetation responses to alternate flow regimes. Vegetation response modelling typically requires input from both a flood model and water balance modelling. At the time of writing, it is understood that a flood model is being developed for the Gellibrand Estuary as part of the upcoming Gellibrand River flood study. The flood study is anticipated to consider climate and sea level rise. A water balance model would be developed as part of recommendation 4b above. This modelling will enable the review and update of estuary environmental flow recommendations to support estuary vegetation.

(d) Estuary fish response modelling

Estuary fish response monitoring is recommended to identify the impacts of alternate flow regimes on fish communities. This model could be based on input from (1) the estuary open state modelling (2) the estuary water quality response modelling and (3) estuary vegetation response modelling. An estuary fish response model would inform the review and update of estuary environmental flow recommendations and inform understanding of fish kill risk with estuary mouth opening.

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Appendices

A.1 Environmental values

Environmental values and objectives for the FLOWS study were detailed in the Site paper (Alluvium 2025) and Issues Paper (Alluvium 2026). Pertinent content on environmental values and objectives has been brought into this appendix.

A.1.1 Geology and geomorphology

The complex geological framework of the Gellibrand catchment strongly influences hydrology and streamflow behaviour. 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.

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 1,000 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.

Implications for stream flow

The geological heterogeneity of the catchment creates distinct hydrologic 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 low flows, increasing the frequency of estuary mouth closures and associated ecological risks.

Waterway geomorphology

The Gellibrand 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 than the unconfined channel found in the mid and lower reaches. There is limited erosional change in response to changes in hydrologic and sediment regime.

Middle and lower 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 have led to increased rates of erosional adjustments in some reaches, while some remnant wet sclerophyll forests and intact geomorphic form remain in others.

Gellibrand estuary

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. A seasonally open estuary entrance is important for migration of some species (e.g. Short-finned eels) between the catchment and ocean. Artificial openings of the estuary have been undertaken, among other reasons, to prevent flooding of the Great Ocean Road.

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

Geomorphic implications for flow recommendations

Environmental flow recommendations seek to provide flow regime that mobilises, transports and deposits bed load and suspended load sediment. These flows are typically associated with high flow events including freshes, bank full and overbank events. Within the context of sediment mobilisation, transport and deposition, these higher flows serve several geomorphic roles. They:

- maintain the area / volume of channel habitat for instream fauna by preventing gross sediment accumulation and or gross channel erosion:
- maintain the condition of pool habitats by mobilising fine sediment accumulating in them
- maintain gravel bar habitat similarly by sediment mobilisation
- contribute to floodplain development and evolution as larger flows deposit river bed material in overbank flows

The provision of high flows and geomorphic processes support the attainment of objectives for dependant values such as instream and riparian vegetation, macro invertebrates, fish, aquatic mammals, amphibians, reptiles and birds.

A.1.2 Vegetation values

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.

Woody (riparian) vegetation

The most common riparian vegetation type along Gellibrand FLOWS study reaches 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.

Critical to note is that the main canopy tree, 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). Determination of environmental flows

for the freshwater reaches of the Gellibrand River and its tributaries therefore considers the flow requirements of these EVC18 Riparian Forest non-canopy species.

Algal biofilms

Algal biofilms on submerged surfaces are abundant across the Gellibrand River system 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.

Non-woody submerged and fringing vegetation

Limited instream submerged and floating leaved vegetation communities [e.g. Water Ribbons *Cycnogeton procerum* (formerly *Triglochin procera*; Eelweed *Vallisneria australis* etc.)] were observed in a number of freshwater reaches during the March 2025 site inspection. High turbidity limited instream visibility during the site assessment in October 2025, however sporadic water ribbons and starwort were observed in several sites, and may be present in other parts of the reach. Few fringing non-woody vegetation such as rushes, reeds and sedges were observed in upper reaches (Reaches 1 – 3b). Common Reed (*Phragmites australis*) was abundant in Reaches 4 and 5. Water-dependent mosses and small ferns were present on coarse woody debris and along lower banks of upper tributaries and upper reach of the Gellibrand River. Of course, submerged and fringing vegetation may be present on parts of the river not examined during the site visits, and a fuller reconnaissance would be needed to better determine their distribution and floristics. The reasons for the general lack of native submerged and floating leaved plants, and fringing emergent macrophytes is unclear, but could be due to high turbidity (preventing light penetration into the water column) in lower reaches, and low light levels / stream shading in upper tributaries.

Wet microclimate 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.

EVC 30 Wet Forest and EVC31 Cool Temperate Rainforest are largely intact in Arkins Creek West Branch, Arkins Creek East Branch and First Creeks. While recruitment is unlikely to be flow-dependent, survival of adults probably requires wet subsoils and hyporheic zone linked to continuous low flows.

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.

Estuary vegetation values

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

The vegetation of the estuary is diverse and spatially complex, with Australian Ecosystems (Osler & Cook 2010) recording 16 wetland EVCs in the Gellibrand estuary during their survey of estuaries of the broader Corangamite region. The largest single vegetation type present in the Gellibrand estuary at the time was EVC 10 Estuarine Wetland, with 103 ha. Sea Rush, *Juncus kraussii*, is the dominant species in this EVC. Two vegetation types dominated by Common Reed, *Phragmites australis*, were the next-most extensive: in the fresher areas, EVC 821 Tall Marsh (105 ha) and in the more saline areas, EVC 952 Estuarine Reedbed (64 ha). Other extensive vegetation types included the *Carex*-dominated Wet Verge Sedgeland (41 ha), the *Melaleuca*-dominated Swamp Scrub (31 ha), EVC 308 Aquatic Sedgeland (20 ha), a community dominated by robust sedges, and EVC 937 Swampy Woodland (12 ha), a community dominated by *Acacia* and *Eucalyptus* trees and shrubs. Note that none of the seven different types of coastal saltmarsh was recorded at the estuary (see Osler & Cook 2010, Table 3); similarly, Boon et al. (2015) did not report the presence of coastal saltmarsh at the site and the most recent vegetation mapping available on the NatureKit website (viewed 25 May 2026) does not indicate the presence of coastal saltmarsh anywhere in the estuary. In total, 409 ha of native estuarine vegetation was recorded by Australian Ecosystems (Osler & Cook 2010). Vegetation condition varied from high-quality, with a number of significant vegetation areas, to highly degraded, the latter often associated with grazing land. Seagrasses were not explicitly recorded, but this may have been a function of the scope of the Australian Ecosystems investigation

It is important to note that the field work for the Australian Ecosystems' investigation was undertaken in 2009. Estuarine vegetation is widely acknowledged as being spatially complex and highly dynamic (e.g.

Osler & Cook 2010, p. 7), and it is possible that the type and distribution of vegetation types supported by the estuary has changed over the intervening 15+ years.

The site visit undertaken in March 2025 was very brief and on-ground inspections were limited to a small part of the most seaward section of the estuary. Observations from this inspection are broadly consistent with the earlier descriptions of the vegetation being dominated by EVC10 Estuarine Wetland and vegetation types dominated by Common Reed, including EVC 952 Estuarine Reedbed and EVC 821 Tall Marsh. A vegetation type that corresponds to EVC 914 Estuarine Flats Grassland may also be present near the part of the estuary visited during the site inspection

Vegetation implications for environmental flow determination

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

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

These different functional groups and settings generally have contrasting wetting and drying requirements, in keeping with their position in the landscape. Different flow components have different functions in maintaining water availability and quality. Tonkin et al. (2020) developed a simple but effective summary of functions of these various flow components (Figure 16).

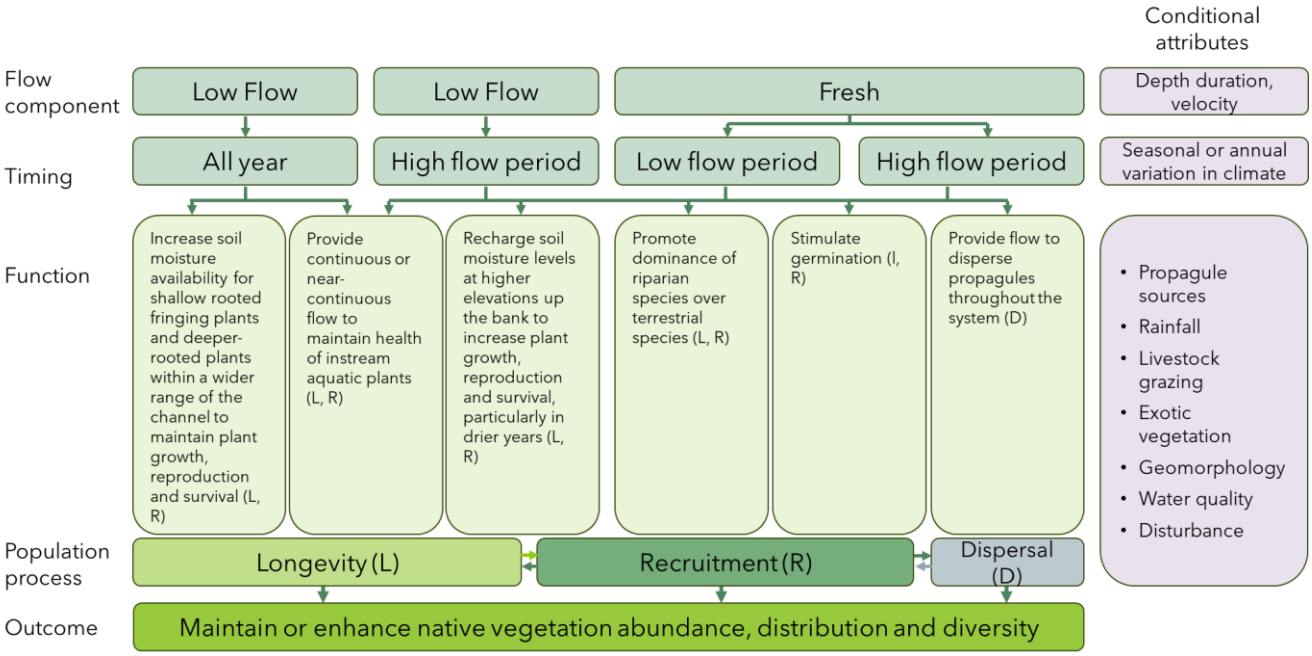


Figure 16. Conceptual model outlining the function of various flow components in maintaining water-dependent vegetation. Adapted from Tonkin et al. (2020, Figure 3.2.10).

The freshwater reaches of the Gellibrand River system are slightly unusual in that (i) they possess few values directly associated with water-dependent vegetation, and (ii) in many cases the critical threats are not flow-related. For these reasons, only a minimal set of flow components have been invoked to support vegetation objectives. The critical flows have been identified as low flows, to maintain the vegetation, and periodic freshes or high flows, to provide ecological disturbance and maintain whatever vertical zonation there is in the fringing vegetation. It is anticipated that flow components required for other values of the waterway (e.g. fish, geomorphology) will "fill in the gaps" for the specific components not identified as being essential to maintain the current vegetation values (e.g. freshes to move plant propagules downstream).

A.1.3 Aquatic fauna values

The fish of the Gellibrand River and Estuary can be classified into six groups that have different requirements (Lloyd et al. 2012). 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 17).

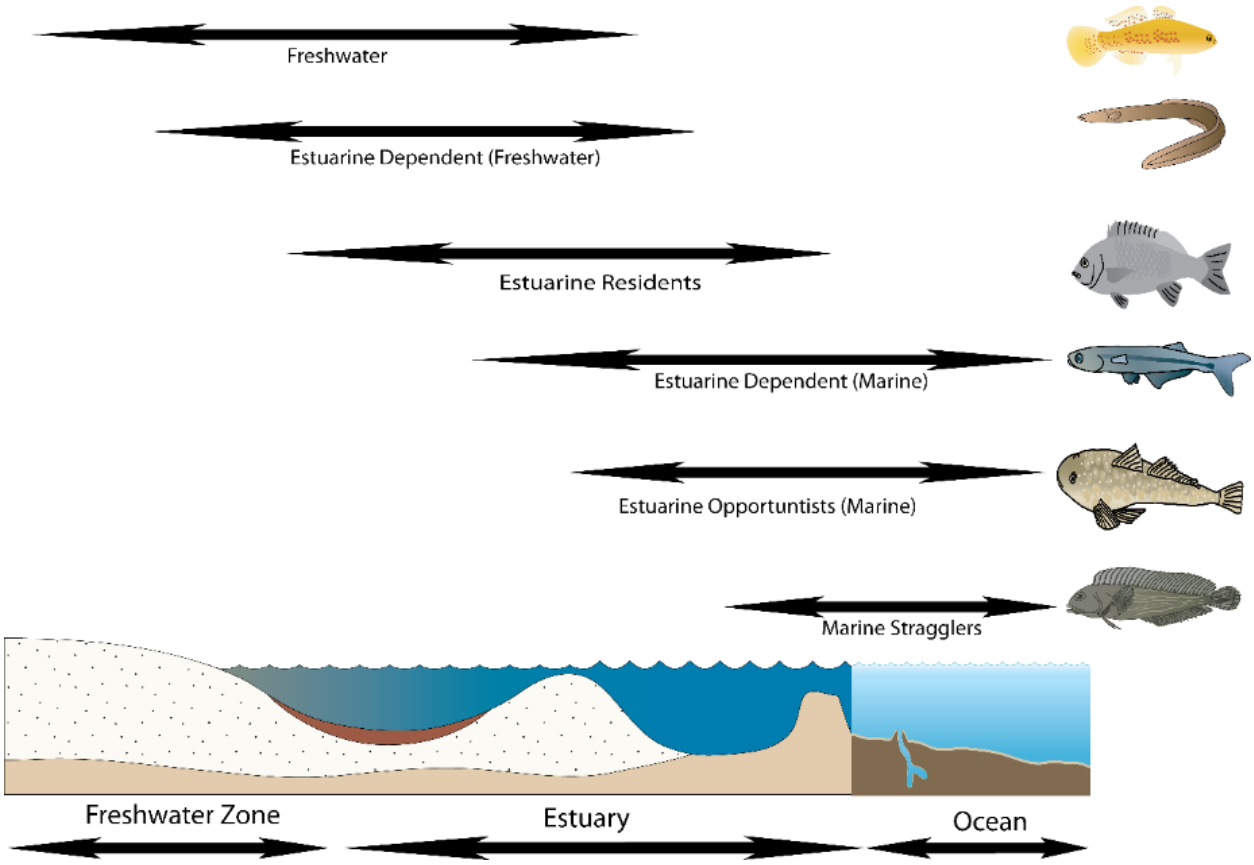


Figure 17. Fish groups in the Gellibrand River and Estuary (Source: Lloyd et al. 2012)

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 28, 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 study.

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 was not 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 are required to remove sediment from breeding habitat in hollow logs and between boulders 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 influence 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 associated with gauging weirs in the Gellibrand River catchment. Significant infrastructure-based barriers to fish passage remain, including West Gellibrand Reservoir and Olangolah Reservoir and diversion weirs in Arkins Creek West, Arkins Creek East and First Creeks (DCCEEW 2018). Barriers negatively affect both local movement and seasonal migrations of fish. Small barriers such as Arkins Creek weirs likely impede movement at low flows, whereas major barriers, such as reservoir dams, effectively eliminate movement during all flows. 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. Rakali are assumed to occur throughout the Gellibrand River and tributaries. Freshwater crayfish are found in the Gellibrand River system and their population dynamics are unknown.

Table 28. Aquatic fauna values FLOWS study reaches

(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	*Philypnodon grandiceps*	+	-	-	-	-	Freshwater								●		■
Brown Trout*	*Salmo trutta*	+	+	-	-	-	Freshwater		■	■	■	■		●	●		■
Rainbow Trout*	*Oncorhynchus mykiss*	+	-	-	-	-	Freshwater								●		
Southern Pygmy perch	*Nannoperca australis*	+	+	-	-	-	Freshwater		■	■	■				●	■	■
Australian Smelt	*Retropinna semoni*	+	+	-	-	-	Freshwater/ estuarine			■	■				●		
Common Galaxias	*Galaxias maculatus*	+	+	-	-	-	Catadromous	Downstream migration in autumn. Spawn in spring.	■	■	■	■		●	●	■	■
River Blackfish	*Gadopsis marmoratus*	+	+	-	-	-	Freshwater		■	■	■	■		●	●		
Ornate Galaxias	*Galaxias ornatus*	+	+	-	-	-	Freshwater		■	■	■	■					
Southern Shortfin Eel	*Anguilla australis*	+	+	-	-	-	Catadromous	Summer to early autumn	■	■	■	■		●	●	■	■
Pouched lamprey	*Geotria australis*	+	+	-	-	-	Anadromous	Late winter to early summer		■		■		●	●		
Spotted Galaxias	*Galaxias truttaceus*	+	+	-	-	-	Catadromous	Autumn to winter	■					●	●	■	■
Tupong	*Pseudaphritis urvillii*	+	+	-	-	-	Catadromous	Autumn to winter	■	■	■				●		■
Australian Grayling	*Prototroctes maraena*	+	+	+	V	E	Catadromous	Late summer to winter		■	■				●		
Climbing Galaxias	*Galaxias brevipinnis*	-	+	-	-	-	Catadromous	Autumn to winter	■	■		■	■	●	●		
Shorthead Lamprey	*Mordacia mordax*	+	+	-	-	-	Anadromous	Late winter to early summer	■	■	■	■		●	●		
Black Bream	*Acanthopagrus butcheri*	+	-	-	-	-	Estuarine										■
Yellow-eye Mullet	*Aldrichetta forsteri*	+	-	-	-	-	Estuarine										■
Sea Mullet	*Mugil cephalus*	+	-	-	-	-	Freshwater/ estuarine/ marine										■
Estuary Perch	*Percalates colonorum*	-	-	-	-	-	Freshwater/ estuarine										■
Smallmouthed Hardyhead	*Atherinosoma microstoma*	+	-	-	-	-	Estuarine										■
Australian Herring	*Arripis georgianus*	+	-	-	-	-	Freshwater/ estuarine										■
Largemouth Goby	*Redigobius macrostoma*	+	-	-	V	-	Estuarine										■
Scary's Tasmangoby	*Tasmanogobius lasti*	+	-	-	-	-	Estuarine										■
Longsnout Flounder	*Ammotretis rostratus*	+	-	-	-	-	Estuarine/ marine										■
Luderick	*Girella tricuspidata*	+	-	-	-	-	Estuarine/ marine										■
Silver Trevally	*Pseudocaranx georgianus*	+	-	-	-	-	Estuarine/ marine										■
Smooth Toadfish	*Tetractenos glaber*	+	-	-	-	-	Estuarine/ marine										■
Australian salmon^	*Arripis trutta*	-	-	-	-	-	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^	*Pseudogobius olorum (assumed)*	-	-	-	-	-	Estuarine		●
Tamar River Goby^	*Afurcagobius tamarensis*	-	+	-	-	-	Estuarine		●
Elongate hardyhead^	*Atherinosoma elongatum*	-	-	-	-	-	Marine derived estuarine dependent		●
Mulloway^	*Argyrosomus sp.*	-	-	-	-	-	Marine derived estuarine dependent		●
King George Whiting^	*Sillaginodes punctatus*	-	-	-	-	-	Marine derived estuarine dependent		●
Platypus	*Ornithorhynchus anatinus*	+	+	-	-	V	Freshwater		● ● ● ● ● ●
Spiny crayfish	*Euastacus yarraensis*	+	+	-	-	-	Freshwater		● ● ● ● ●
Common freshwater shrimp	*Paratya autraliensis*	-	-	-	-	-	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

Aquatic fauna implications for environmental flow determination

Environmental flows are designed to support the life histories of aquatic fauna from spawning/breeding and juvenile through to adult life stages. This includes the provision of habitat for breeding, foraging and refuge, and the provision of flow cues and longitudinal connectivity to support migratory movements.

The rationales for the development of flow objectives to support aquatic fauna are detailed in the issues paper (Alluvium 2026). In brief flow objectives include:

(1) The support of freshwater fish through the provision of habitat (depths in pools and over riffles), the maintenance of water quality in pool habitats, the flushing of sediments from habitats, and allowing for fish movement between pools

(2) the provision of freshes during fish breeding seasons to cue spawning and to enable movement of migratory species between freshwater and estuary reaches, and between the estuary and the sea.

(3) the provision of freshwater flows to the estuary to maintain estuary mouth dynamics (consistent with an intermittently open and closed estuary) and support the passage of migratory species between the freshwater, estuary and marine environments. Flows are required to maintain appropriate estuarine salinity ranges, the salt wedge and good (> 5mg / L) dissolved oxygen concentrations.

(4) Freshwater crayfish require cool, clear flowing water, therefore flow objectives include the maintenance of good water quality and pool turnover, the flushing of habitats to prevent siltation, and the provision of bankfull / overbank flows to maintain soil moisture and support riparian vegetation. Cease to flow periods should be avoided.

(5) Platypus environmental objectives aim to improve the abundance and distribution of the Platypus population, and include the maintenance of adequate depths in pools and over riffles, the provision of longitudinal connectivity to support movement between pool habitats, and the provision of scouring flows to flush silt from and maintain foraging habitats. Platypus objectives satisfy the life history requirements of Rakali.

(6) Maintenance of the macroinvertebrate communities requires maintenance of suitable low flows in all reaches at all times (Earth Tech 2006b). The low flow should be sufficient to inundate the major habitats including bed (keep damp, inundate leaf packs and woody debris), edge (inundate fringing vegetation) and riffles/runs (flowing water). Freshes are required to prevent the build-up of fine sediment on the bed of riffle habitats, to improve pool water quality during summer (through pool turnover and preventing stratification), and to disturb biofilms on rocks and woody debris in winter to maintain habitat and diversity of food sources (Earth Tech 2006b). High flows that inundate benches and overbank flows are also required to entrain organic material from outside the channel.

A.2 Environmental objectives and hydraulic criteria

The process used to develop environmental objectives was detailed in the issues paper (Alluvium 2026) and is consistent with the FLOWS method Ed. 2 (DEPI 2013). Environmental objectives for the present FLOWS study are summarised below and are carried from the Issues Paper (Alluvium 2026).

Table 29. Freshwater reach environmental objectives and hydraulic criteria

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
Fish (F1)	Maintain abundance and diversity of native fish assemblage	All	Habitat availability for all life stages (run/glide habitat)	Low flow	All year		
			Habitat availability for all life stages (riffle habitat)	Low flow	Summer - autumn	10 cm depth over riffles	Earth Tech (2006b) Alluvium (2024b)
			Maintain water quality	Low flow and Fresh	Summer - autumn	Velocity and pool turnover adequate to prevent water quality decline	See Geomorphic objectives
Fish (F2)	Improve abundance of River blackfish	1-5	As above for objective F1				
Fish (F3)	Maintain self-sustaining populations of freshwater fish (galaxias, gudgeon, pygmy perch, blackfish)	1-5	Habitat availability for small-bodied fish	Low flow	All year	% wetted area	
			Habitat maintenance – water quality	Low flow	Summer - autumn	See above	
			Refresh water quality and flush habitat Facilitate local movement	Fresh	Summer - autumn	See above 10 cm depth above low flow	Alluvium (2024b)
			Flush/disturb habitat Facilitate local movement	Fresh	Winter - spring	Velocity and shear stress adequate to remove deposited fine sediments (critical values unknown)	See geomorphic objectives
		Gellibrand mainstem where billabongs and floodplain exist	Inundate floodplain and billabong/wetland habitats	Overbank	Winter-spring, Chinnup, Larneuk	Bankfull / Overbank Inundate floodplain and billabong habitats	
Fish (F4)	Maintain self-sustaining populations of migratory species (Australian grayling, Short-finned eel, Lamprey, Tupong)	1-6	Habitat availability	Low flow	All year	Pools remain full (min 30 cm depth for Grayling)	Earth Tech (2006b)
			Prevent water quality decline (mixing and destratification)	Low flow and Fresh	Summer - autumn	Velocity and pool turnover adequate to prevent water quality decline	See geomorphic objectives
			Facilitate upstream migration of juvenile eels, facilitate	Fresh	Late summer – autumn, Kooyang		Crook et al. (2014)

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

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
			groundwater connectivity)				
Platypus (P1)	Improve condition and extent of Platypus population	1 – 6	Habitat connectivity - pools	Low flow	All Year	No fixed criteria – riffle and run flows will maintain pool depths	
			Maintain riffle habitat	Low flow	All Year	10 – 30 cm depth over riffles	Alluvium (2024b); Jacobs et al. (2016)
			Habitat maintenance and longitudinal connectivity	Low flow	Summer - autumn	Velocity and shear stress adequate to remove deposited fine sediments (critical values unknown)	
			Maintain gravel beds and flush silt	Fresh	Spring		Alluvium (2024b)
Rakali (R1)	Maintaining self-sustaining populations of Rakali		As for Platypus				
Macro-invertebrates (M1)	Maintain self-sustaining populations of macroinvertebrates	All	Maintain habitat availability (pool, riffle, slackwater)	Low flow	All year	10 cm depth over riffles, inundate leaf packs and CWD Maintain wet bed Connectivity between habitat (edge to edge)	Earth Tech (2006b)
			Maintain habitat condition (Water quality / sediment)	Low flow	Summer - autumn	Maintain water quality	Earth Tech (2006b)
				Fresh	Summer - autumn	Mobilise silt/sediment from surfaces Maintain water quality Inundate fringing veg/CWD	Earth Tech (2006b)
			Disturb biofilm and LWD/flush habitat to prevent sediment accumulation	Fresh	Winter - spring	Mobilise silt/sediment from surfaces Maintain WQ in pools	Earth Tech (2006b)
			Entrain terrestrial carbon	Overbank	Anytime (typically occur winter - spring) – Chinnup and Larneuk	Bankfull/overbank	Earth Tech (2006b)
Vegetation (V1)	Maintain, and where possible improve	All	Keep biofilms inundated	Low flow	All year	In-stream rocks and CWD submerged by low flow	Vannote et al. (1980)

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
	algal biofilms on submerged rocks and CWD	(plus Arkins Creek & associated headwaters)					
			Provide ecological disturbance: remove mature / senescent biofilms and turn-over cobbles etc, in order to create fresh habitat for new biofilms to colonise and develop	Freshes / high flows	Any time	High-flow scour sufficient to remove attached biofilms	Francoeur & Biggs (2006)
Vegetation (V2)	Maintain, and where possible improve submerged and floating-leafed plants in stream channel	1, 2a, 2c, 4 **Note:** owing to the scarcity of in-stream plants across all the reaches, this is secondary objective	Keep submerged plants inundated	Low flow	All year (short-term desiccation allowable)	> 0.5 m but < 2 m depth	Casanova (2011) Greet et al. (2011a) Roberts & Marston (2011) Rogers & Ralph (2011) Webb et al. (2013)
			Provide ecological disturbance: remove or disturb mature/senescent plants, in order to create fresh habitat for new plants to colonise and develop	Freshes / high flows	Any time	High-flow scour sufficient to remove or disturb submerged plants	
Vegetation (V3)	Maintain, and where possible improve water-dependent mosses and small ferns growing on exposed CWD and along lower banks	1, 2a, 2b, 2c, 3a, 3b	Keep fringing ferns and mosses wet (see also flow objective for maintaining damp microclimates, below)	Low flow	All year	Unknown: assume >0.5 m depth is sufficient	Jacobs (2020)

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
Vegetation (V4)	Maintain, and where possible improve damp microclimates in riparian zone	Arkins Creek & associated headwaters, Reach 1	Prevent fringing ferns and mosses from experiencing desiccation	Low flow	All year	Unknown: assume >0.5 m depth is sufficient	Ryan & McAlpine (2005) Davis et al. (2019) Jacobs (2020)
Vegetation (V5)	Maintain, and where possible improve emergent aquatic plants on lower benches and banks	2a, 2b, 4, 5	Maintain damp soils on lower benches and banks	Low flow	All year	Unknown: assume >0.5 m depth is sufficient	Brock & Casanova (1997, 2000) Casanova (2011) Greet et al. (2011b) Roberts & Marston (2011) Rogers & Ralph (2011) Webb et al. (2013) Poff & Zimmerman (2014)
	Note 1: Owing to the scarcity of fringing plants across all the reaches except for Reaches 4 & 5, this is secondary objective **Note 2**: Control of extensive swards of Common Reed may be required in Reaches 4 & 5, but this is mostly a non-hydrologic matter						
			Maintain vertical zonation of plants on benches and lower banks	Freshes	All year	Freshes sufficient to inundate benches and lower banks	
Vegetation (V6)	Maintain, and where possible with complementary actions, improve condition and extent of vegetation in the riparian zone	All Note: owing to the narrowness and generally poor condition of the riparian zone across all the reaches except for Reach 2b, this is secondary	Maintain damp sub-soils in riparian zone	Low flow	All year	Unknown: assume >0.5 m depth is sufficient	Hansen et al. (2010) Casanova (2011) Roberts & Marston (2011) Rogers & Ralph (2011) Webb et al. (2013)

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
		objective; see Hansen et al. 2010; Jones et al. 2022					Poff & Zimmerman (2014) Gawne et al. (2020)
Vegetation (V7)	Inundate wetland depressions on the floodplain on a seasonal basis	4, 5	Inundate wetland depressions to provide still-water biological habitat on the floodplain, support food-web structure etc.	Freshes / high flows	Anytime (as we have no control over high flows) but typically winter-spring	Sufficient to exceed 'Commence to Flow' for inlet channels to wetlands	Brock & Casanova (1997, 2000) Casanova (2011) Roberts & Marston (2011) Rogers & Ralph (2011) Webb et al. (2012) Gawne et al. (2020)
Geo-morphology (Geo1)	Maintain area / volume of channel habitat by preventing gross sediment accumulation and or gross channel erosion	All alluvial reaches	Maintain both the effective discharge and the total effective work i.e. the work applied by the parts of the flow regime that exceed the threshold of motion of bed and bank material	All flow components that contribute to the effective work applied to the stream channel (typically winter / spring freshes and higher)	All year	Total effective work	FISRWG 1998 Tilleard J. W (2001)
Geo-morphology (Geo2)	Maintain condition of pool habitat	All alluvial reaches	Mobilising fine sediment in the bed of pools	Fresh	Winter - spring	Threshold of motion for silts on the bed of pools	Threshold of motion studies e.g. Shields 1937

Value	Environmental objective	Reach	Flow process /function	Flow component	Timing	Hydraulic criterion	Reference(s)
Geo-morphology (Geo3)	Maintain gravel bar habitat	All alluvial reaches	Scouring biofilms from gravel bars with aid of fine sediment movement	Fresh	Summer - autumn	Threshold of motion for silts and on in-channel gravel bars	Watts et al. (2006) Informed by threshold of motion studies by Shields (1937), and more recently reviewed by Buffington and Montgomery (1997)
			Mobilising fine sediment from gravel bars	Fresh	Winter - spring	Threshold of motion for sands on in-channel gravel bars	Threshold of motion studies e.g. Shields (1937)
Geo-morphology (Geo4)	Contribute to floodplain development and evolution	Alluvial reaches i.e. with adjoining floodplains	Mobilise sediment from bed and banks onto the floodplain	Overbank events	Anytime	Threshold of motion for sands on point bars	Threshold of motion studies e.g. Shields (1937).

Gellibrand estuary environmental objectives.

An EFTP review of the 2008 EEFAM-based estuary recommendations found that estuary values and objectives have not substantially changed, and the 2008 ecological objectives and environmental flow recommendations therefore remain generally applicable. The EFTP noted uncertainty and ambiguity regarding the stated summer - autumn low flow objective and whether the nominated low flow magnitude (100 ML/day) was suitable to achieve the objective. New estuary low flow objectives were developed in this FLOWS study in a workshop involving the EFTP and PSC (Table 30). Other environmental objectives from the Gellibrand estuary environmental flows study (Lloyd et al. 2008) have been carried into this FLOWS study (Table 31).

Table 30. Revised Gellibrand estuary low flow objectives

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

Table 31. Ecological and hydrological objectives for the Gellibrand estuary (Carried from the 2008 EEFAM study by Lloyd et al. 2008)

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

Ecological and Hydrological Objectives for Coastal Salt Marsh						
2a	Depth and extent of floodplain depressions	Retain water from high estuary levels, local rainfall.	Geomorphic processes to maintain depression depth of approximately 0.5 m and current extent	N/A	N/A	Not required
2b	Flooding by saline water in summer and autumn	Promote salt-tolerant charaphytes, herbs, grasses and forbs Exclude emergent macrophytes	Peak salinity (between refreshing events) of 7.5 ppt to 20 ppt in summer and autumn in depressions	Low flow	Summer / autumn	Median salinities in shallow (<1 m deep) estuary water downstream of cross section10 exceeds 5 ppt in summer and autumn.
2c	Flooding by brackish water in winter and spring	Promote salt-tolerant charaphytes, herbs, grasses and forbs Exclude emergent macrophytes	Peak salinity (between refreshing events) of 5 ppt in winter and spring in depressions	Low flow	Winter / spring	Median salinities in shallow (<1 m deep) estuary water downstream of cross section10 exceeds 3 ppt in winter and spring
2d	Persistent flooding in winter and spring by fresh / brackish water	Promote salt-tolerant charaphytes and submerged vascular macrophytes Exclude emergent macrophytes	Persistent flooding to depth of 0.25 to 1.0 0.5 m (predominantly 0.5 m) from May to October	As per 2c	May - October	Median interval between events where water level at cross section 10 exceeds 1.5 1.0 m AHD is 2 weeks in May to October.
2e	Shallow flooding in late spring / early summer	Provide habitat for salt-tolerant grasses, sedges, herbs and forbs	Average water level from November to December is 50% of average water level from August to September	Low flow	Summer / autumn	Median interval between events where water level at cross section 10 exceeds 1 m AHD is 3 weeks in summer and autumn
2f	Intermittent flooding in summer and autumn	Maintain *Sarcocornia quinqueflora*	Depressions less than 20% of maximum depth 80% of the time over summer autumn	Low flow	Summer / autumn	Median interval between events where water level at cross section 10 exceeds 1 m AHD is 8 weeks in summer and autumn
2g	Waterlogging by saline groundwater in summer and autumn	Maintain *Sarcocornia quinqueflora*	Groundwater depth less than 0.4 m to maintain evaporative concentration of salts in surface soil. Groundwater salinity 10 to 60	N/A	N/A	No assessment possible

Ecological and Hydrological Objectives for Estuarine Scrub						
3a	Seasonal waterlogging	Maintain *Gahnia* tussock sedgeland and *Leptospermum lanigerum*	Groundwater less than 0.2 m deep for 4 to 8 months of the year	N/A	N/A	No assessment possible
3b	Low salinity groundwater	Maintain growth and health of *L. lanigerum* and *Gahnia* tussock sedgeland	Groundwater salinity less than 3000 EC	N/A	N/A	No assessment possible
3c	Infrequent inundation	Maintain *Gahnia* tussock sedgeland and *Leptospermum lanigerum*. Prevent invasion by *Phragmites australis*.	Less than 10 inundation events per year. No single inundation event longer than 10 days duration	High flow fresh	Any month	Median duration of events where water level exceeds 1.5 m AHD at cross section 9 is 1 to 2 weeks. Frequency of events where water level exceeds 1.5 m at cross section 9 is 5 per year.
3d	Inundation by brackish to fresh surface water	Maintain *Gahnia* tussock sedgeland and *Leptospermum lanigerum*. Prevent invasion by *Bolboschoenus caldwelli* and *Juncus kraussii*.	None listed	Fresh	Autumn (March – May) Winter / spring	Median salinities in shallow (<1 m deep) estuary water downstream of cross section 9 is less than 3 ppt in summer and autumn. Winter and spring salinities may this salinity or fresher.
Ecological and Hydrological Objectives for Swamp Scrub						
4a	Perennial waterlogging	Maintain dense *L. lanigerum* canopy	Groundwater less than 0.2 m deep at all times	N/A	N/A	No assessment possible
4b	Low salinity groundwater	Maintain growth and health of *L. lanigerum, P. tenuissima*	Groundwater salinity less than 1000 EC	N/A	N/A	No assessment possible
4c	Brief and infrequent inundation	Exclude aquatic macrophytes from understorey. Prevent flood stress to *L. lanigerum, P. tenuissima*.	Less than 5 inundation events per year. No single inundation event longer than 5 days duration	Moderate overbank	Any time	Median duration of events where water level exceeds 2.0 m AHD at cross section 10 is less than 1 week. Frequency of events where water level exceeds 2.0 m at cross section 10 is less than 5 per year. Zero events per year is acceptable.
Ecological and Hydrological Objectives for Herb-rich Foothill Forest						
5a	Shallow low-salinity groundwater	Maintain *Acacia melanoxylon* and *Eucalytpus ovata* overstorey	Groundwater depth less than 2 m at all times Groundwater salinity less than 1000 EC	N/A	N/A	No assessment possible
5b	Rare, brief flooding	Maintain *Acacia melanoxylon* and	Flooded to a maximum of 10 days per year.	Moderate overbank	Any time	Water level exceeds 3.0 m AHD at cross section 2 for a total of less than 10 days per year (median).

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

Ecological and hydrological objectives for King George Whiting						
8a	Entrance of larvae to estuary	Allow migration to estuary from the sea	Open Mouth August to late October	High flow fresh	August – October (Winter – spring)	Mouth 30-50cm deep during period August to October (inclusive)
8b	Larval fish habitat in estuary	Provide habitat for larvae to survive and grow	Up to 5 months (settlement in spring summer Jenkins and May 1994, Jenkins, Wheatley and Poore 1996) shallow sea grass and macroalgae. Salinities greater than 25 ppt in bottom water. DO greater than 5 mg/L in bottom water during this period.	Low flow	Spring and summer	Steady state conditions which create salinity greater than 25 ppt in bottom 1 m more than 80% of the time below cross section 12 (lowest Bridge) during spring and summer. Set maximum DO residence time of 2 days below cross section 12 (lowest Bridge) in bottom 1 m.
Ecological and hydrological objectives for Australian Grayling						
9a	Flow fresh	Adult spawning	Low salinity pulse	Low flow Fresh	Late autumn	Flow event that creates max salinity of 2 ppt at 9,600 m (third bridge) (top section of estuary or just upstream) – throughout water column in autumn.
9b	Freshwater in upper estuary	Egg development	Larvae take 14 + days to develop, they require Flow Fresh, required for a few days to develop in <5 salinity. High O_2 in pools to allow survival	Fresh	May - July	Flow event which creates salinity of less than 5 ppt at 9,600m (third bridge) in autumn or winter. Residence time of <= 2 days
9c	Estuary Mouth State	Marine Migration by larvae	Mouth open during May to July (downstream movement) Velocity create flow after the mouth open (flow sufficient to move silt downstream) Velocity sufficient to take larvae 4 days to get down to an already open mouth (from GOR Bridge – with a small mouth open)	High flow fresh	May - July	Require open mouth during May to July. Salinity is not critical - up to 35 is OK for periods of up to a 7 days with 2-3 events during the season
9d	Estuary Mouth State	*Migratory cue to return to estuary*	Uncertain. Presumed met by flows required to provide passage.	N/A	N/A	No assessment required
9e	Estuary Mouth State	Freshwater Migration to estuary from sea by juveniles	30 – 50 cm deep river mouth Mouth open during Oct – Dec (upstream migration)	High flow fresh	Oct - Dec	Require open mouth, 30 – 50 cm deep, during Oct-Dec, salinity not material, duration should be for up to 7 days with 2 – 3 events during the season

9f	Low Flow fresh	Migration from estuary to freshwater reaches by juveniles	Flow cue to migrate upstream	Fresh	Spring Dec - May	Require access to upstream reaches over riffles - Upstream riffle depth at least 0.3 m min. (Thalweg depth a bar/riffle 0.3 m) At least 2 events in spring (to provide 2 opportunities). Dec – May, min 4 events
Ecological and hydrological objectives for Common Jollytail (*Galaxias maculatus*)						
10a	High Flow Fresh	Migration to estuary in autumn before spring tides	Flow cue to migrate downstream	Fresh	Autumn	Require access to estuary over riffles - Upstream riffle depth at least 0.3 m min. At least 2 events in autumn (to provide 2 opportunities)
10b	Flooded samphire or estuarine floodplain vegetation	Adults spawning	Spring tide in autumn following migration event	Fresh	Autumn (March – May)	Inundation of emergent vegetation or samphire at the upper extent of the intertidal zone (once every two weeks based on the tidal regime). Requires mouth to be open with mean daily tidal range equal to or greater than 0.2 m at lower bridge (cross section 10).
10c	Estuary Mouth State	Marine Migration by larvae	30 – 50 cm deep mouth open during May to July (downstream movement) Velocity create flow after the mouth open (flow sufficient to move silt downstream) Velocity sufficient to take larvae 4 days to get down to an already open mouth (from GOR Bridge – with a small mouth open)	High flow fresh	May - July	Require open mouth during May to July, salinity is not critical so up to 35 ppt is OK for periods of up to a 7 days with 2 – 3 events during the season (as per 9c)
10d	Estuary Mouth State	*Migratory cue to return to estuary*	*Uncertain. Presumed met by flows to provide passage*	N/A	N/A	No assessment required
10e	Estuary Mouth State	Freshwater Migration to estuary from sea by juveniles	30 – 50 cm deep river mouth Mouth open during July to December (upstream migration)	High flow fresh	Oct - Dec	Require open mouth, 30 – 50 cm deep, during Oct-Dec, salinity not material, duration should be for up to 7 days with 2 – 3 events during the season
10f	Riffles, stream bars, flow freshes	Migration from estuary to freshwater reaches by juveniles	flow cue to migrate upstream – probably flow freshes	Fresh	Winter - Spring	Require access to upstream reaches over riffles - Upstream riffle depth at least 0.3 m min (0/3 m thalweg depth at rock bar / riffle). At least 2 events in spring (to provide 2 opportunities)

A.3 Catchment scale threats

Catchment threats were described in the Site Paper (Alluvium 2025) and Issues paper (2026). Hydrologic analyses for each reach were presented in the Issues Paper (Alluvium 2026), which should be read on conjunction with Appendices A.3.1 and A.3.2

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

A.3.1 Impacts of development

Note: 'development' refers to 'water system development in the catchment' – i.e. urban and rural demands (extraction under entitlements, licences, groundwater pumping, farm dams, plantation forestry etc.), and broader river operations (storage, flow routing etc.).

A.3.1.1 Modelled impacts on flow

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

December – May flows

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

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

June – November flows

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

Flows in Lardner Creek

Lardner Creek (Reach 2c) is the only FLOWS study reach where modelled flows seem largely unaffected by development, and this is despite the reach being subject to extractions for the Gellibrand township under a Bulk Entitlement. This is because the annual extraction of 60 ML from Lardner Creek is dwarfed by

the creek's average annual flows of 25 GL. The natural flow regime makes Lardner Creek particularly valuable in the context of the broader catchment for the provision of refugia.

A.3.1.2 Impacts of extractions and diversions on ecological values

The harvesting of surface water and groundwater ultimately leads to there being less water in the environment. This can result in changes to the water availability and quality and, if not managed correctly, can put ecosystems under stress. Bulk entitlement diversions without passing flow requirements exist in Arkins and First Creeks, and flows below the weirs cease when inflows are insufficient to overtop the weirs. This most commonly occurs during low flow periods and is not reflected in the modelled data for Reach 3a. Bulk entitlements with passing flow rules that allow take of all flow in the river when flows are ≤12 ML/day (at the North and South Otway offtakes) exist in Reach 4. There are legacy issues due to other historically licensed extractions/diversions throughout the catchment that may now not be viewed as sustainable, given current knowledge and accepted best practice. This includes the residual impacts from Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield that reduced groundwater discharge into an approx. 2km section of Yahoo Creek (within Reach 1) and approx. 15 km section of the Gellibrand River (within Reach 2a) (BlueSphere, 2024). Based on the latest understanding, Barwon Water's historic groundwater pumping activities at the Barwon Downs borefield contributed to a 19-26% reduction in low flows at Love Creek at Gellibrand (stream gauge #235234) and a 3-6% reduction in low flows at the Gellibrand River at Bunkers Hill (stream gauge #235227) (BlueSphere 2024). The impacts of Wannon Water's groundwater pumping activities at the Carlisle River bores, where 10% of extracted groundwater is estimated to come from a portion of Reach 4 of the Gellibrand River (GHD, 2014) were also considered as part of this work.

Extractions and diversions pose greater impacts in some reaches than others. This is particularly relevant in areas that, in part, rely on discharge from underlying groundwater systems to sustain flows during dry periods. Where acid sulfate soils are present, extractions and diversions can lead to changes in soil moisture and make these more susceptible to activation, which can have flow on effects on water quality.

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

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

A.3.1.3 Barriers to fish movement

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

A.3.2 Impacts of climate

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

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

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

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

There has been an increasing shift towards the consideration of climate change in water management and understanding impacts of climate on water resources (DELWP 2020). A 2024 review of the FLOWS method recommended increased consideration of climate change in the setting of flow

recommendations (Alluvium 2024). This built on a requirement of the FLOWS method Ed. 2 (DEPI 2013) for flow recommendations to be seasonally adaptive (i.e. with different recommendations developed for dry, average and wet years).

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

Implications for determining environmental flow recommendations

Climate change does not alter the environmental values and objectives that flow recommendations are designed to protect – rather, it affects how frequently flow recommendations can be met under projected future conditions. Stage 2 will test flow recommendations against the 2040 medium climate scenario to provide water resource managers with an understanding of the degree to which recommended flows can be delivered as the climate dries. The seasonally adaptive approach (DEPI 2013) will be used to set priorities for environmental water delivery under drought, dry, average, and wet year conditions, recognising that not all flow components may be achievable in all years and that management priorities will need to adapt accordingly. This approach is consistent with Action 8-9 of the Central and Gippsland Region Sustainable Water Strategy (DELWP 2022b), which identifies improving summer flows in the Gellibrand River as a priority even as the climate continues to shift.

A.3.3 Bushfire impacts

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

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

In January 2026, parts of the Gellibrand catchment (including Reach 2b and 4) were directly impacted by bushfires. FLOWS study Site 2b was directly impacted, with the Bunkers Hill streamflow gauge destroyed (note, the gauge has since been reinstated). Riparian vegetation was burned, with complete loss of ground storey vegetation at most cross sections. Substantial loss of foliage in canopy and mid-storey occurred through direct scorch or post-fire leaf fall. Bracken and blackberry were actively regrowing in

March 2026. Post-fire regrowth of mid and overstorey vegetation is anticipated to reduce catchment run-off in Reach 2b and 4. A reduction of waterway shading may impact water temperature and evaporation/evapotranspiration, the extent to which is unknown. A substantial pulse of sand has also been delivered to waterways and drainage lines at Site 2b.

A.3.4 Artificial estuary openings

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

A.3.5 Land use and threats to water quality

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

- Forestry – sedimentation, runoff, chemicals;
- Fire – impact to flow, sedimentation, riparian cover, fire operations;
- Stock grazing – particularly cattle access, erosion, trampling, weed introduction, vegetation impact, high nutrient/chemical runoff.

Land use and catchment management challenges have significant potential to undermine the achievement of environmental objectives in the Gellibrand catchment. The presence of potential and actual acid sulfate soils within the Gellibrand catchment also presents a potential water quality and ecological risk.

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

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

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

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

A.3.6 Introduced plant and animal species

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

A.3.7 Illegal and non-compliant fishing

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

A.4 Approach to the application the FLOWS method in the Gellibrand catchment

The FLOWS method Ed. 2 (DEPI 2013) was applied for the determination of environmental flow recommendations in all reaches except for Reach 3a. A hydrologic approach was used to determine low flow recommendations for reach 3a. These approaches are described below.

A.4.1 Determination of recommendations for Reaches 1, 2a, 2b, 2c, 3b, 4 and 5

- Water-dependent values in the system were identified via a review of available literature and data, site visits, and discussions with the PAG, Project steering committee and EMAC. Values were documented in detail in the Site Paper (Alluvium 2025) and Issues paper (Alluvium 2026).
- A preliminary site visit was held 24-25 March 2025 to determine reach boundaries and select representative sites for the FLOWS study. The FLOWS study site assessment was held 28-31 October 2025, during which the EFTP selected cross sections for survey and hydraulic modelling.
- Ecological objectives were developed by the EFTP to support the maintenance and, where possible improvement of, water-dependent values based on site assessment, broader catchment policies and strategies, EFTP knowledge, and consultations with EMAC, the PAG and PSC.
- Flow objectives and hydraulic criteria were developed by the EFTP to support achievement of environmental objectives. Typically, hydraulic criteria support the life histories of flora and fauna and maintain physical riverine processes. Hydraulic criteria were based on existing literature, conceptual models and expert elicitation. Key hydraulic criteria applied for each flow component, together with the objectives supported by the criteria are summarised in Table 32.

Table 32. Hydraulic criteria applied for each flow component in the flow recommendations workshop

Flow component	Timing	Hydraulic criteria	Objectives supported
Low flows	Dec - Apr	Criteria for pool depth and habitat availability to support aquatic fauna Pools ≥ 1 m deep Depth ≥ 0.1 m over riffles to provide connectivity and enable movement by fauna Criteria (water in landscape through low flows) indirectly supports damp subsoils, wet microclimates.	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V4, V5, V6
	May	Hydraulic criteria not applied	Indirect support for F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V4, V5, V6
	Jun - Oct	Hydraulic criteria as for Dec – Apr fresh, with flows occurring on all days during Jun - Oct	F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V5, V6
	Nov	Hydraulic criteria not applied	Indirect support for

Flow component	Timing	Hydraulic criteria	Objectives supported
			F1, F2, F3, F4, FC1, P1, R1, M1, V1, V2, V3, V4, V5, V6
Fresh	Dec - Apr	Criteria relate to habitat availability, longitudinal connectivity for fauna movement, and pool turnover and flushing to support water quality ≥ 0.1 m additional increase in depth over riffles (i.e. above depth achieved by low flows) to support migration and provide cues Increase in wetted width Velocity to support pool turnover Inundate (≥ 0.1 m depth) low benches and instream physical features to support aquatic fauna and vertical zonation of vegetation on banks Simulate spawning (grayling late autumn – winter)	F1, F2, F3, F4, FC1, M1, V1, V2, V5, Geo3
	May - Nov	Hydraulic criteria related to depth, zonation of vegetation on banks, habitat availability, migration, breeding cues, and geomorphic work Inundate higher benches (≥ 0.1 m above low flows) – vertical zonation of vegetation, increasing habitat availability, facilitate migratory movement (galaxiids and grayling early winter), stimulus for spawning (grayling late autumn – early winter) Flows with sufficient shear stress (1 N/m^2) to mobilise fine sediments, flush sediments, maintain gravel bars • Engage backwater creeks and inflowing channels, where present	F3, F4, P1, R1, M1, V1, V2, V5, Geo1, Geo2, Geo3
Bankfull	Any time	Flow rate to fill the channel at most surveyed cross sections. Maintain effective geomorphic work on channel	V1, Geo1
Overbank	Anytime	Flow rate to overtop banks on cross sections and engage floodplains, wetlands and billabongs, where present. Maintain effective geomorphic work, contribute to floodplain development and evolution	F3, M1, V7, Geo1, Geo4

Note, aquatic fauna objectives F5, F6 and F7 relate to estuarine resident fish, estuary connection to the marine environment and estuary habitat, respectively. These objectives are supported by the Reach 4 recommendations and the Gellibrand estuary flow recommendations set by Lloyd et al. 2008.

- Hydraulic models were developed for one representative site per study reach. The hydraulic models relate flow rates to other parameters of water in motion, including depth, velocity, shear stress and wetted width.
- In a two-day workshop held 10-11 June 2026, the EFTP assessed hydraulic model outputs and identified the flow magnitude required for each flow component to satisfy the relevant hydraulic criteria.

- Flow duration curves for the Source-modelled unimpacted flow regime (post 1975 climate) were examined to assess the exceedance percentile, and therefore the relative frequency of occurrence/exceedance, of each draft flow magnitude. This check confirmed that the draft magnitudes were not unreasonably high or low. As a general rule of thumb, low flow recommendations are often close to the 80th exceedance percentile flow, while freshes are commonly close to the 20th exceedance percentile flow. Bankfull and overbank flows occur less frequently and have lower exceedance percentiles. (Please note, the EFTP was deliberately conservative when setting low flow recommendations for Lardner Creek (Reach 2c), resulting in lower exceedance percentiles for low flow recommendations than for other study reaches (approximately 55%-68%, rather than the 80% exceedance percentile 'rule of thumb'). This was done to preserve a greater proportion of low flows in the creek as part of the precautionary approach to application of the FLOWS method in Lardner Creek.
- The EFTP explicitly considered hydraulic model uncertainty and confidence when setting flow recommendations. Model uncertainty was higher in some reaches due to calibration challenges arising from limited streamflow gauge data, and the need to calibrate water levels that were surveyed on multiple days. To account for this uncertainty, the EFTP recommended flow ranges for freshes in some reaches rather than a single flow magnitude. The lower magnitude in the range represents a minimum flow likely to satisfy hydraulic criteria at multiple cross section, while the upper magnitude reflects a flow that satisfies criteria more consistently and with greater confidence, given known variance/degree of error in the hydraulic models.
- The frequency and duration of peak flow components (freshes, bankfull and overbank) was determined by spells analysis (River Analysis Package v3.0.8, Marsh et al. 2008) and generally correspond to the *median* frequency and *median* duration of threshold events for the period (months) in which they apply.

A note on the determination of peak flow event frequency and duration:

For each year of hydrologic data, River Analysis Package (RAP) calculates the number of events that meet/exceed the threshold magnitude (1/071900 – 30/06/2022), and the mean duration of those events that occurred in the year. Frequency and duration data is therefore generated for each year of analysed hydrologic data.

Annual data were then summarised to determine the median frequency and the median duration of threshold events that occurred from 1900-2022. These median frequencies and durations were adopted for freshes, bankfull and overbank flows.

The approach is deliberately conservative however results in a high bar for achievement in performance analyses.

- The draft flow recommendations were refined in consultation with the EFTP following further hydrologic and spells analyses. Note: The frequency of Dec – Apr freshes in Reaches 2a and 5 was increased from the calculated median of 1 event to 2 events per season. Multiple freshes support system robustness, and redundancy reduced the need for all Dec – Apr environmental objectives (support fish movement, spawning cues, refreshment/flushing of habitats and maintenance of water quality) to be achieved by a single fresh event.

- Performance assessments were undertaken to understand the achievement of the flow recommendation under different unimpacted and current levels of development in a post 1975 (current) climate. Additional development and climate scenarios were selected by the PAG, PSC and EMAC for performance assessment.

Determining the magnitudes of low flows in transition months

Because May and November represent transitional periods between true wetter months (June – October) and true drier months (December – April), and no specific hydraulic criteria apply during these months, low flow recommendations were derived using a hydrologic interpolation approach. For each reach, the exceedance percentiles associated with the December-April and June-October low flow recommendations were averaged, and the corresponding flow magnitudes (for the average exceedance percentile flow) was obtained from the May and November flow duration curves. Recommendations were rounded to the nearest whole number. This approach ensures a gradual seasonal transition in recommended flows while maintaining consistency with the broader flow regime.

A.4.2 Hydrologic determination of low flow recommendations in Reach 3a (Arkins Creek West and East branches, and First Creek)

The steep, bedrock-confined physical form of Arkins Creek West Branch, Arkins Creek East Branch and First Creek precludes the development of stable one-dimensional HEC-RAS hydraulic models, which are the standard tool used in the FLOWS method to relate flow rate to water depth and velocity at key habitat features. The confined channel form and absence of depositional instream features also limit the application of hydraulic criteria for higher magnitude flow components. Accordingly, the EFTP has applied a hydrologic approach to the setting of low flow recommendations for all three Reach 3a creeks, using Source modelled unimpacted inflow (post 1975 climate) to the weirs as the primary reference. This approach is a recognised adaptation of the FLOWS method where site conditions preclude hydraulic modelling (DEPI 2013).

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

The EFTP was provided with flow datasets representing *inflows* to the combined Arkins Creek and First Creek weirs (HARC 2025) under different development and climate scenarios. The flow data has been subsequently split for Arkins Creek West Branch, Arkins Creek East Branch and First Creek based on the relative areas of each sub-catchment (Table 33), as determined by spatial analysis (HARC 2025).

Table 33. Split of weir inflow across Arkins Creek West Branch, Arkins Creek East Branch and First Creek

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

Sub-catchment (split) flow data for inflows under unimpacted post 1975 climate were used to derive the low flow recommendations for Arkins Creek West Branch, Arkins Creek East Branch and First Creek, as described below.

Approach to the development of low flow recommendations for Reaches 3ai, 3aii and 3aiii

1. Before developing preliminary low flow recommendations, the EFTP confirmed that the Reach 3a flow duration curves (split hydrologic inflow data, unimpacted level of development, post 1975 climate) were comparable to those of other study reaches and that low flow recommendations derived using hydraulic criteria for other reaches generally aligned with the 80th exceedance percentile rule of thumb.
2. Preliminary low magnitudes for December – April, May, June - October and November were set at the 80th exceedance percentile flow in the corresponding season, consistent with the general exceedance percentile rule of thumb for low flows.
3. Low flow magnitudes were rounded up to the nearest 0.1 ML/day for Arkins Creek West and East branches, and to the nearest 0.05 ML/day for First Creek.

A.4.3 Approach to seasonal adaptation and identification of climate condition

In this study, the EFTP has set flow recommendations based on the hydraulic requirements of environmental values, and the frequency and durations set based on annual medians of modelled-unimpacted flow regime in a current climate. As described below, the project team has undertaken further spells analyses to understand trends in the frequency and duration of peak events in very dry, dry, wet and very wet conditions, and therefore inform manager expectations as to how the flow recommendations may be achieved under different climate conditions. This very dry – very wet climate condition approach was taken to better consider central (above/below median) climates and extreme conditions and to align the condition classifications with the Bureau of Meteorology's approach to long-term rainfall forecasts.

Method (very dry, dry, wet, very wet).

The EFTP adopted very dry, dry, wet and very wet climate condition terminology. The following approach was used to classify each year of Source modelled data according to climate condition.

1. Calculate total annual flow for each 'flow' year (1 June to 31 May) using the modelled unimpacted post 1975 flow record.
2. Rank years from the lowest to highest annual flow.
3. Assign each year an annual flow percentile, where the driest year equals 0% and the wettest year equals 100%.
4. Classify each year for its climate condition according to its annual flow percentile:

Climate Condition	Annual flow percentile	Interpretation
Very dry	0% < f ≤ 20%	Very dry years are the driest 20% of years in the modelled record
Dry	20% < f ≤ 50%	Dry years comprise the next 30% of years (below median, 20th–50th percentile annual flows).
Wet	50% < f ≤ 80%	Wet years comprise the next 30% of years (above median, 50th–80th percentile annual flows)
Very wet	80% < f ≤ 100%	Very wet years are the wettest 20% of years in the record (80th–100th percentile annual flows)

Where *f* is the annual flow percentile.

A.4.4 Approach to performance assessment

Performance was assessed using eFlow Predictor v3.0.134 (Marsh et al. 2009) to determine the extent to which the recommended flow regime would be achieved under different Source-modelled development and climate scenarios (Table 34).

Table 34. Source modelled development and climate scenarios for performance testing.

Level of development	Climate	Description
Unimpacted	Post 1975	Assessment of the reasonableness of the recommendations had the system never been developed (i.e. natural flows with no diversions or water storages), in a current climate.
Current	Post 1975	The extent to which the recommendations are achieved under the current level of development and climate.
Current	2040 High	Performance at/near the end of the lifetime of the recommendations, with the current level of development.
Full urban and rural uptake[1]	Post 1975	Performance should all water users access their maximum entitlement each year, in a current climate.
Full urban and rural uptake[1]	2040 High	Performance should all water users access their maximum entitlement each year, under a 2040 high climate change scenario (i.e. worst case scenario).
Full urban and rural uptake[1]	2065 High	Performance should all water users access their maximum entitlement each year, under a 2065 high climate change scenario (i.e. worst case scenario).

[1] In the model, full urban and rural uptake is subject to existing operating rules including restrictions and bans. This means that users may not be able to access their maximum take limits in every year.

Annual performance scores for each recommended flow component for each reach are provided in Appendix A.6. Performance charts are provided for the unimpacted development, post 1975 climate scenario, and heat maps of annual performance scores are provided for all scenarios. Average annual performance (summarising the annual performance scores from 122 years of modelled flow data) is provided for each reach in Section 5.

Interpretation of performance scores:

EFlow Predictor (Marsh et al. 2009) determines the extent to which a flow component is achieved in each year (beginning June 1) of the modelled hydrologic dataset, for the period 1900-2022. Scores range from 0 – 1. For a given year:

- A performance score of 0 (i.e. 0%) indicates that the flow component was not achieved at all.
- A performance score of 1 (i.e. 100%) indicates that the flow component was achieved in full.
- A performance score between 0 and 1 indicates the extent of partial achievement of the flow component.

Low flows and event-based peak flows (i.e. freshes, bankfull and overbank flows) differ in the way in which performance is scored.

Low Flows: The performance score represents the mean annual proportion of days in the relevant time period in which the low flow magnitude is met. For example, in Reach 2a, low flows of at least 20 ML/day are required on all days during December – April (151 days). If flows equalled or exceeded 20 ML/day on 70 days during December – April in a given year, the performance score for that year would be 70/151= 0.46. Annual result data for 122 analysed years is then compiled and summarised to produce mean annual performance metrics (shown on the graphs in Figure 5 - Figure 14). Annual performance for each of the 122 analysed years is also presented in heat map form in Appendix 0, to provide an indication of year-to-year variability.

Event-based peak flows: The performance score represent the proportion of required events that were achieved in the relevant season. To be successfully achieved, the flow must equal or exceed the required magnitude *AND* equal or exceed the required duration. If either of the recommended magnitude or duration criteria are not met, the event is scored as unsuccessful. For example,

- In Reach 2b, the achievement of six of the required eight 450 ML/day freshes in May – November, each lasting for a minimum of 5 days, would result in performance score of 0.75 for the year. (Note: if a May – November peak flow event exceeded 450 ML/day but only lasted for four days, the event would be scored as unsuccessful).
- In Reach 5, the successful achievement of one bankfull flow event exceeding 1650 ML/day for one day in a given year would be scored as 1. A peak flow event of 1640 ML/day for one day in Reach 5 would not meet the bankfull flow requirements, and receive a score of 0.

A seven-day spell independence criterion was applied to event-based peak flows. i.e. Two freshes must occur at least seven days apart to be scored as separate events. Peak flows separated by less than seven days are scored as one event.

Annual result data for 122 analysed years is then compiled to produce mean annual performance metrics (shown on the graphs in Section 5). Annual performance for each of the 122 analysed years is also presented in heat map form in Appendix A.6 to provide an indication of year-to-year variability.

Note: Due to the varied nature of flows within and across years, and the setting of freshes according to median annual frequencies and durations, high performance is not expected. Poor performance alone does not justify the revision of the flow recommendations. The EFTP does not aim to achieve a performance score of 1 in the unimpacted flow scenario, as this would imply that the recommended flow is achieved every year, including the driest of modelled years. Environmental flow recommendations are intended to reflect the magnitude, frequency and duration of ecologically important flow events and be cognisant of hydrologic variability. Consequently, poor performance is expected in some years, even under modelled unimpacted conditions.

Performance testing in Reach 3a.

Sub-catchment (split) flow data for inflows under unimpacted post 1975 climate were used to derive the low flow recommendations for Arkins Creek West Branch, Arkins Creek East Branch and First Creek.

Flow datasets representing *outflow* from the combined Arkins and First Creeks were also provided by HARC. However, as each weir may be subject to different levels of extraction (where extraction is not necessarily proportional to sub-catchment area and does not adequately reflect the potential for creeks to cease to flow downstream of the weirs), it was deemed not appropriate to spilt catchment outflows on the relative areas of each sub-catchment. The lack of weir-specific outflow data precluded analyses of performance in Reaches 3ai, 3aii and 3aiii under different development scenarios.

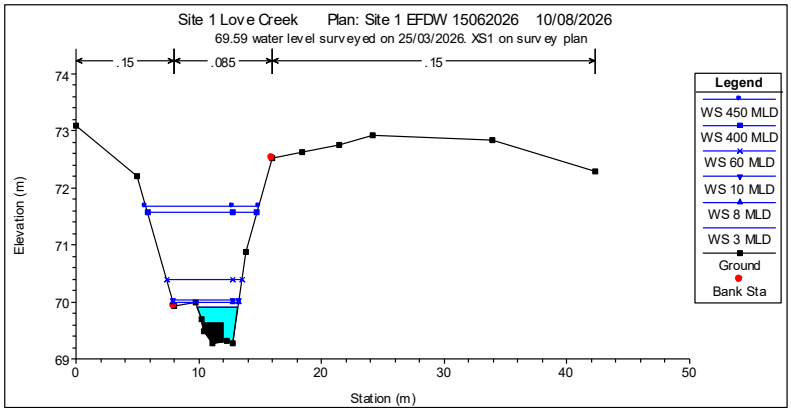
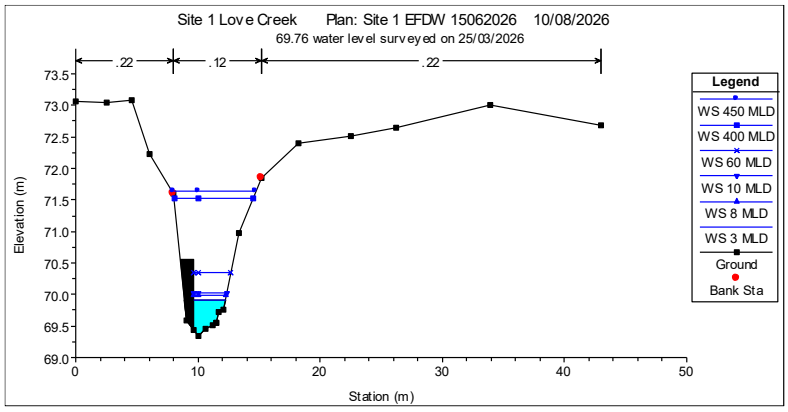
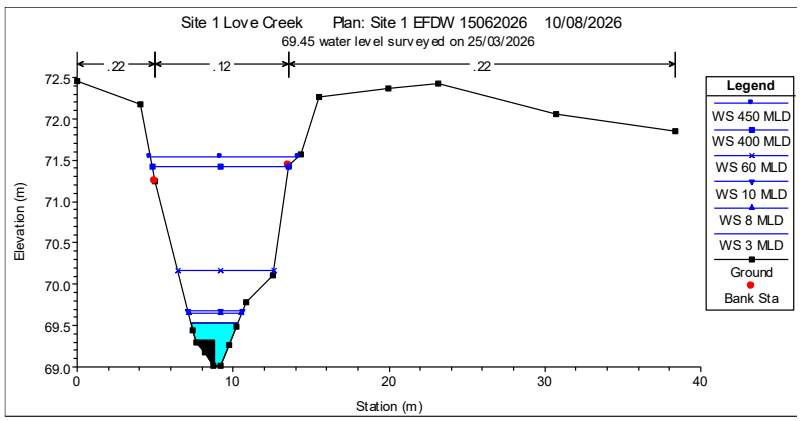
Sub-catchment (split) flow data for inflows under different climate scenarios (unimpacted level of development in 2040 high and 2065 high climates) were used in performance testing.

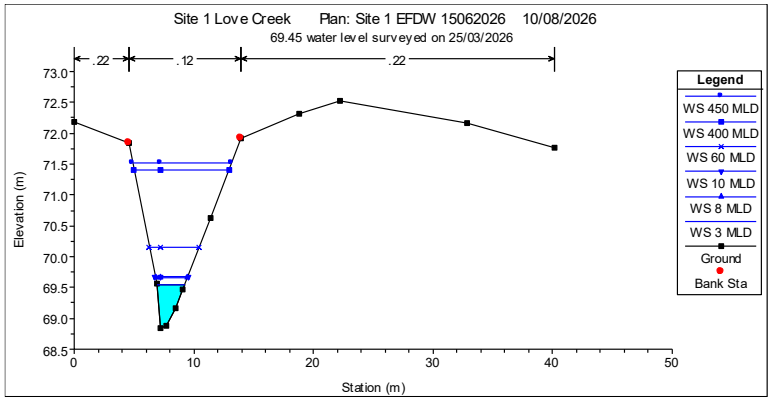
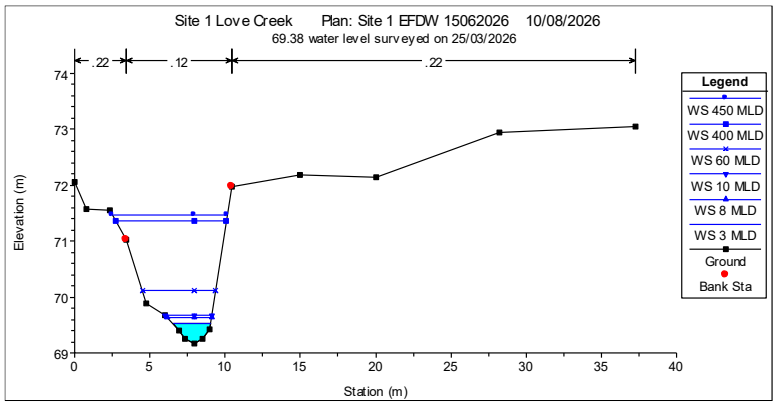
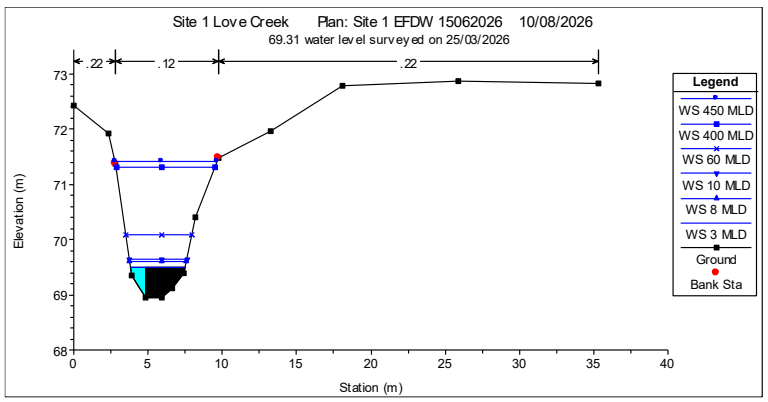
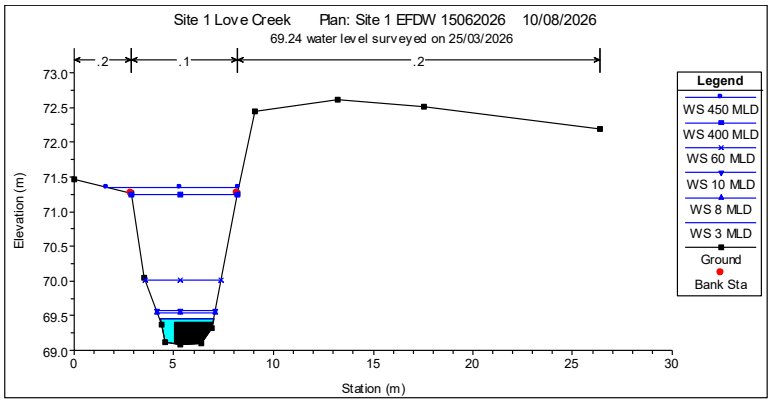
A.5 Hydraulic model cross sections and photos

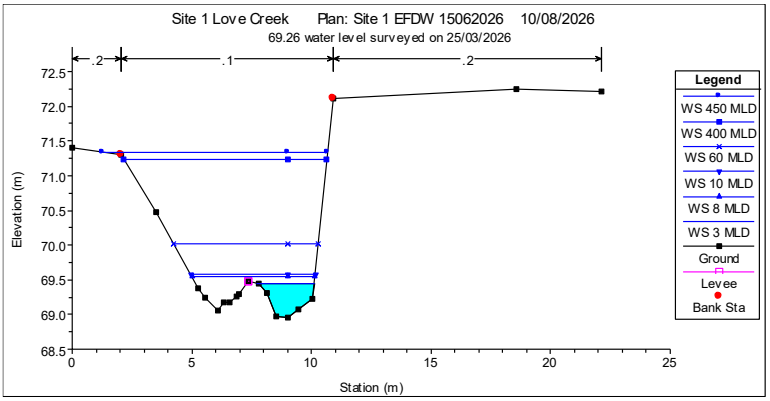
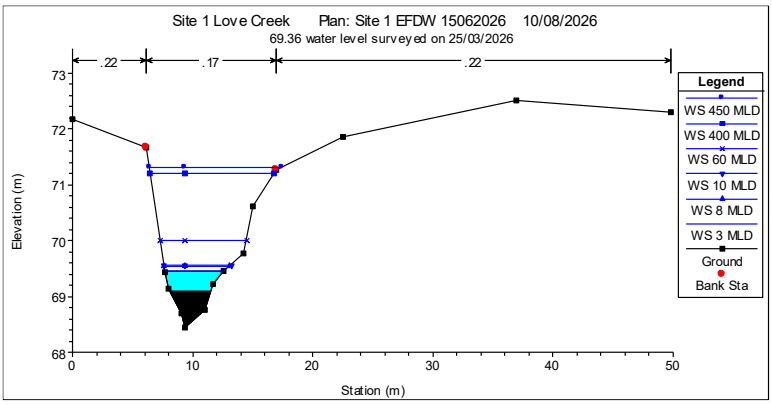
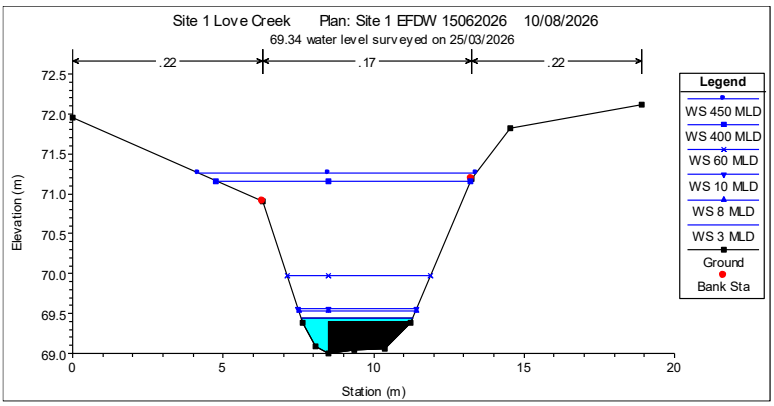
Note: RS: River Station, XS: Cross section. Water levels achieved for each flow recommendations are marked on each cross section. Black shading within the cross section represents blocked obstructions, which represent the effects of in-channel large wood.

Hydraulic models were developed for Reaches 1, 2a, 2b, 2c, 3b and 4 in this FLOWS study. The 2006 hydraulic model for Reach 5 was suitable for re-use. Reach 3a was not amenable to hydraulic modelling.

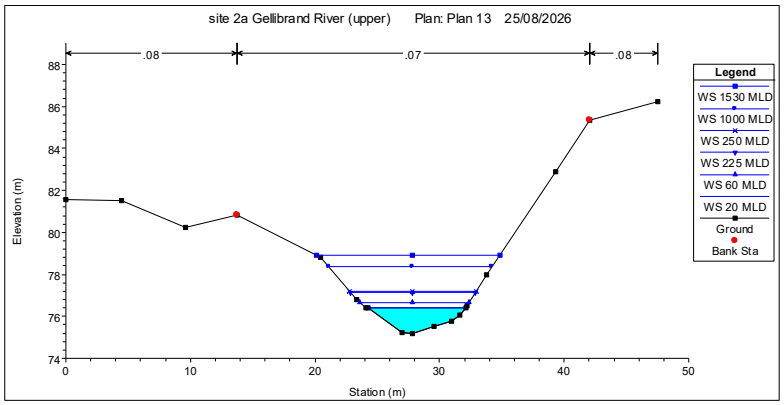
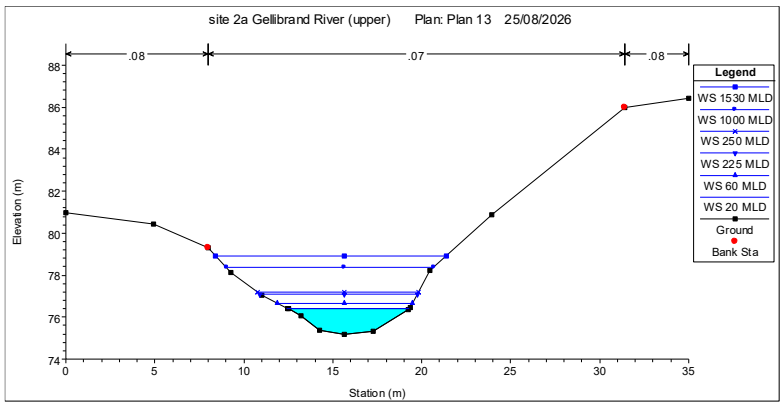
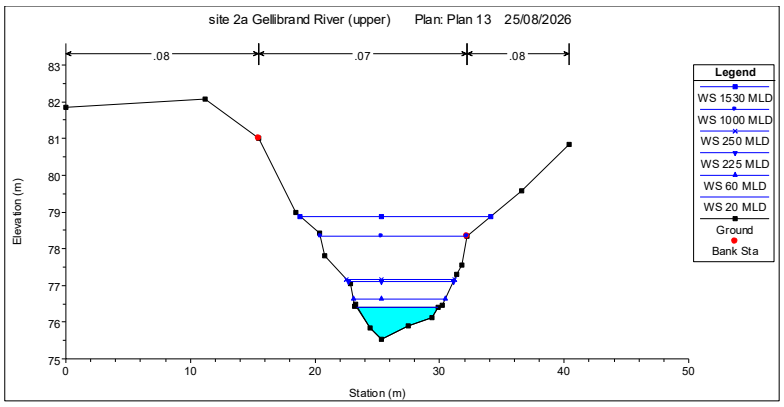
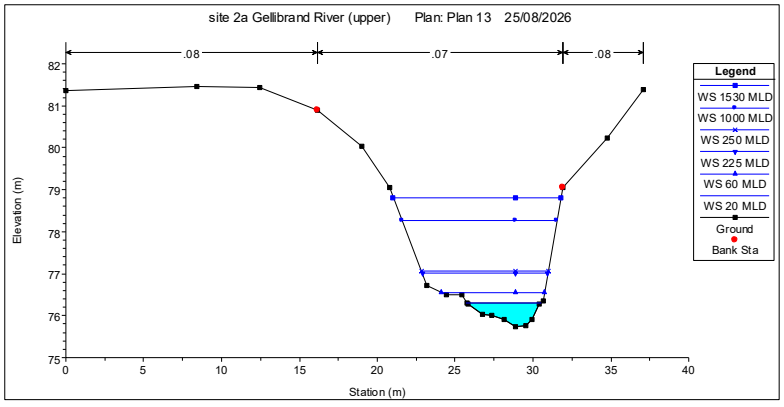
A.5.1 Reach 1 – Love Creek

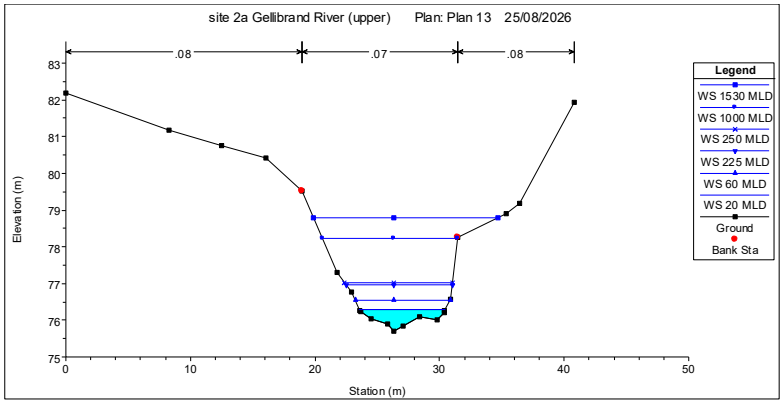
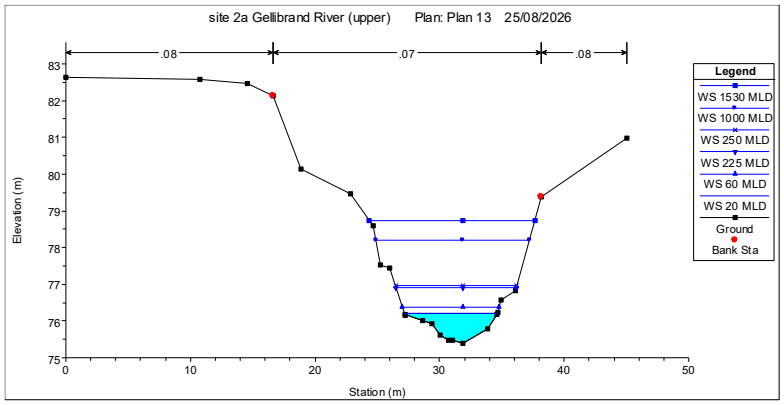
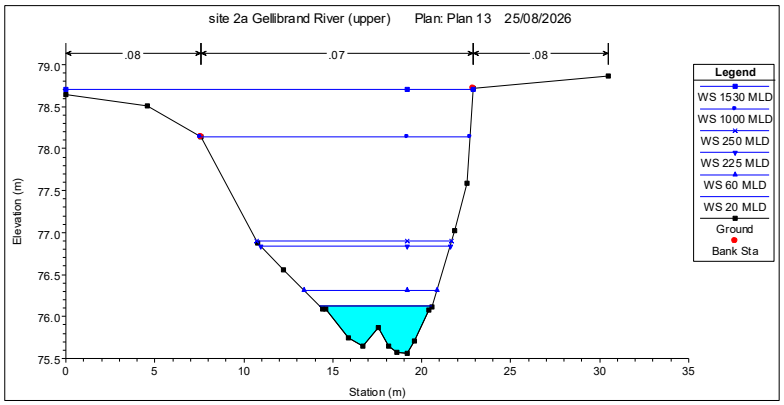
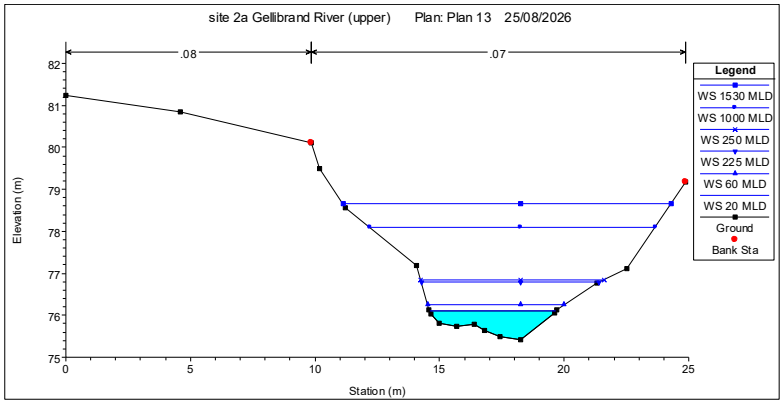
RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
188		10	
171.6789		9	
137.0302		8	

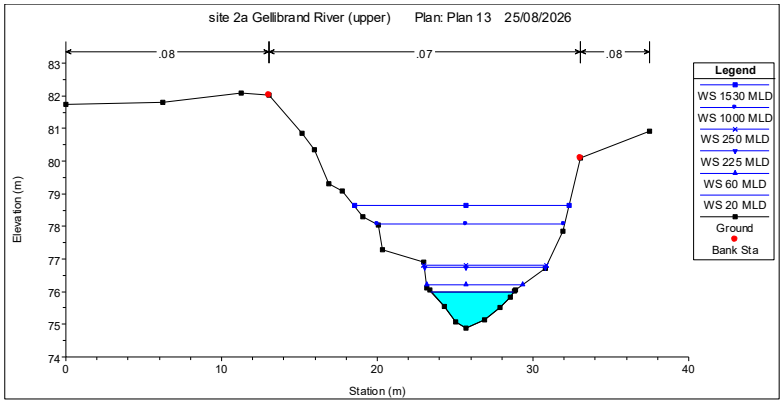
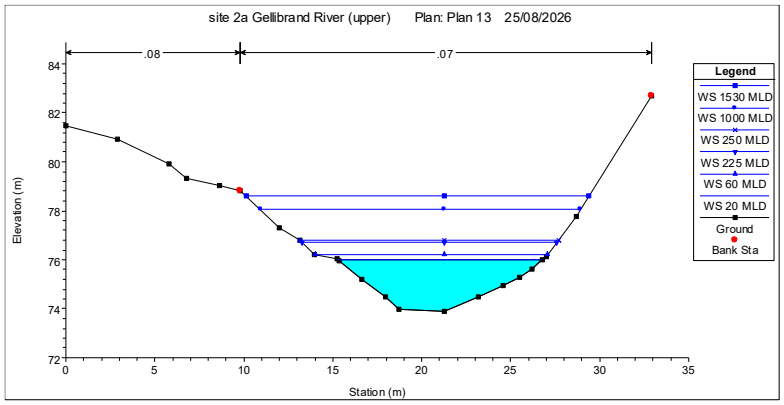
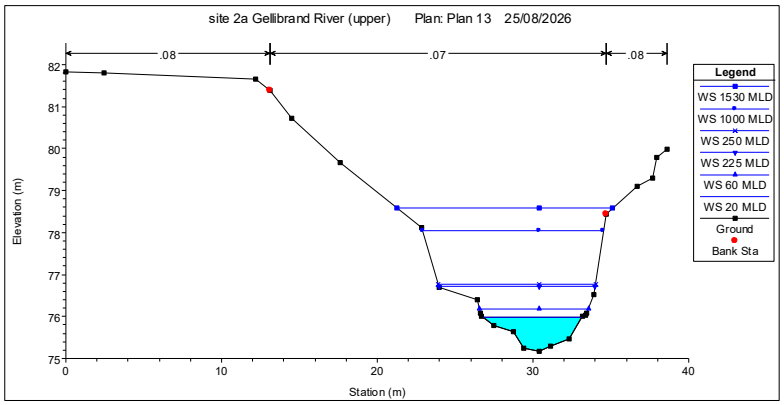
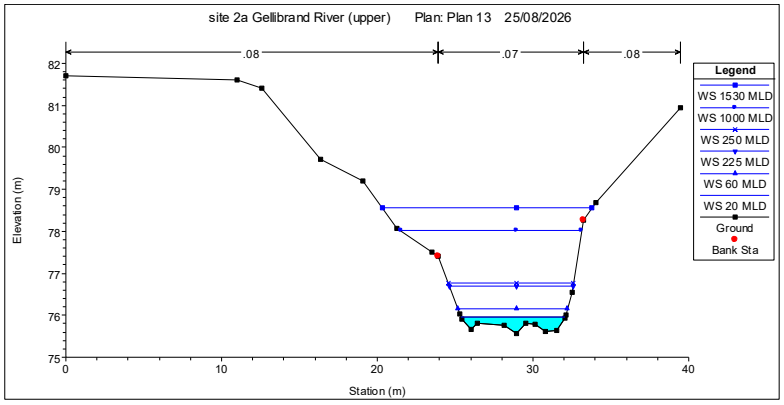
RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
128.6904		7	
112.9727		6	
95.65345		5	
73		4	

RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
67		3	
46		2	
30		1	

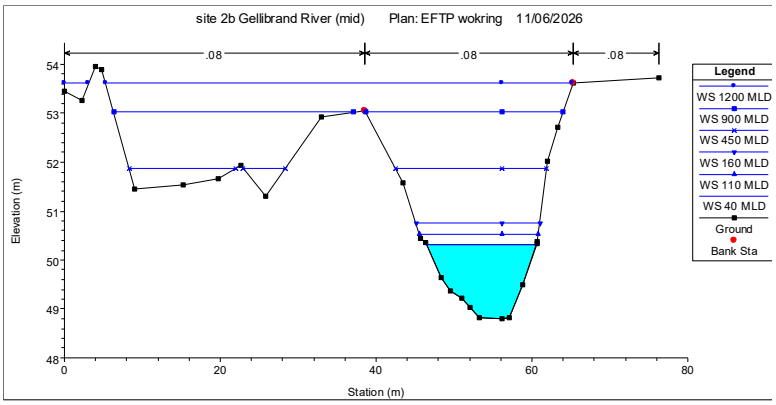
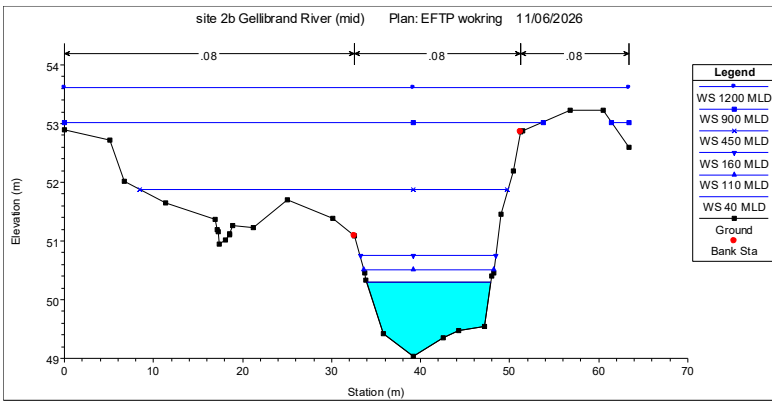
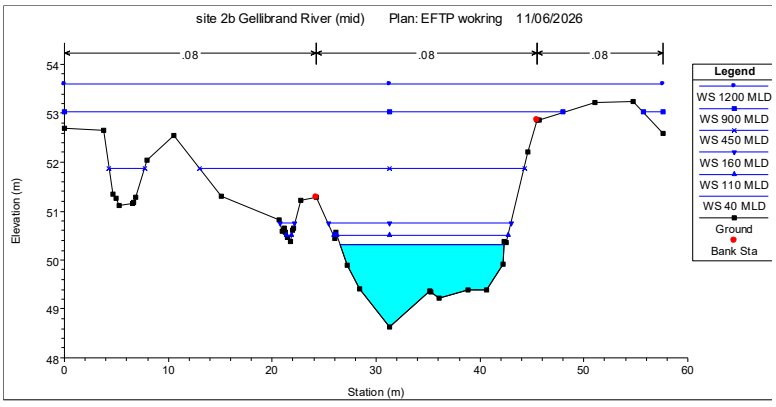
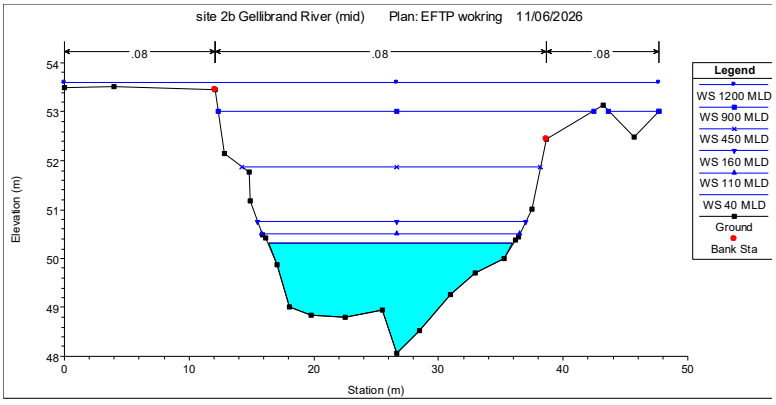
A.5.2 Reach 2a – Gellibrand River (upper)

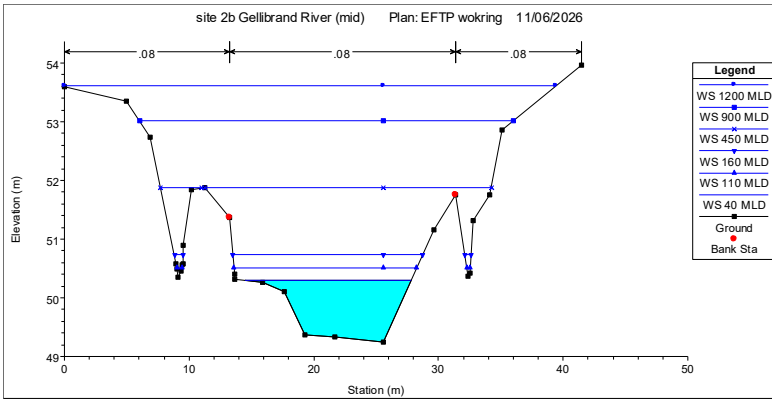
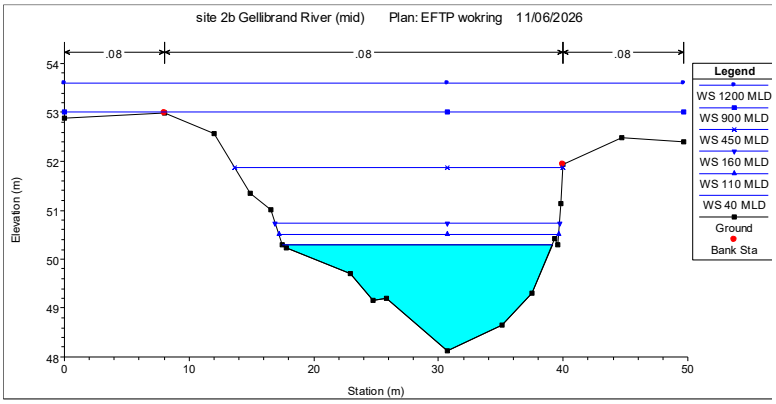
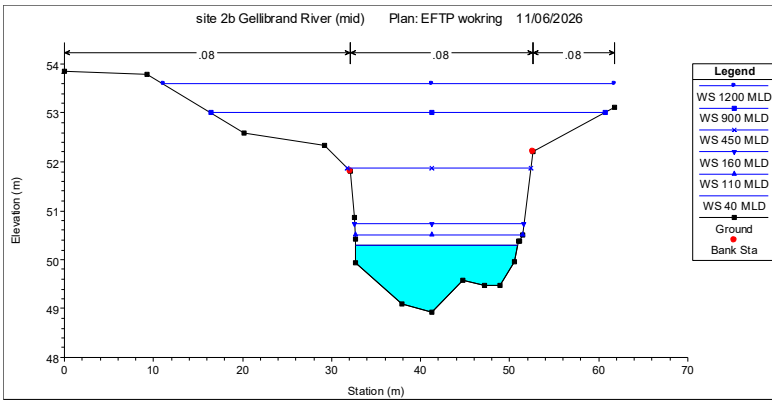
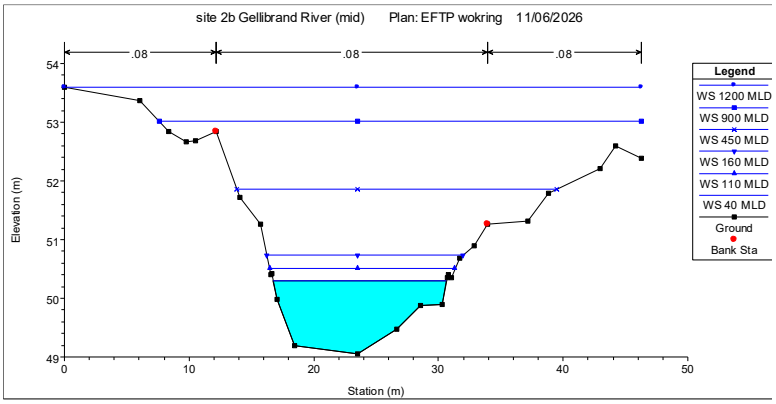
RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
436		1	
428		2	
392		3	
341		4	

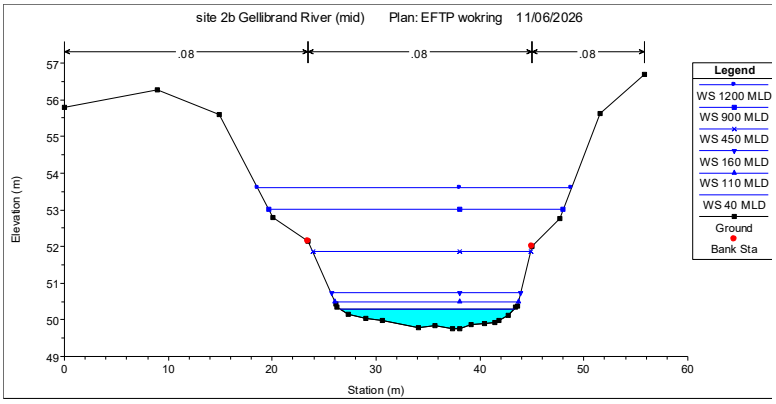
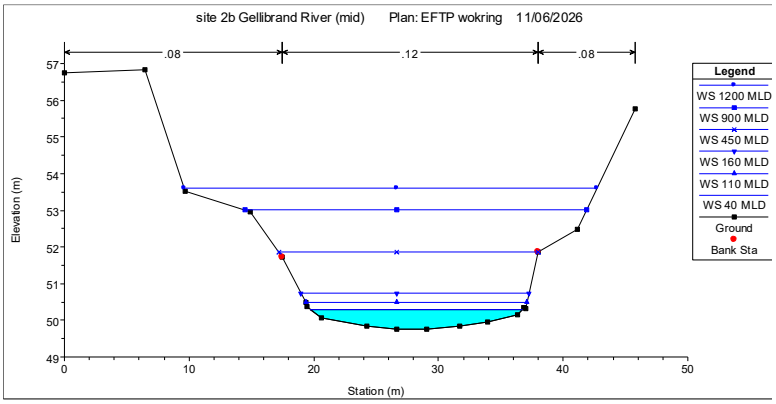
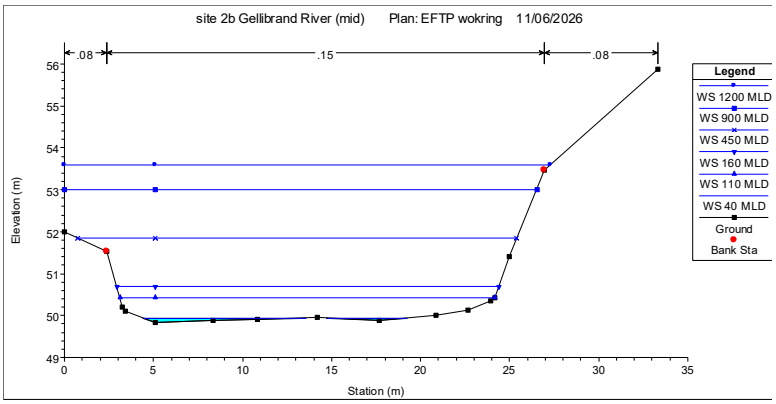
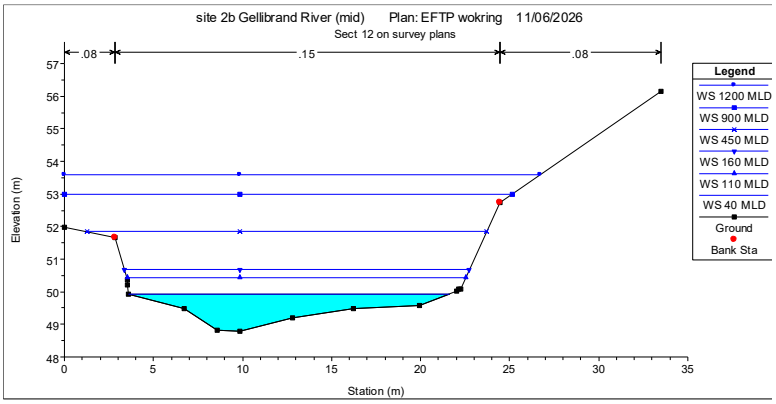
RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
314		5	
266		6	
216		7	
180		8	

RS	HEC-RAS cross section at river station (RS)	XS	Site inspection photos
153		9	
103		10	
82		11	
64		12	

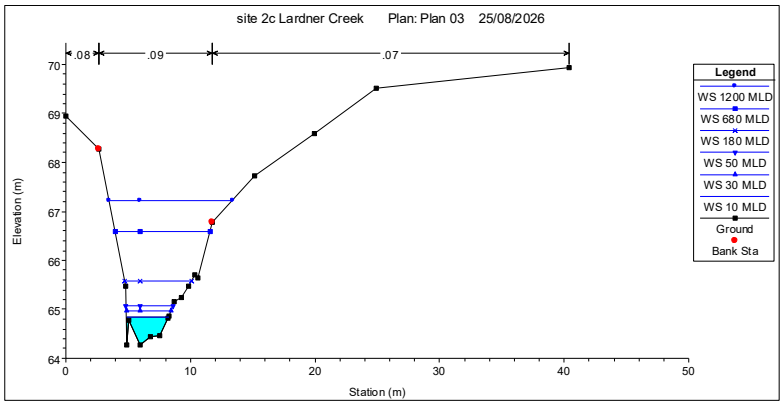
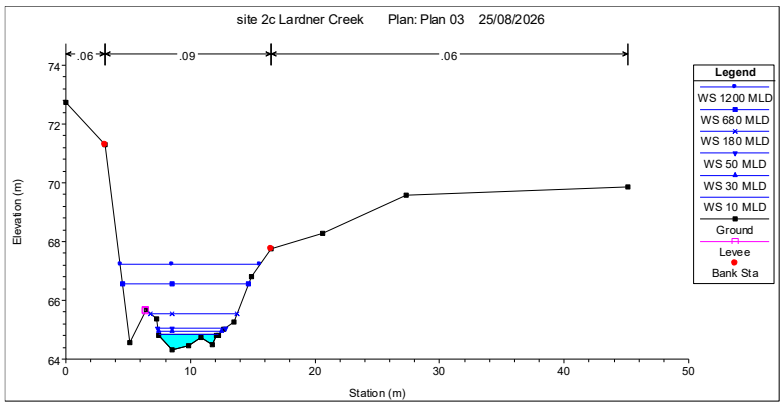
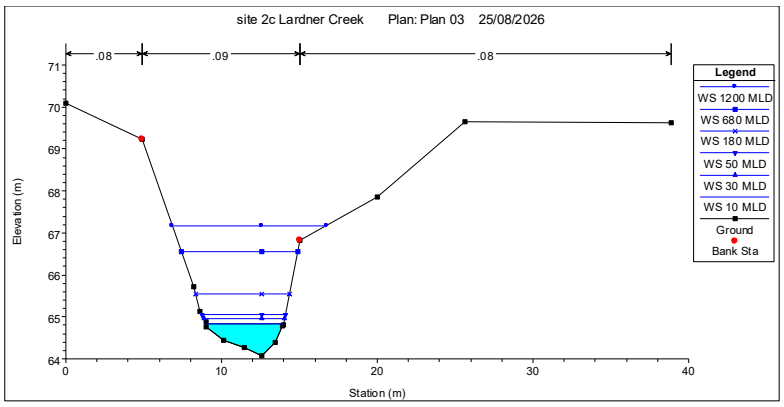
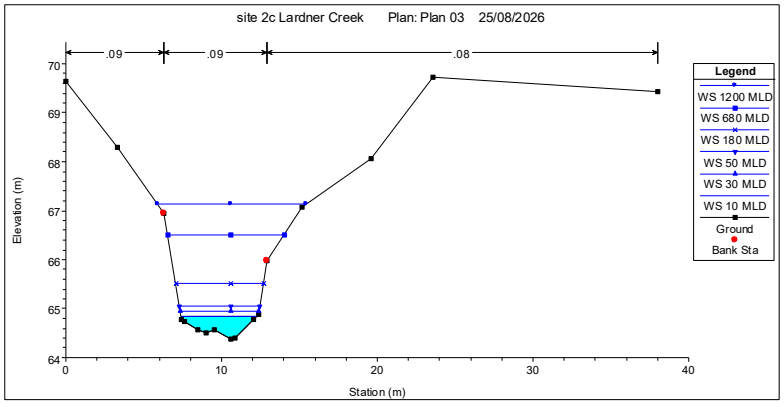
A.5.3 Reach 2b – Gellibrand River (mid)

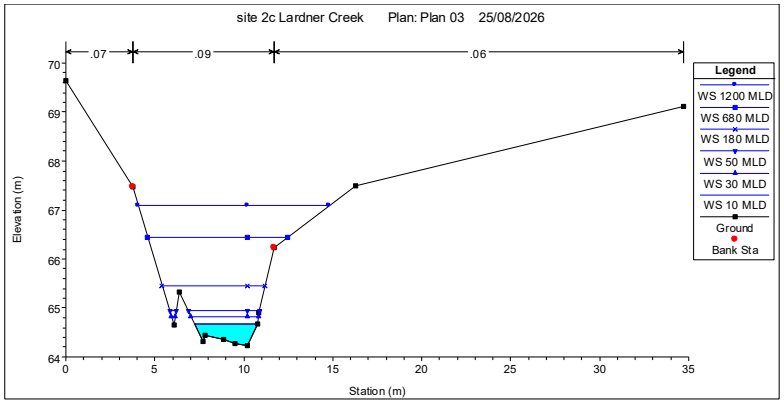
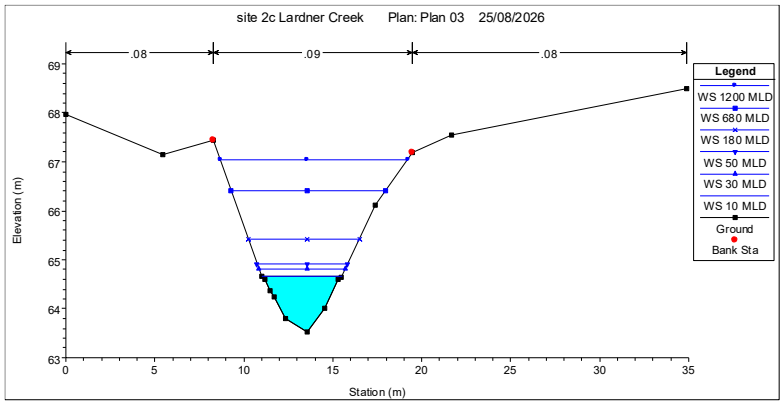
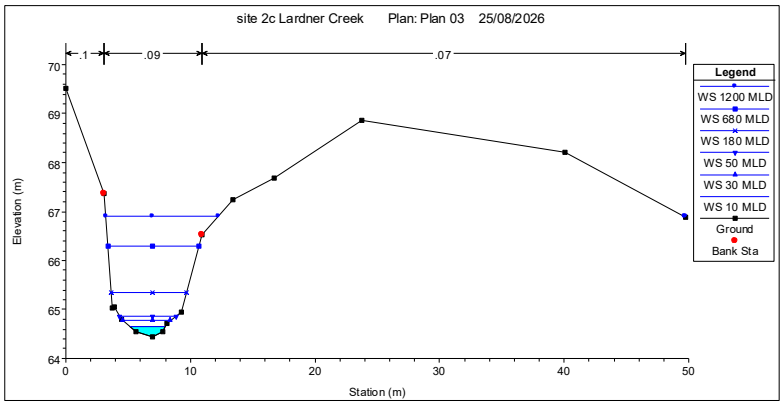
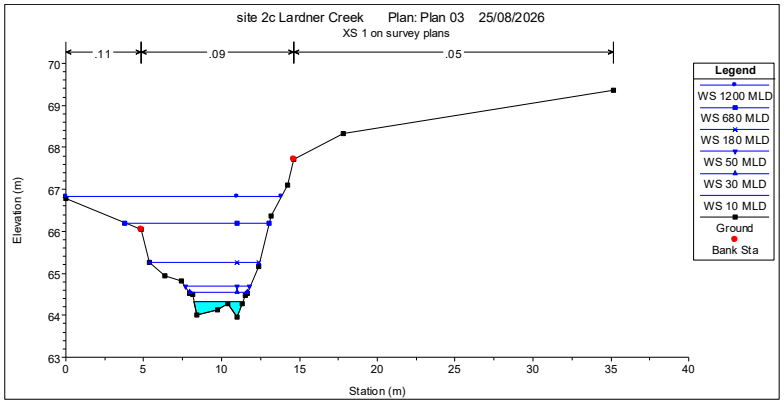
RS	Hec Ras geometry	XS	Site inspection photos
525		1	
492		2	
488		3	
456		4	

RS	Hec Ras geometry	XS	Site inspection photos
380		5	
263		6	
167		7	
105		8	

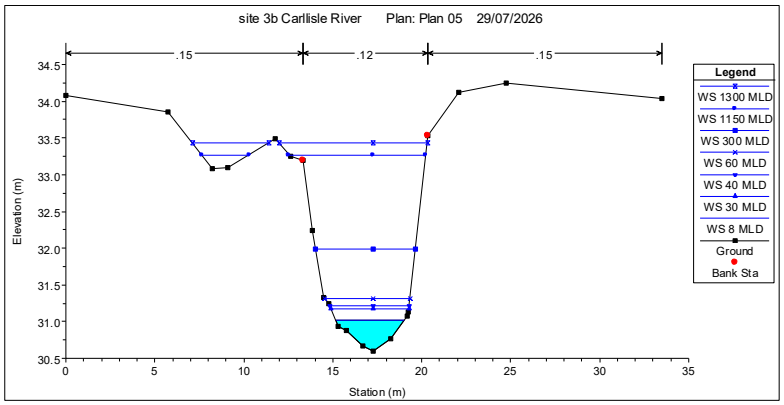
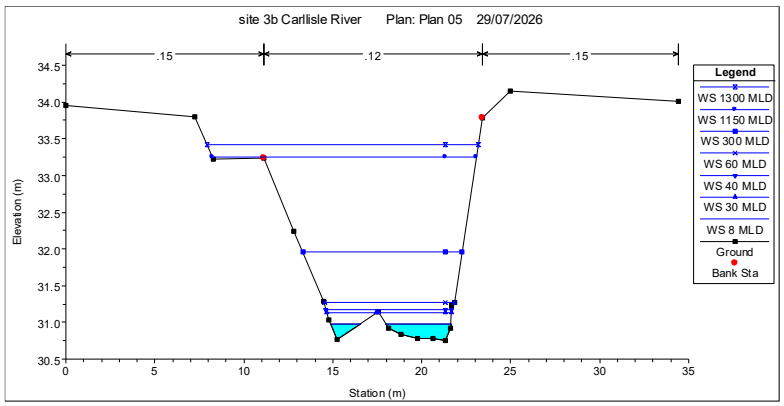
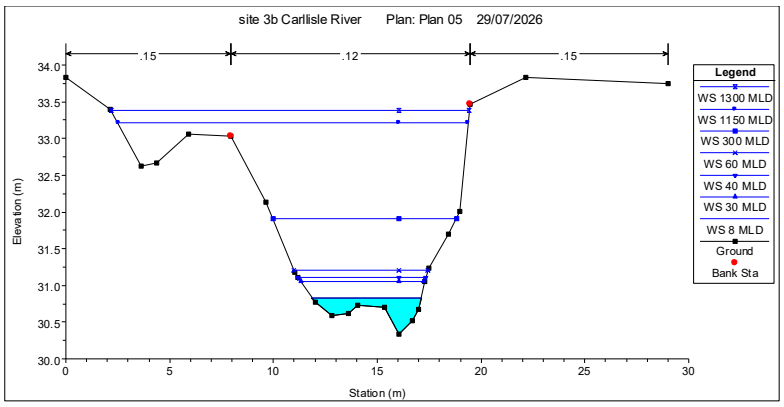
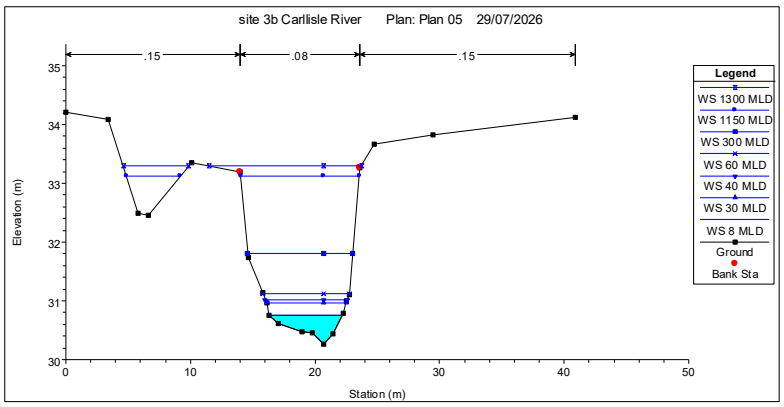
RS	Hec Ras geometry	XS	Site inspection photos
61		9	
55		10	
12		11	
0		12	

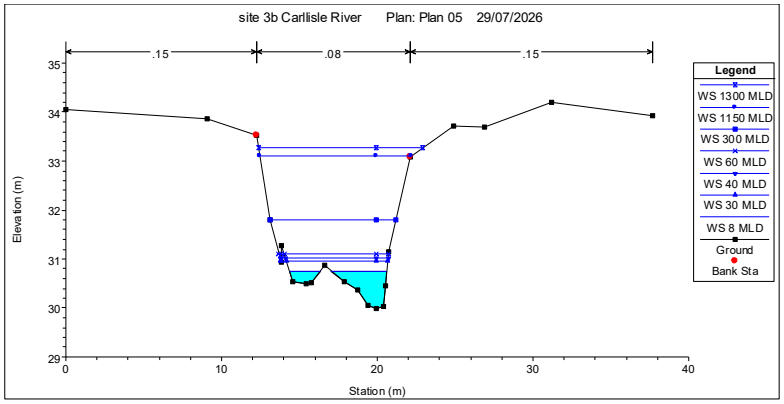
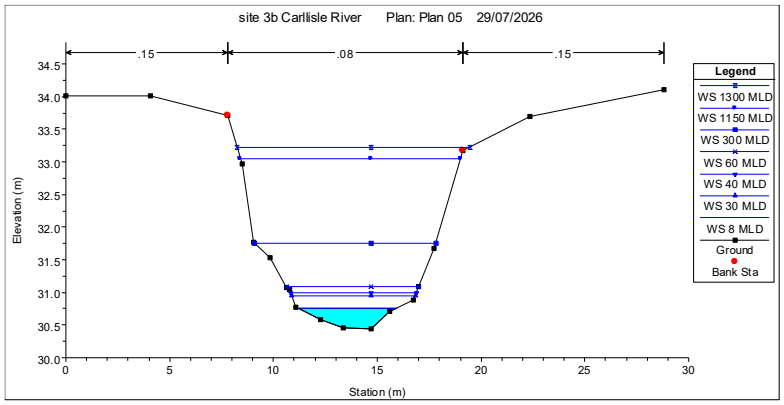
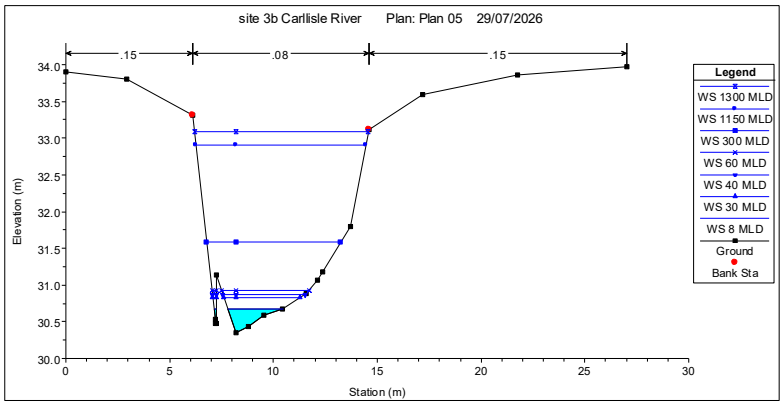
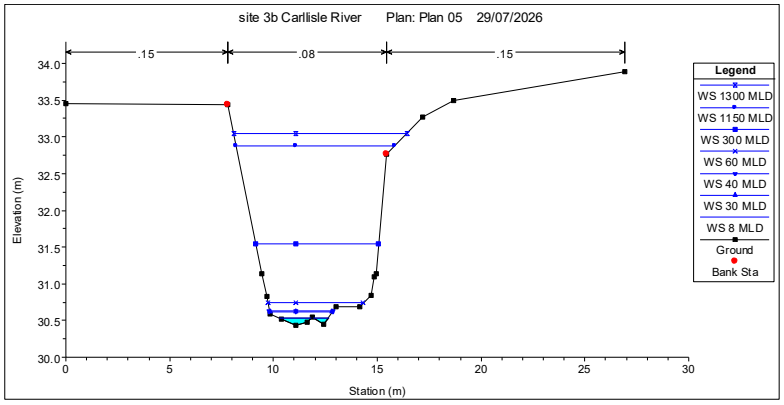
A.5.4 Reach 2c – Lardner Creek

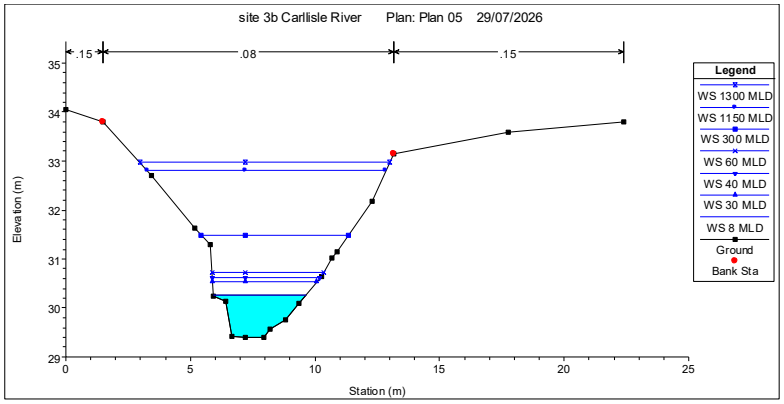
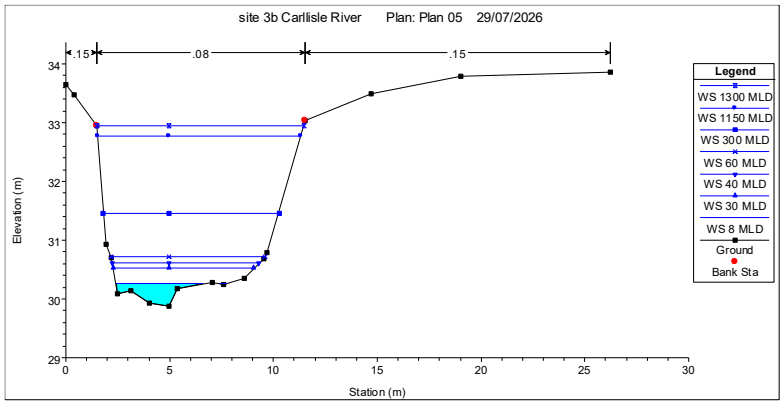
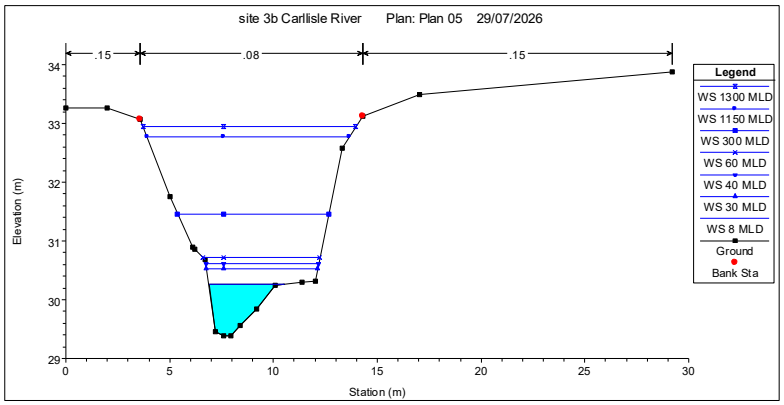
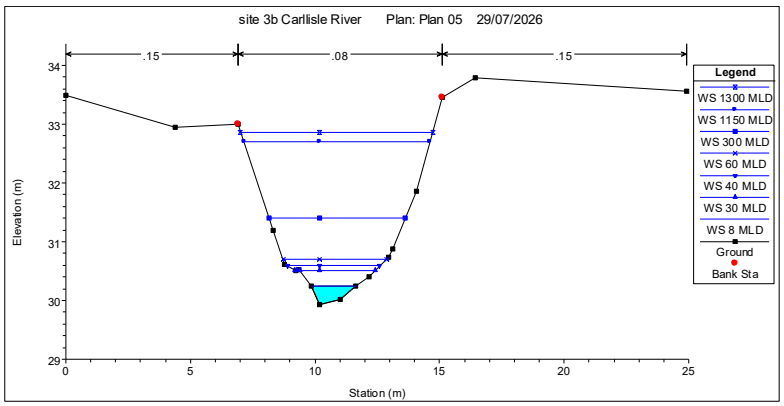
RS	HEC-RAS cross sections at river station (RS)	XS	Site inspection photos
173		3	
168.18		4	
153.17		5	
142.09		6	

RS	HEC-RAS cross sections at river station (RS)	XS	Site inspection photos
126.08		7	
109.04		8	
67.19		9	
39.99		10	

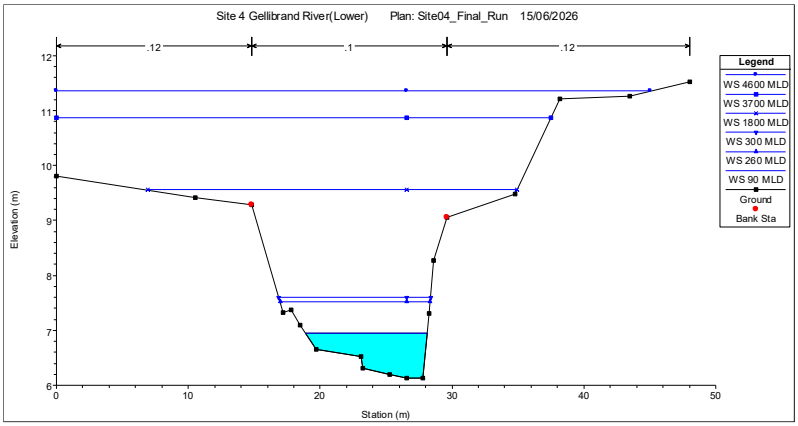
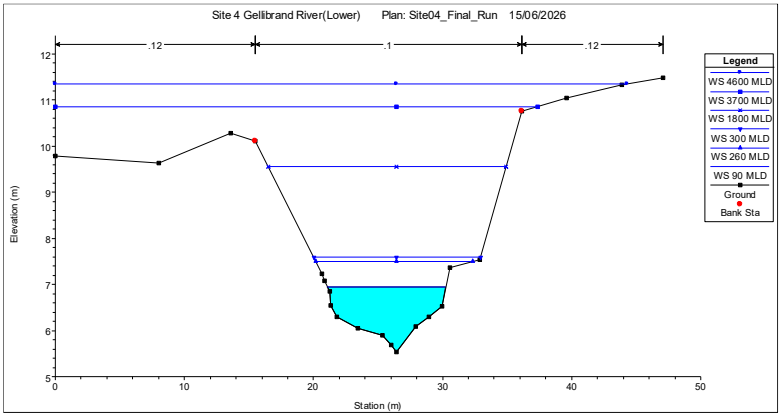
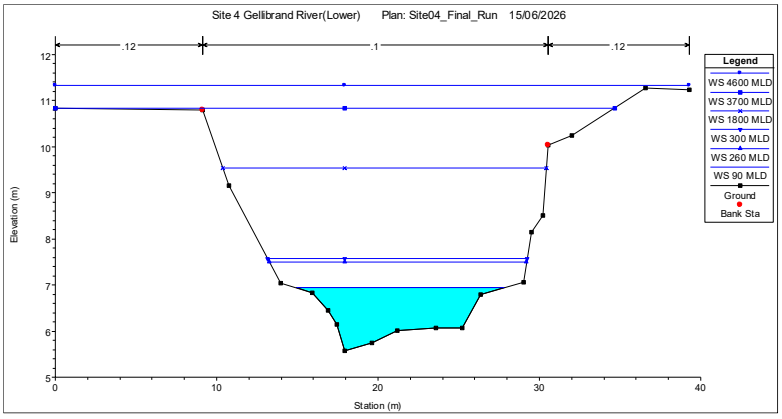
A.5.5 Reach 3b – Carlisle River

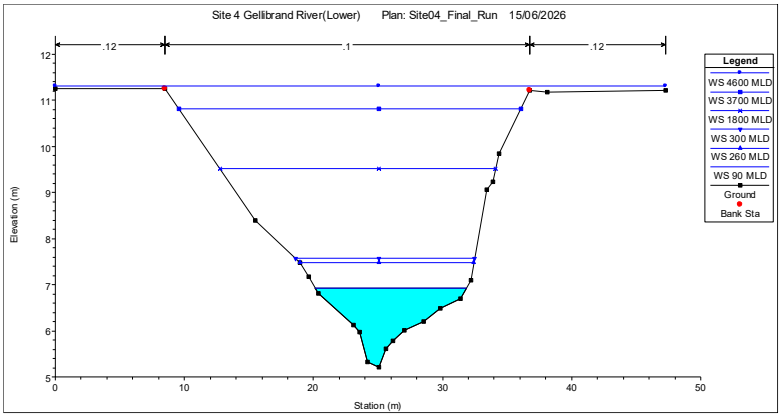
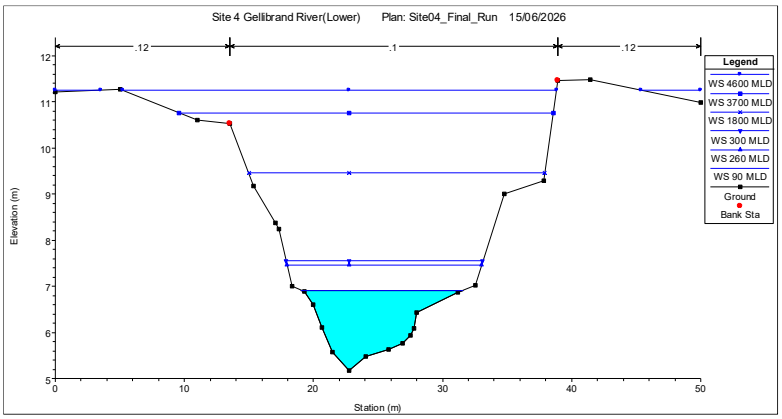
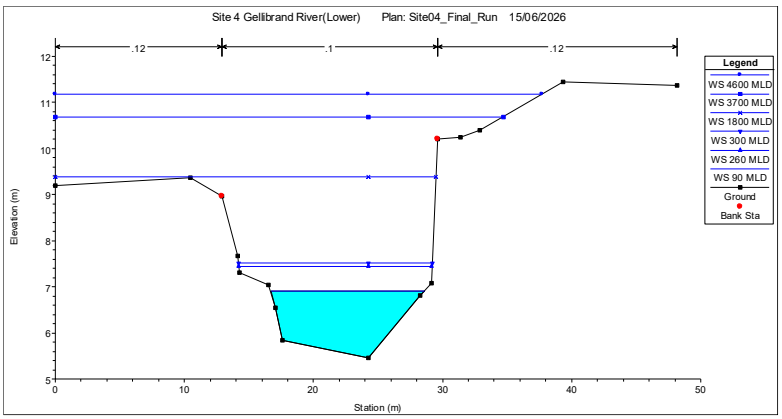
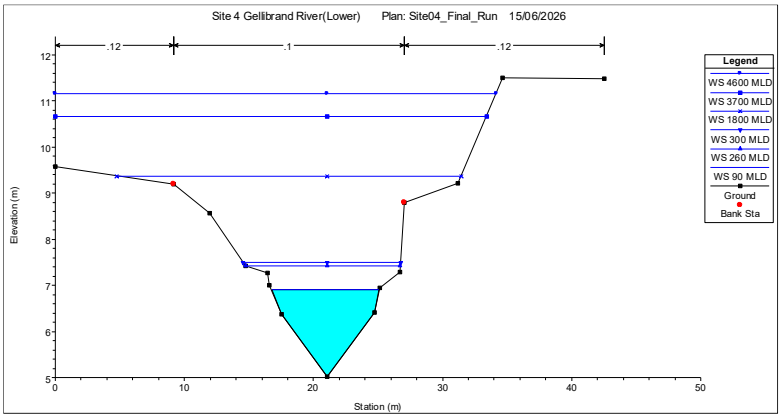
RS	Hec Ras geometry	XS	Site inspection photos
245		1	
237		2	
223		3	
183		4	

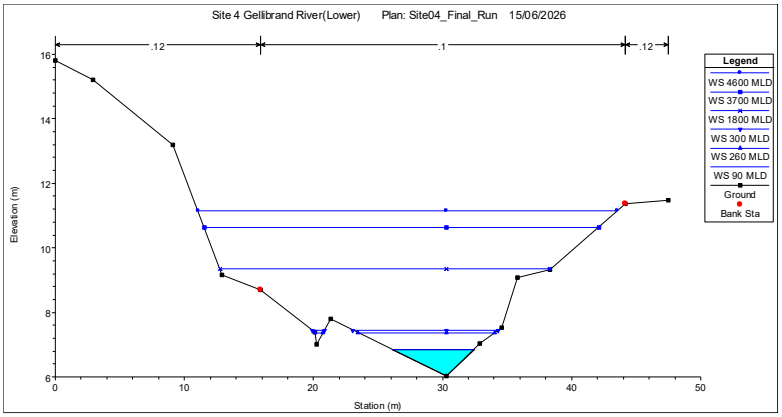
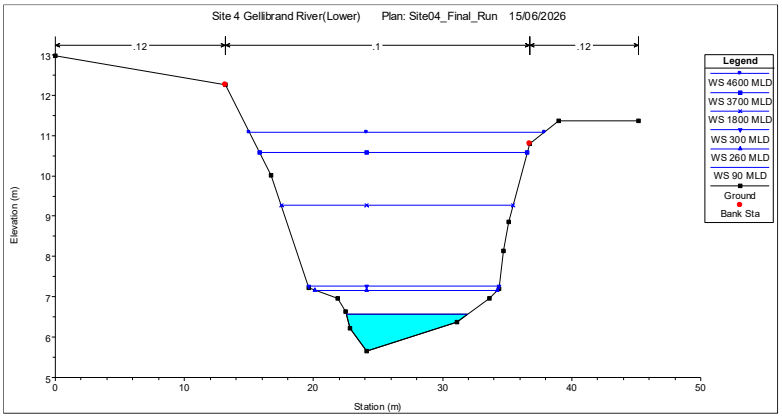
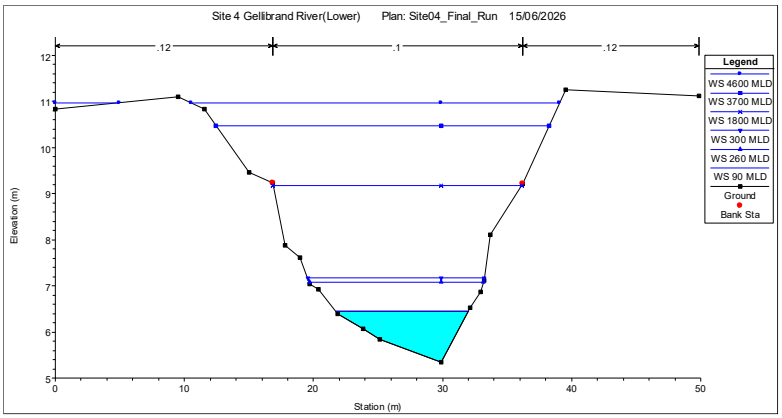
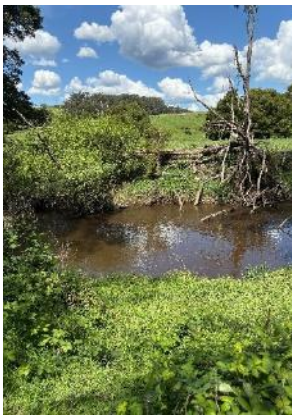
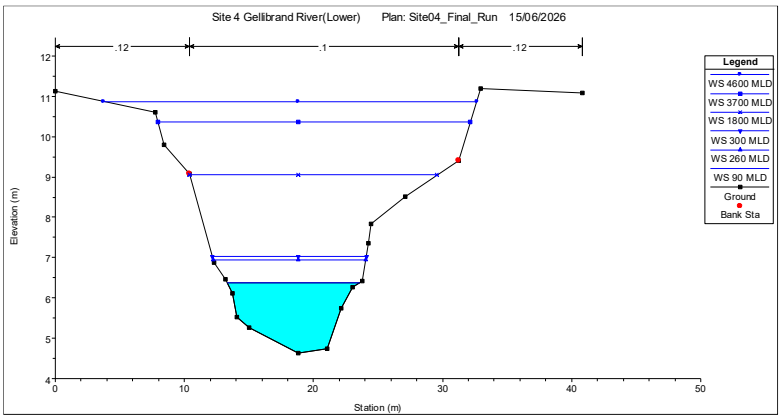
RS	Hec Ras geometry	XS	Site inspection photos
164		5	
135		6	
80		7	
72		8	

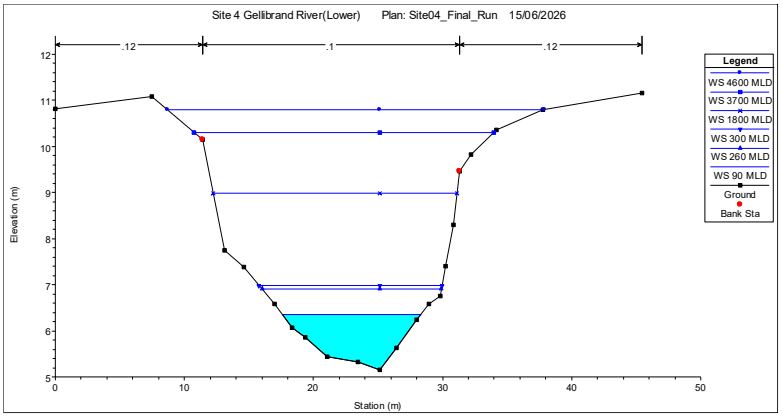
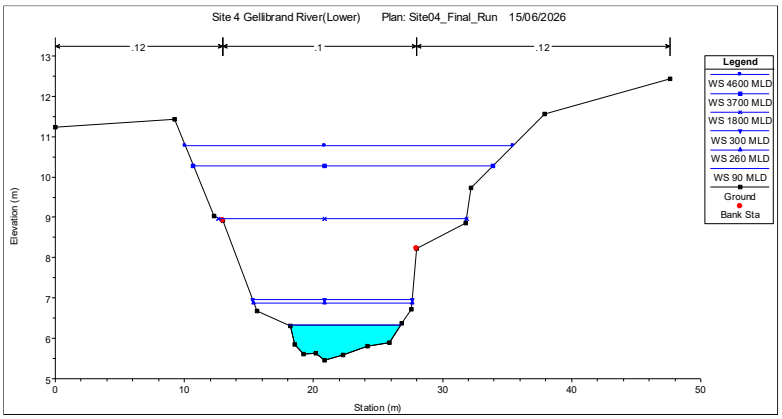
RS	Hec Ras geometry	XS	Site inspection photos
40		9	
23		10	
21		11	
0		12	

A.5.6 Reach 4 – Gellibrand River (lower)

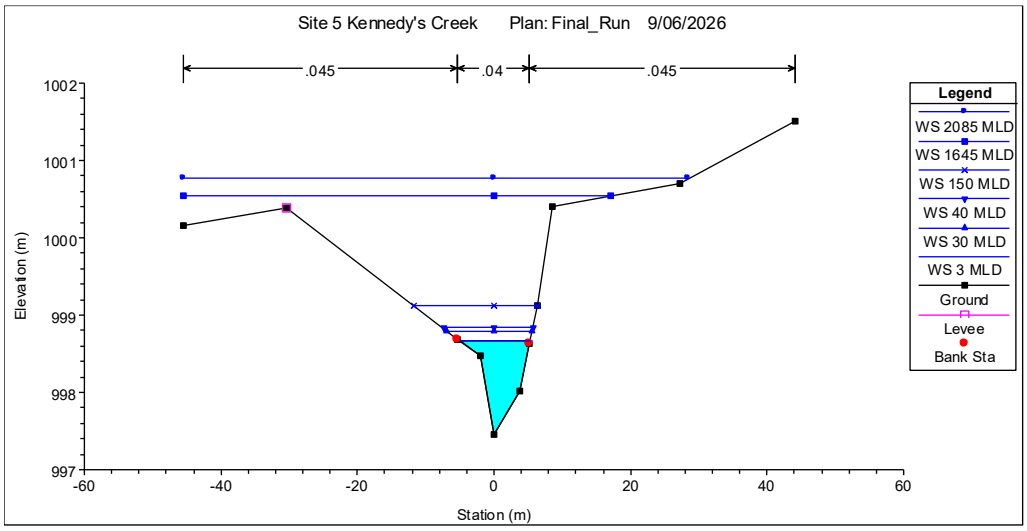
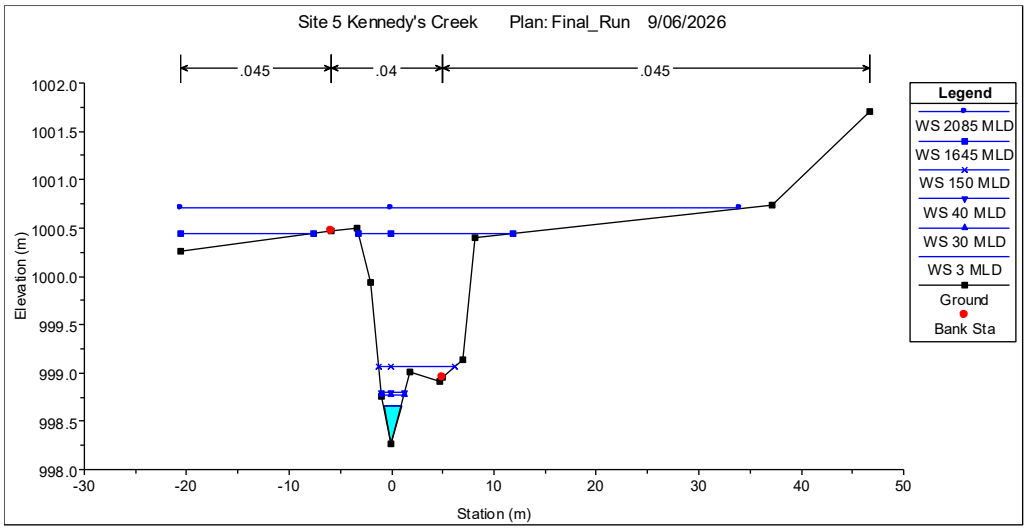
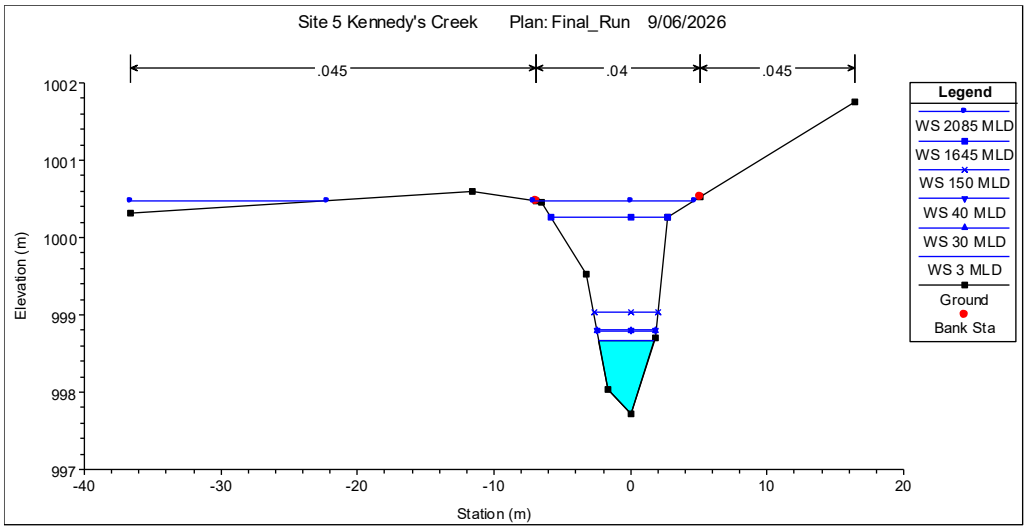
RS	Hec Ras geometry	XS	Site inspection photos
800.0		1	
789.1		2	
759.6		3	

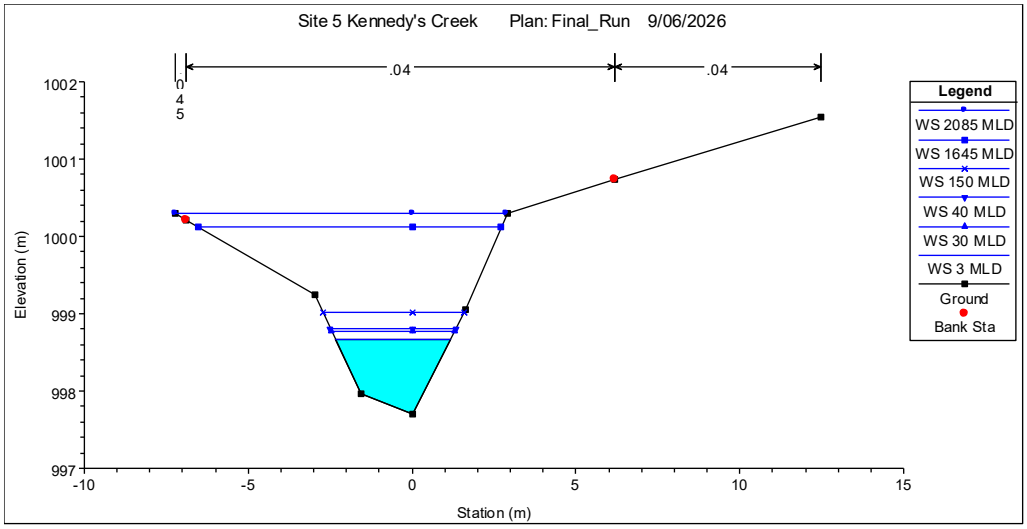
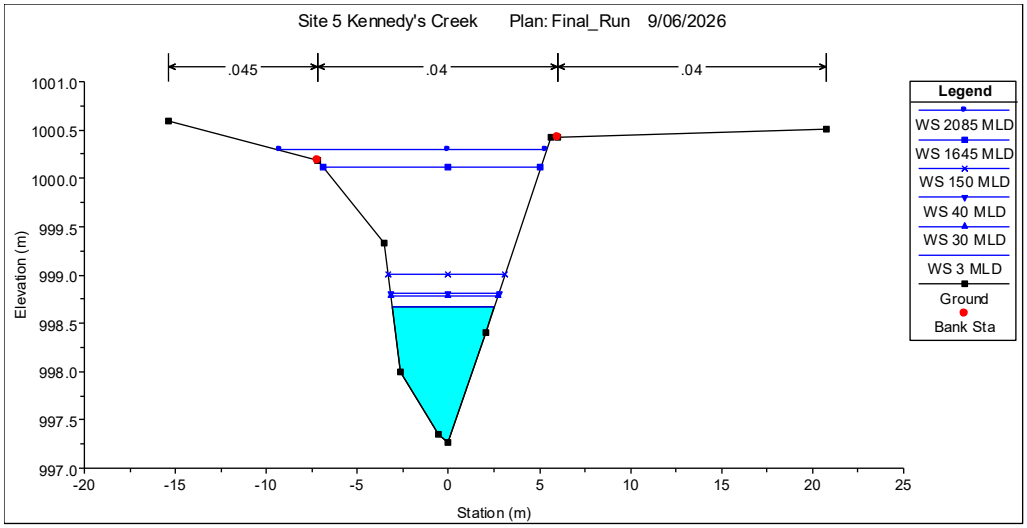
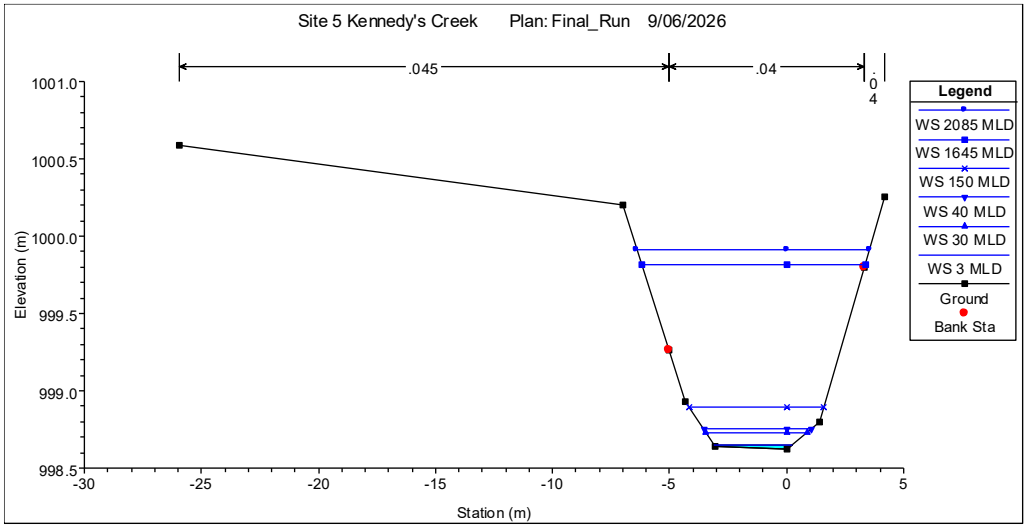
RS	Hec Ras geometry	XS	Site inspection photos
716.1		4	
633.0		5	
497.8		6	
474.2		6b	

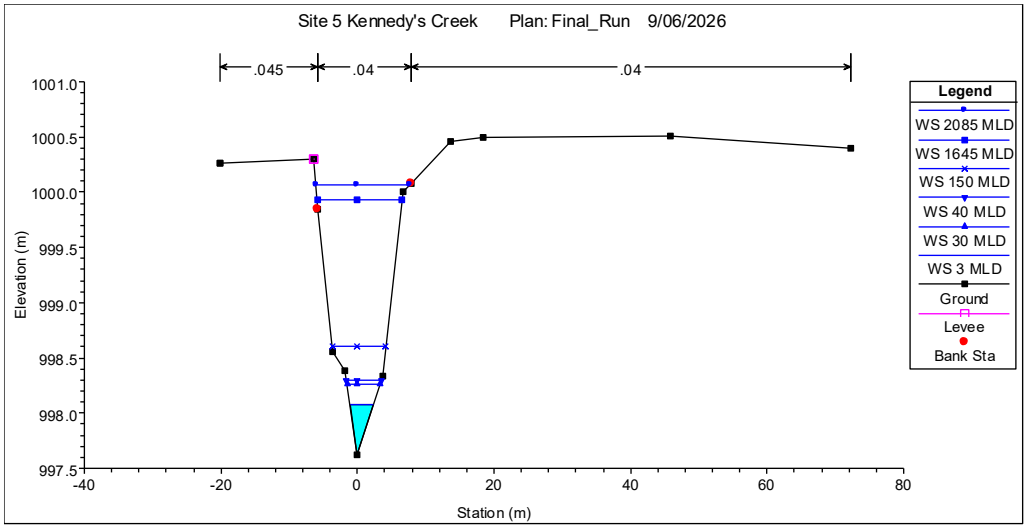
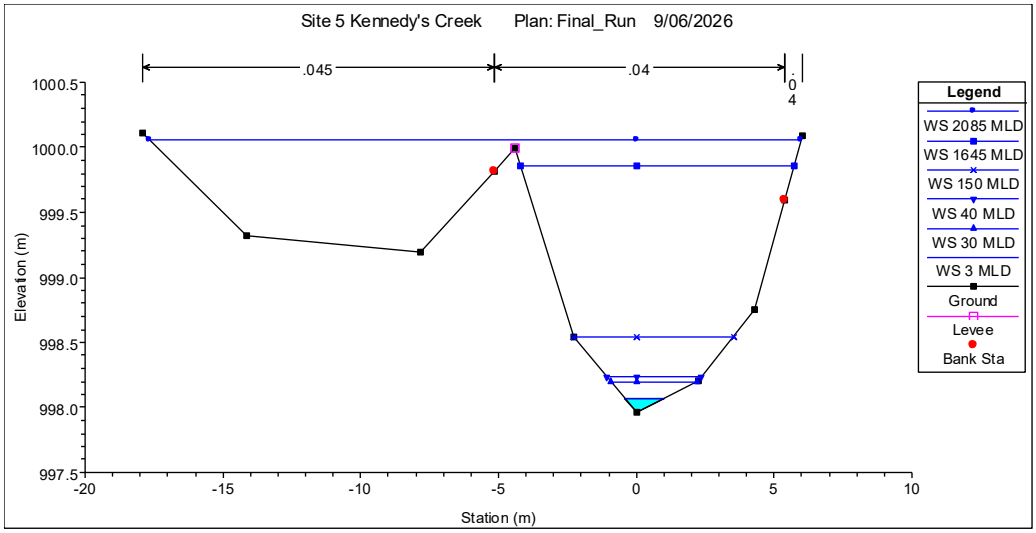
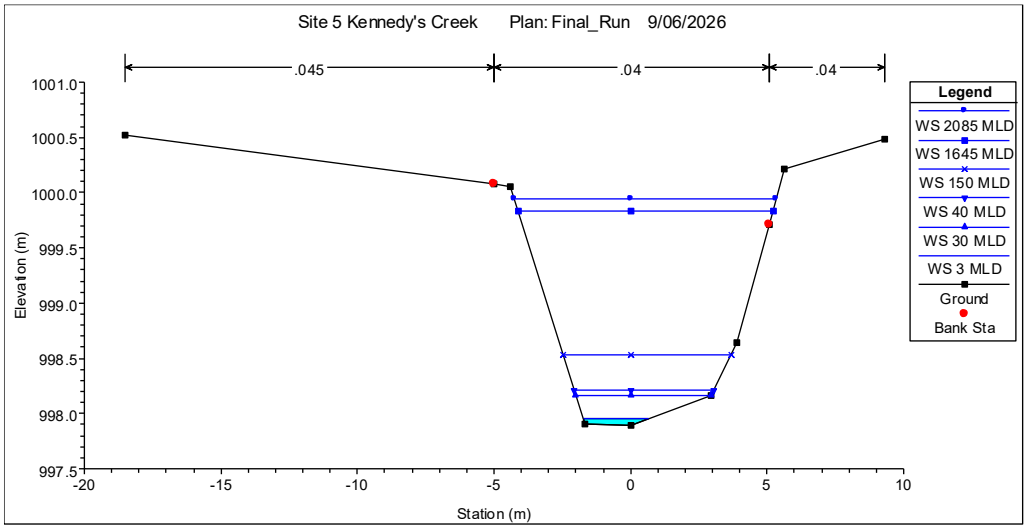
RS	Hec Ras geometry	XS	Site inspection photos
437.5		7	
389.4		8	
246.5		8a	
125.0		8b	

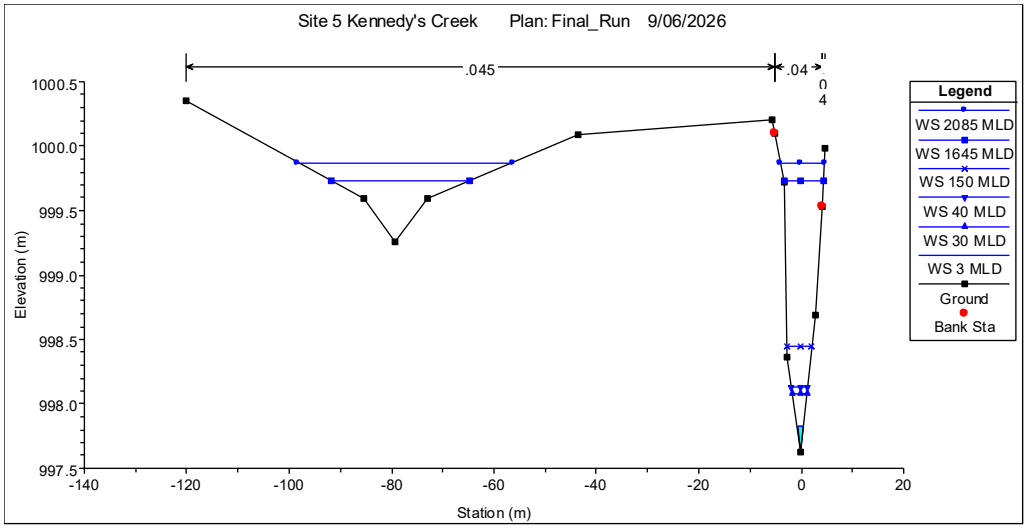
RS	Hec Ras geometry	XS	Site inspection photos
43.3		9	
25.2		10	

A.5.7 Reach 5 – Kennedys Creek

RS	Hec Ras geometry
183	
174	
130	

RS	Hec Ras geometry
103	
78	
58	

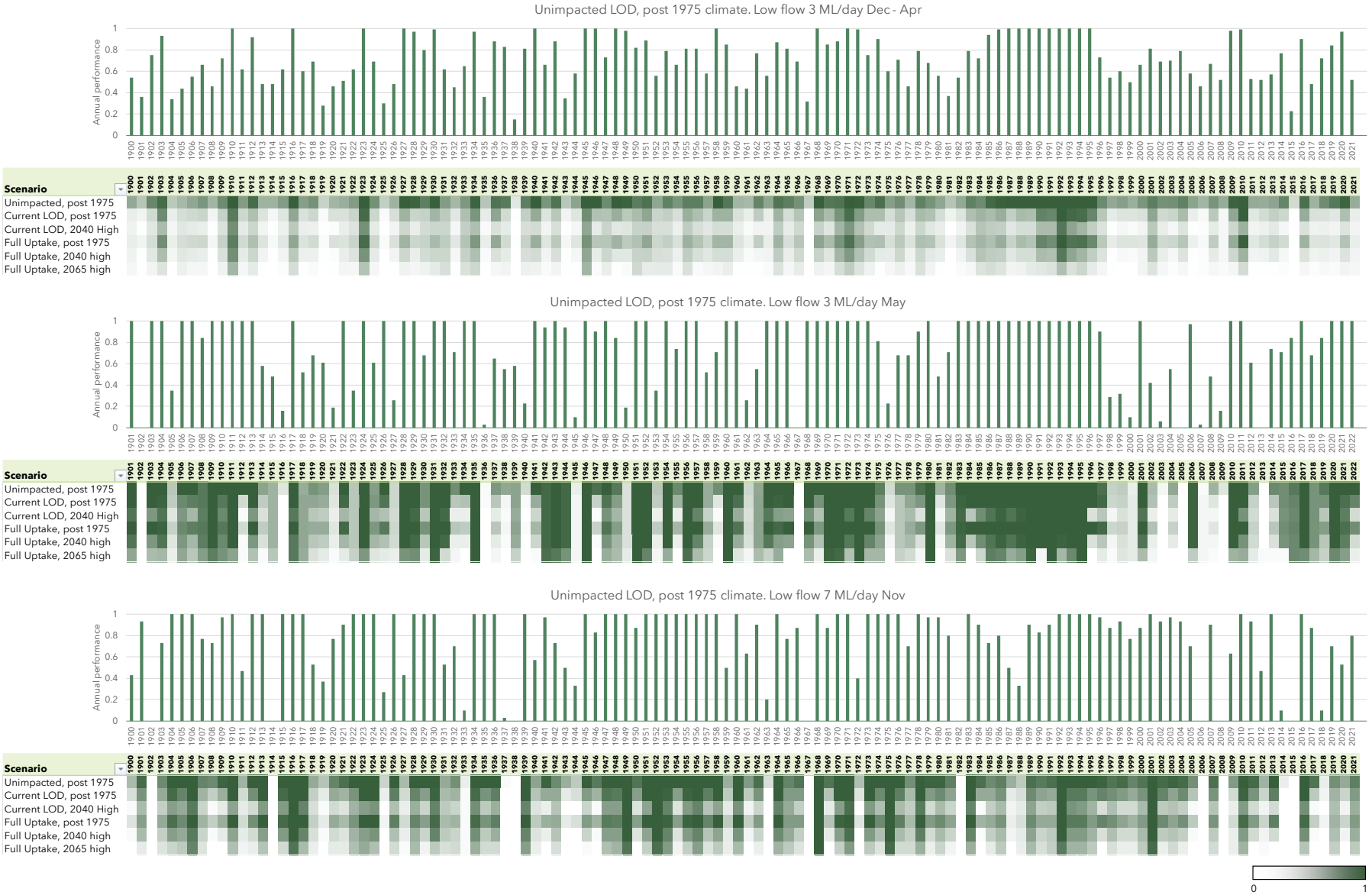
RS	Hec Ras geometry
48	
38	
27	

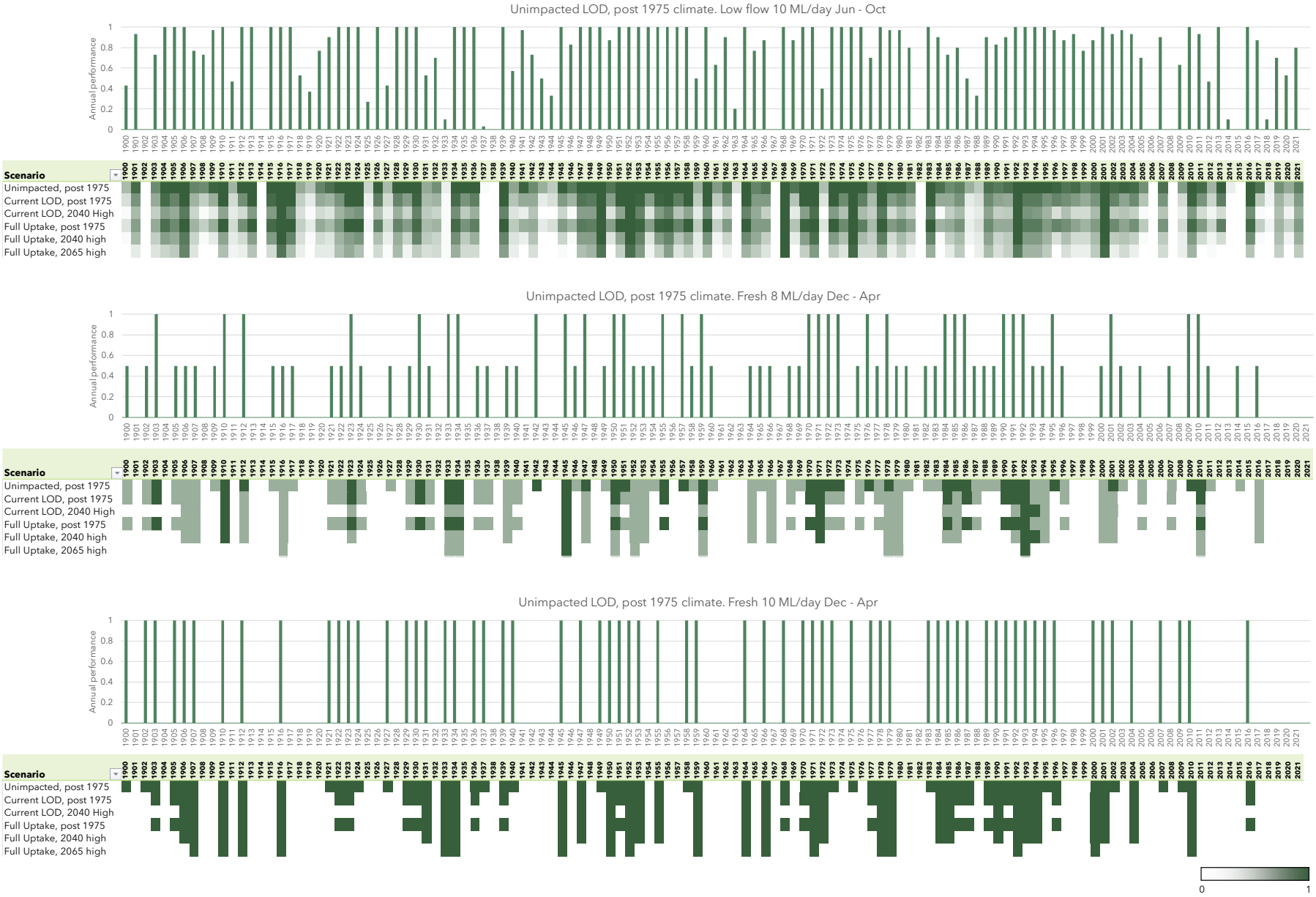
RS	Hec Ras geometry
0	

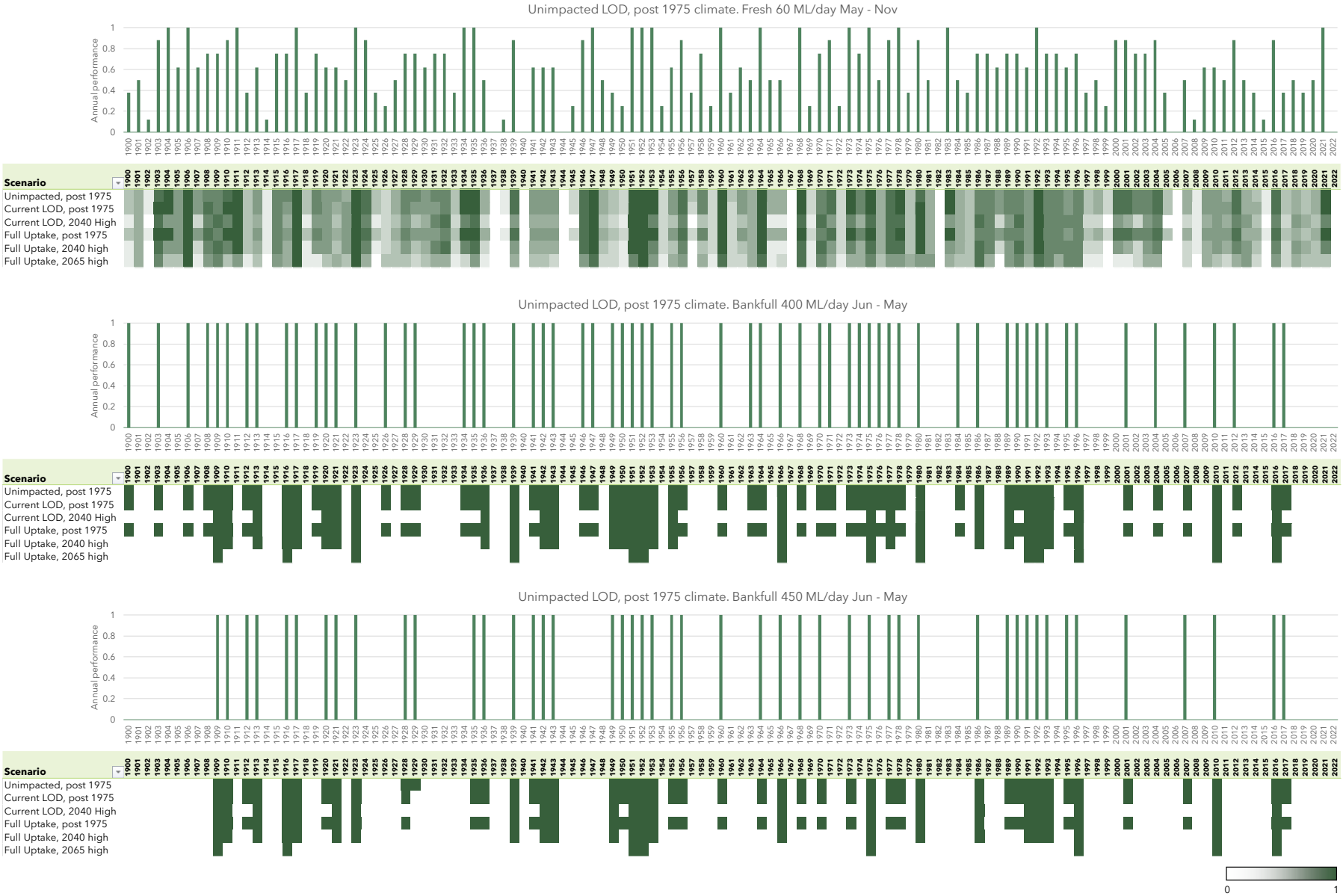
A.6 Performance assessment

Annual achievement (in 122 analysed years of modelled flow data) of the recommended flow components in each reach is presented below in heat map form. The intensity of shading reflects the annual performance score. Heat maps are provided for the development and climate scenarios requested by the PSC and PAG. A bar chart showing annual performance in modelled unimpacted development, post 1975 climate flows is provided for each flow component and corresponds to the first row of each heat map. Summarised mean annual performance data are presented for each reach in Section 5 of the main report.

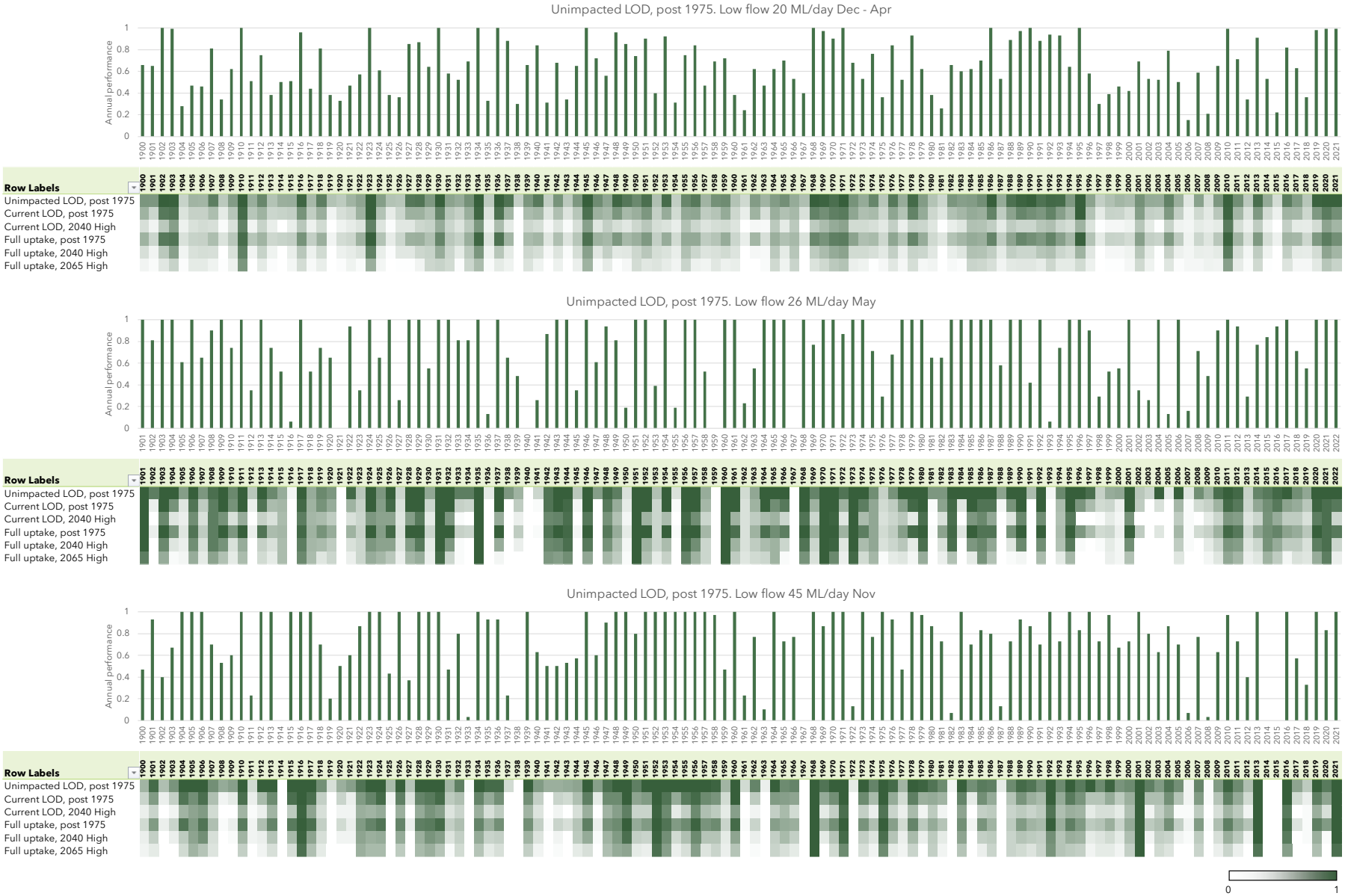
A.6.1 Reach 1a – performance

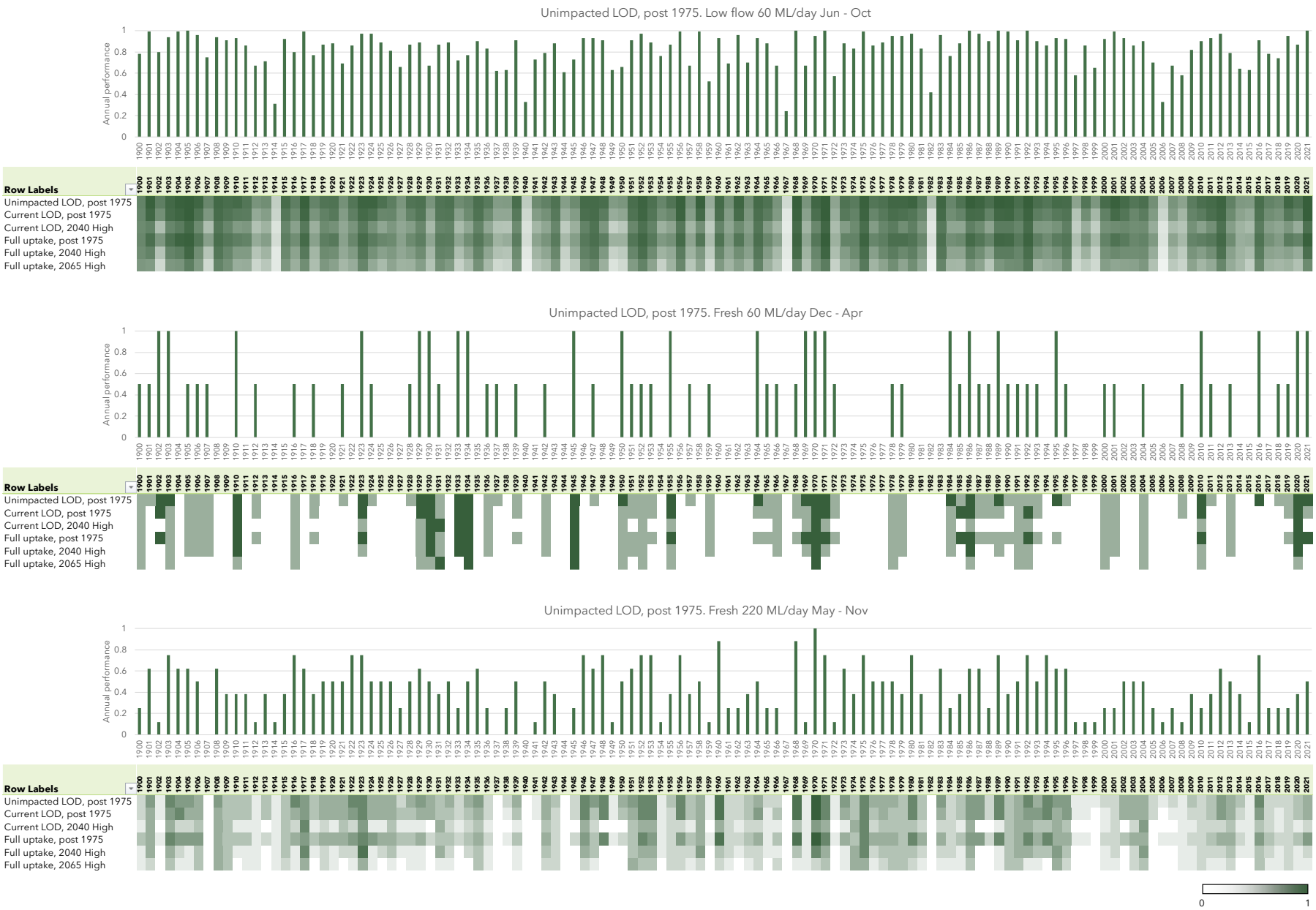


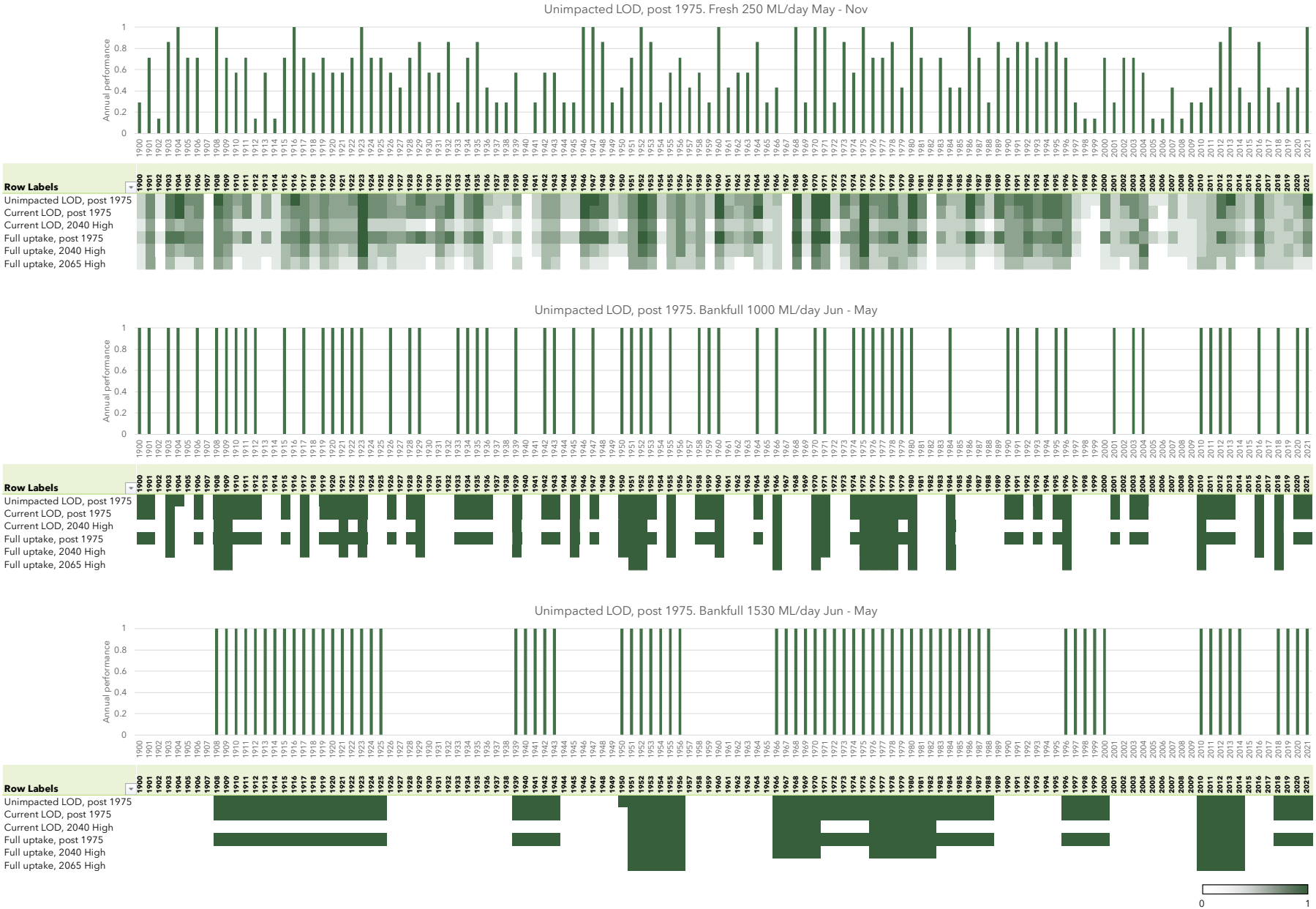

Unimpacted LOD, post 1975 climate. Low flow 10 ML/day Jun - Oct
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
Unimpacted LOD, post 1975 climate. Fresh 8 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
Unimpacted LOD, post 1975 climate. Fresh 10 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
0
1


Unimpacted LOD, post 1975 climate. Fresh 60 ML/day May - Nov
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
Unimpacted LOD, post 1975 climate. Bankfull 400 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
Unimpacted LOD, post 1975 climate. Bankfull 450 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full Uptake, post 1975
Full Uptake, 2040 high
Full Uptake, 2065 high
0
1

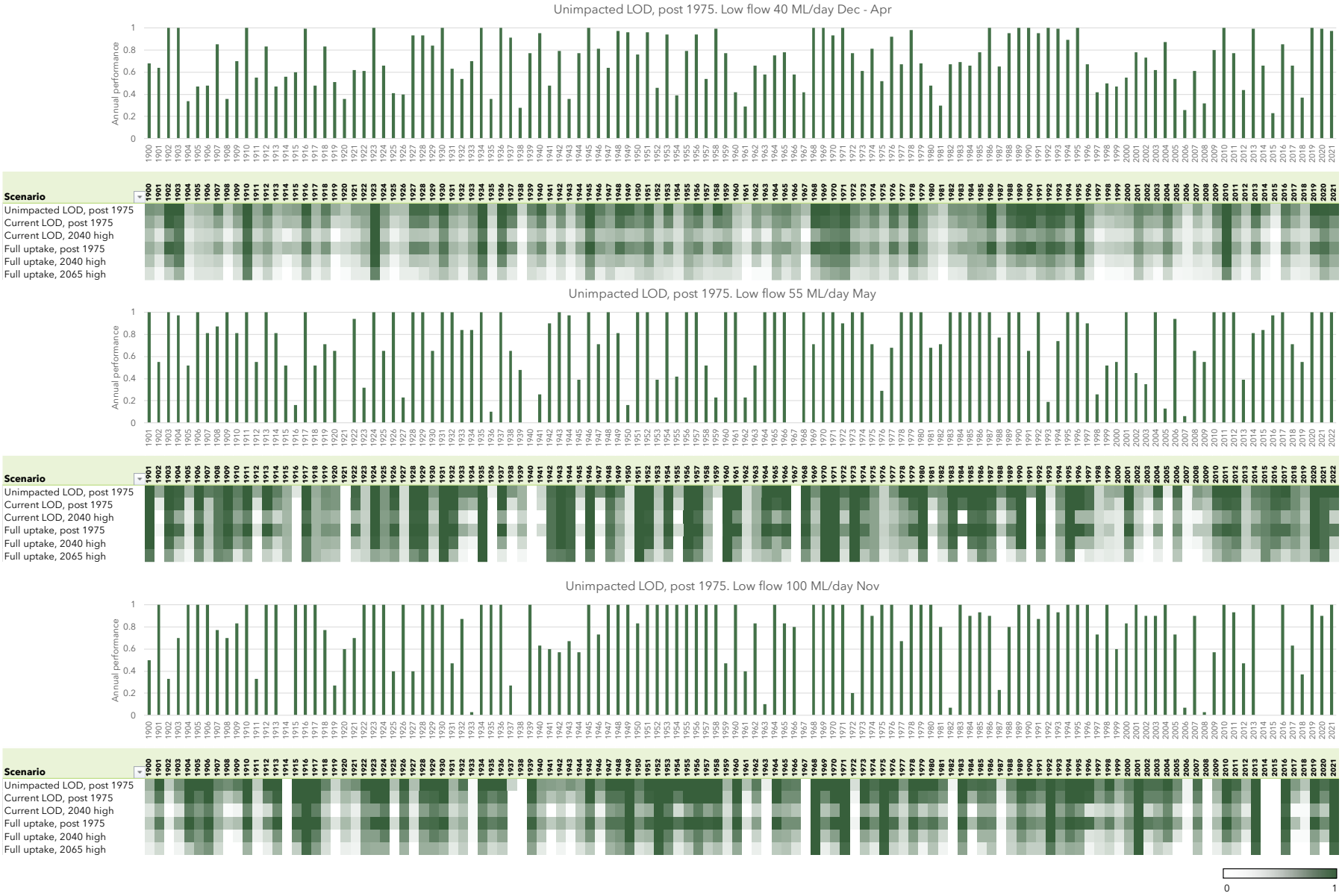
A.6.2 Reach 2a – Performance

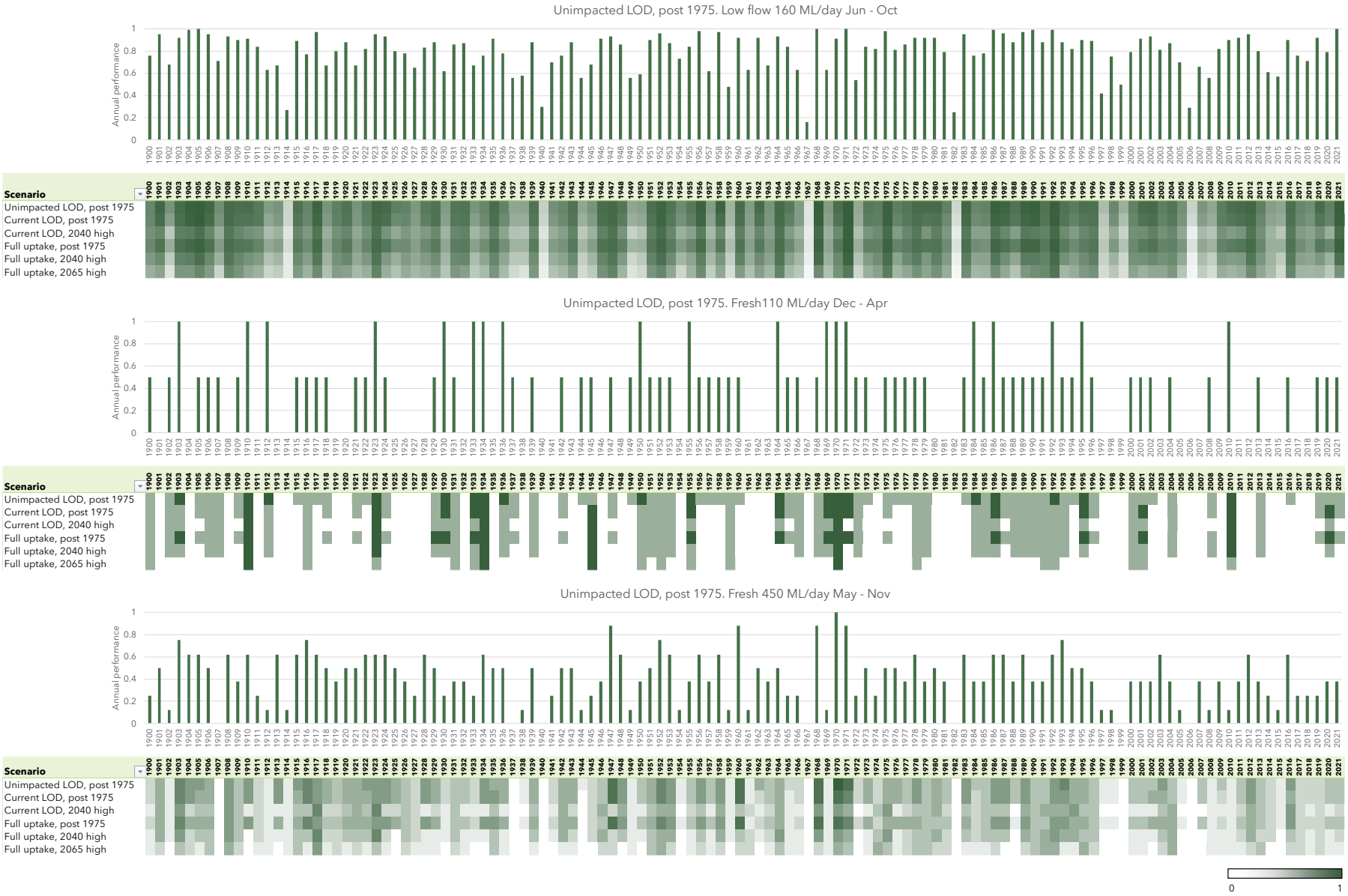


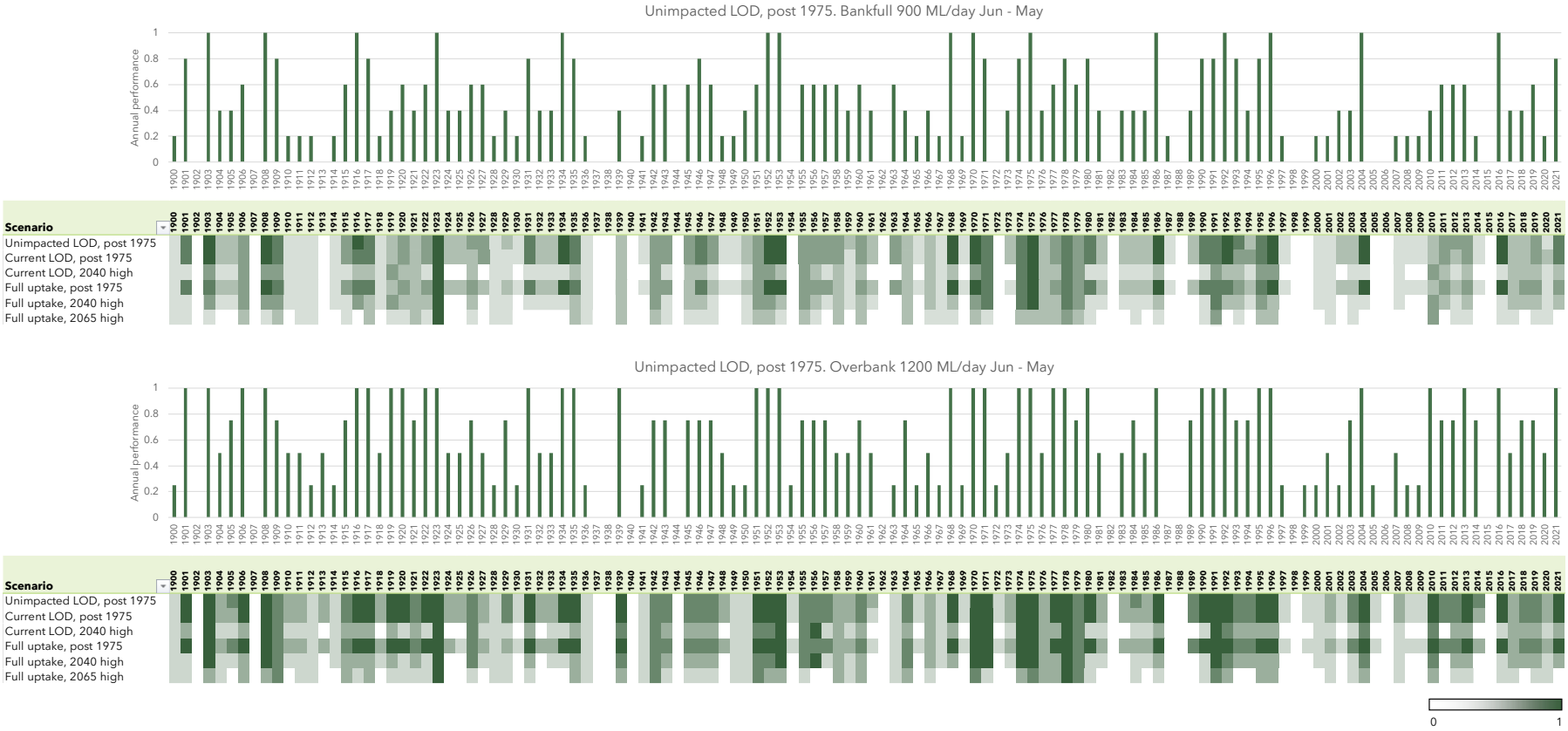

Unimpacted LOD, post 1975. Low flow 60 ML/day Jun - Oct
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
Unimpacted LOD, post 1975. Fresh 60 ML/day Dec - Apr
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
Unimpacted LOD, post 1975. Fresh 220 ML/day May - Nov
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
0
1


Unimpacted LOD, post 1975. Fresh 250 ML/day May - Nov
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
Unimpacted LOD, post 1975. Bankfull 1000 ML/day Jun - May
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
Unimpacted LOD, post 1975. Bankfull 1530 ML/day Jun - May
Annual performance
Row Labels
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 High
Full uptake, post 1975
Full uptake, 2040 High
Full uptake, 2065 High
0
1

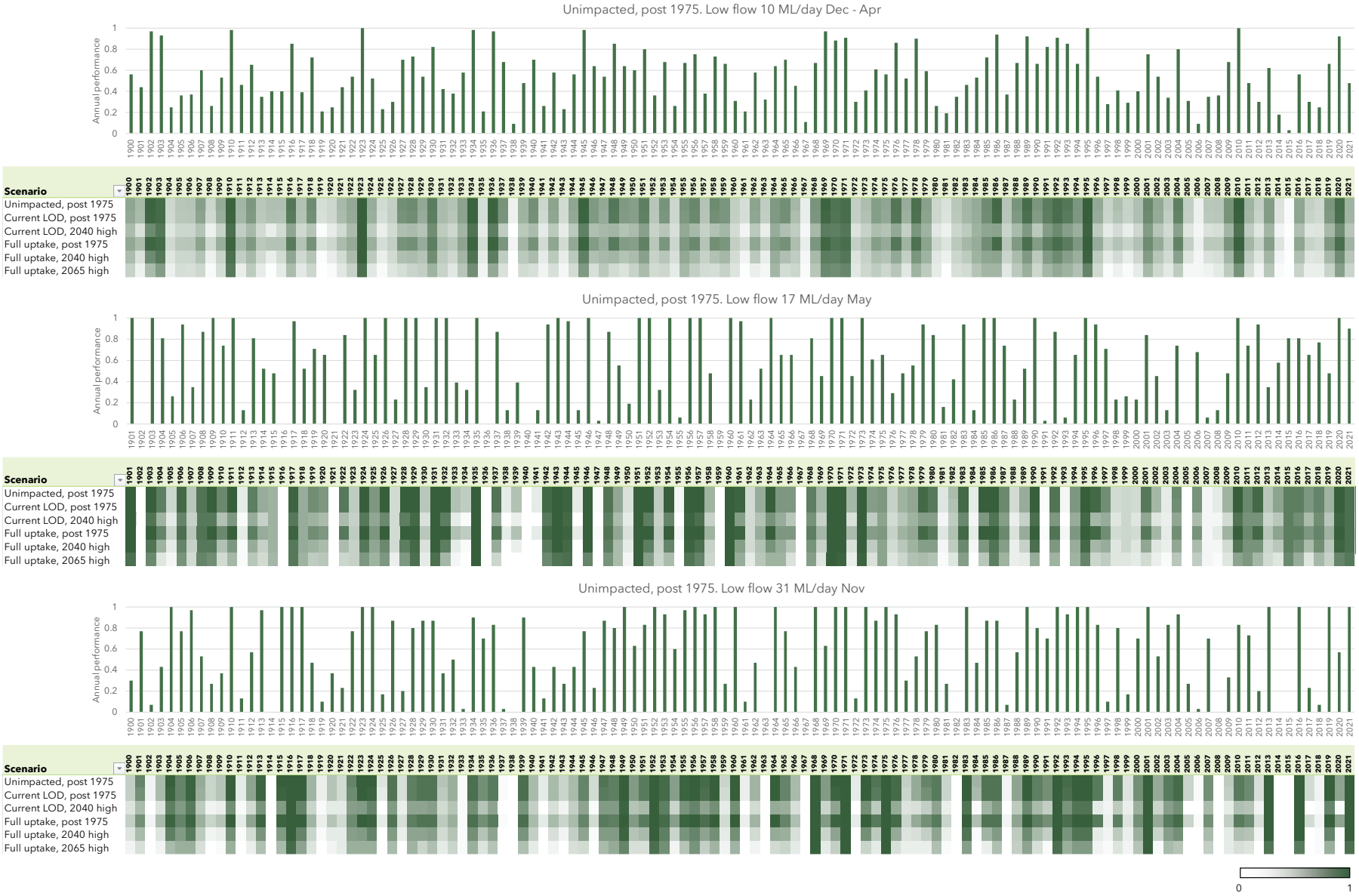
A.6.3 Reach 2b - Performance

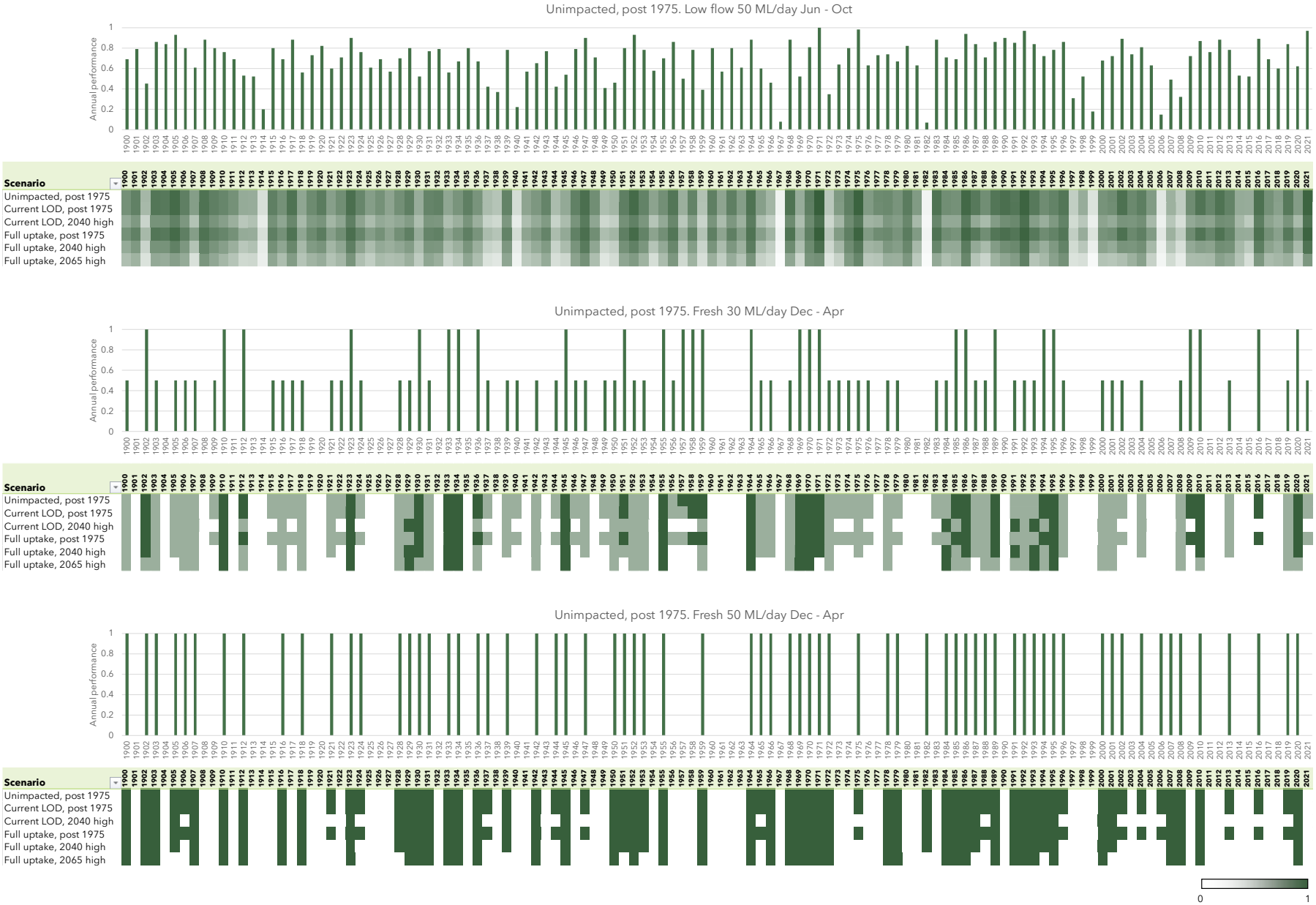


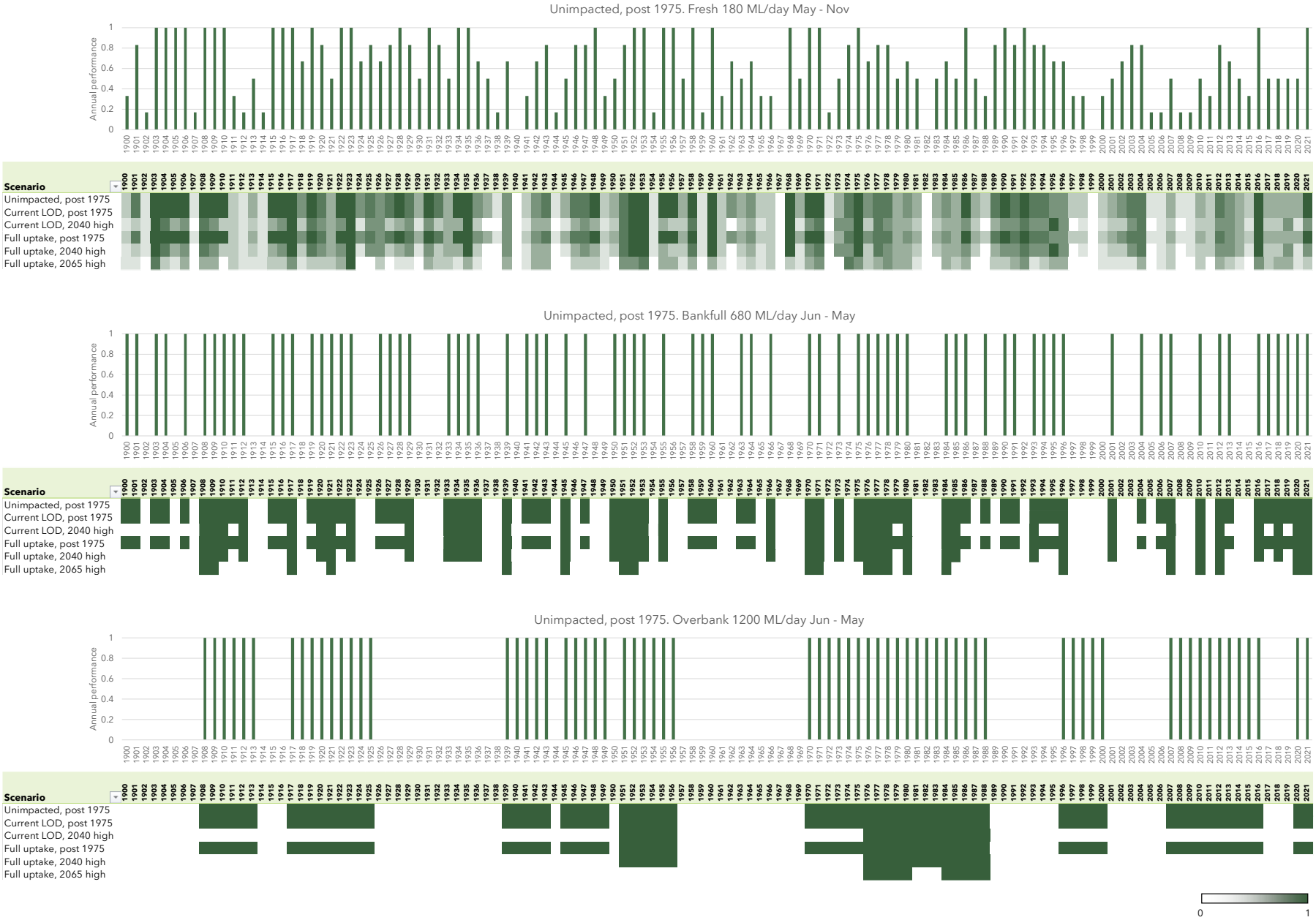

Unimpacted LOD, post 1975. Low flow 160 ML/day Jun - Oct
Annual performance
Scenario
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted LOD, post 1975. Fresh110 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted LOD, post 1975. Fresh 450 ML/day May - Nov
Annual performance
Scenario
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1


Unimpacted LOD, post 1975. Bankfull 900 ML/day Jun - May
Annual performance
Scenario
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted LOD, post 1975. Overbank 1200 ML/day Jun - May
Annual performance
Scenario
Unimpacted LOD, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

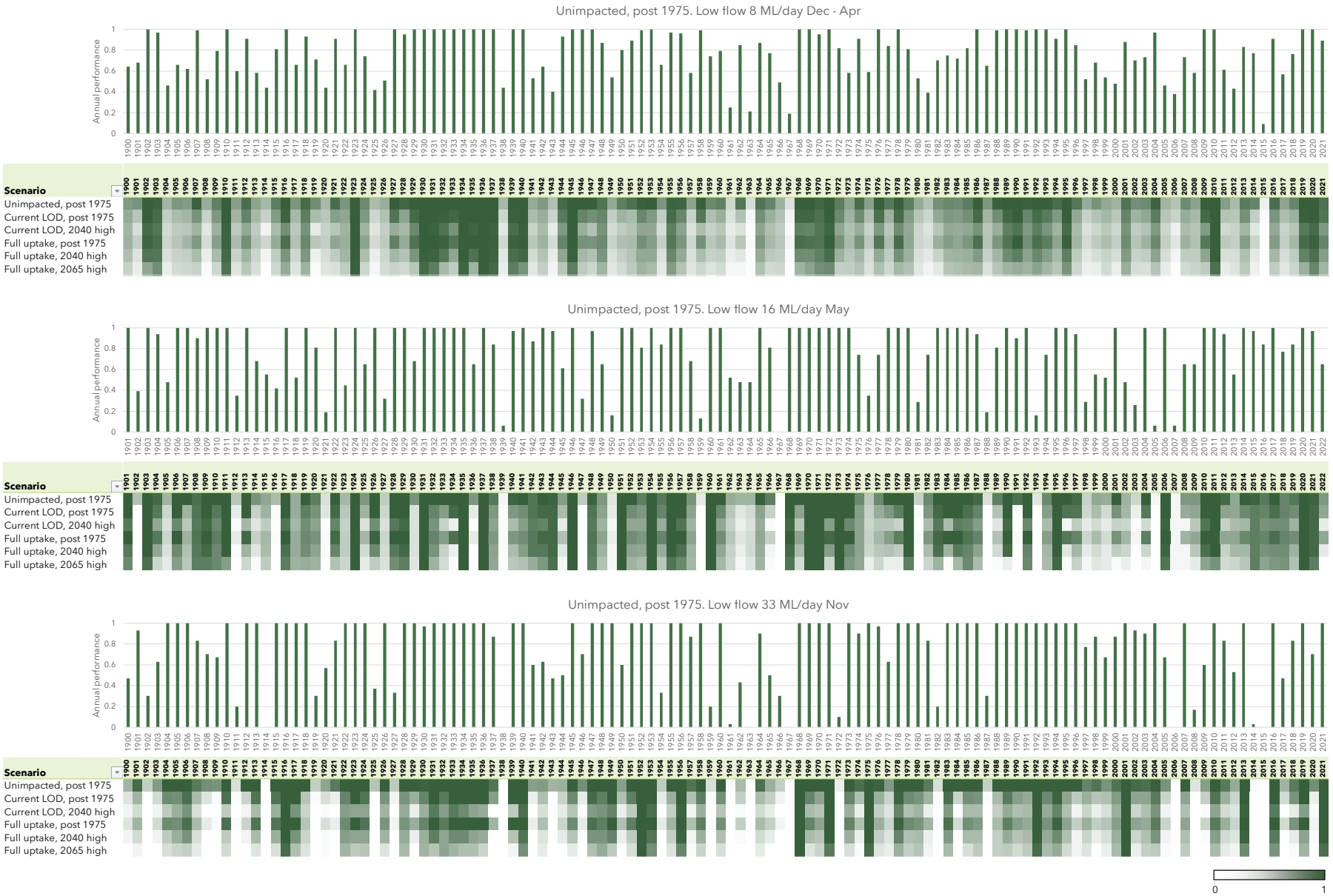
A.6.4 Reach 2c – Performance

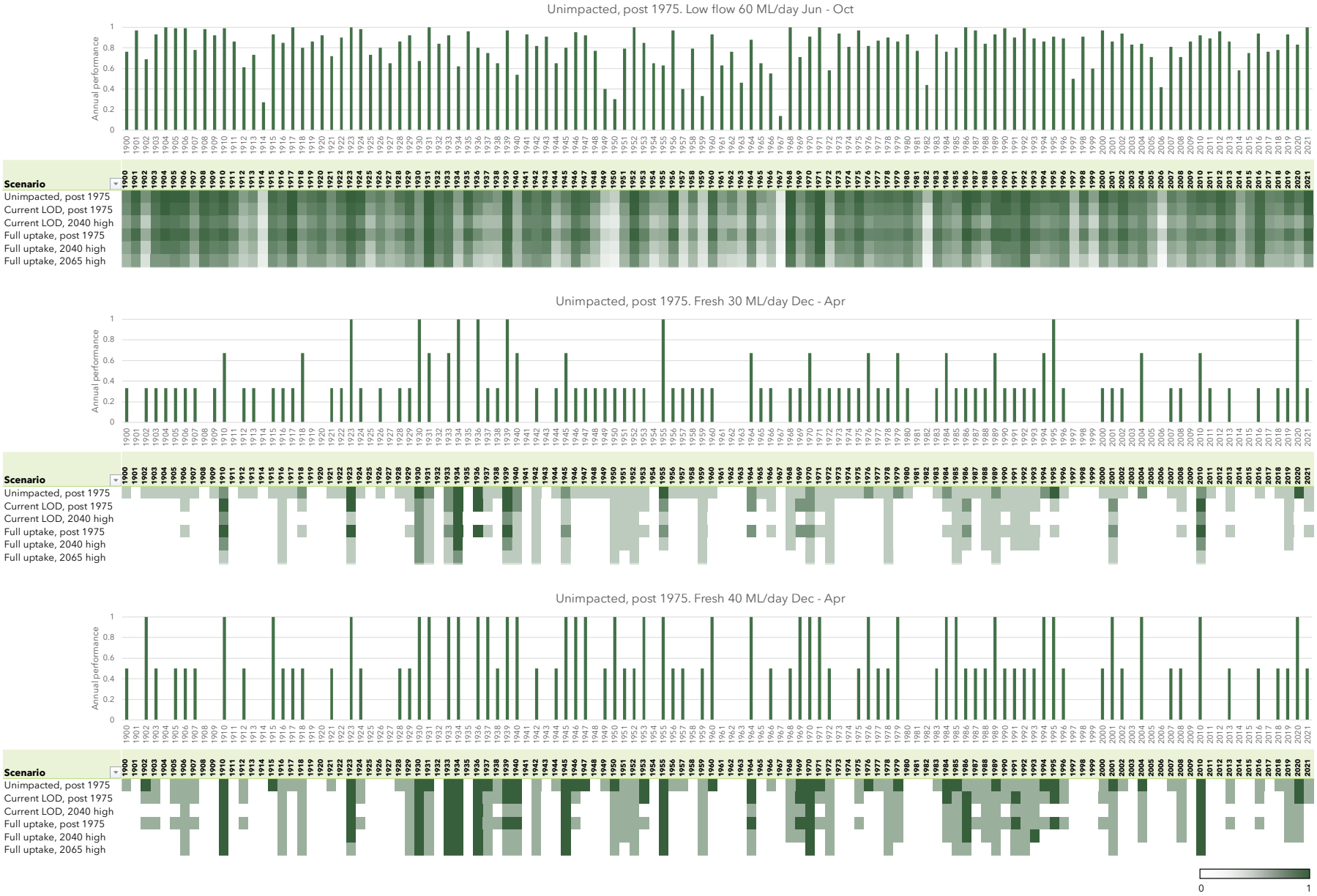


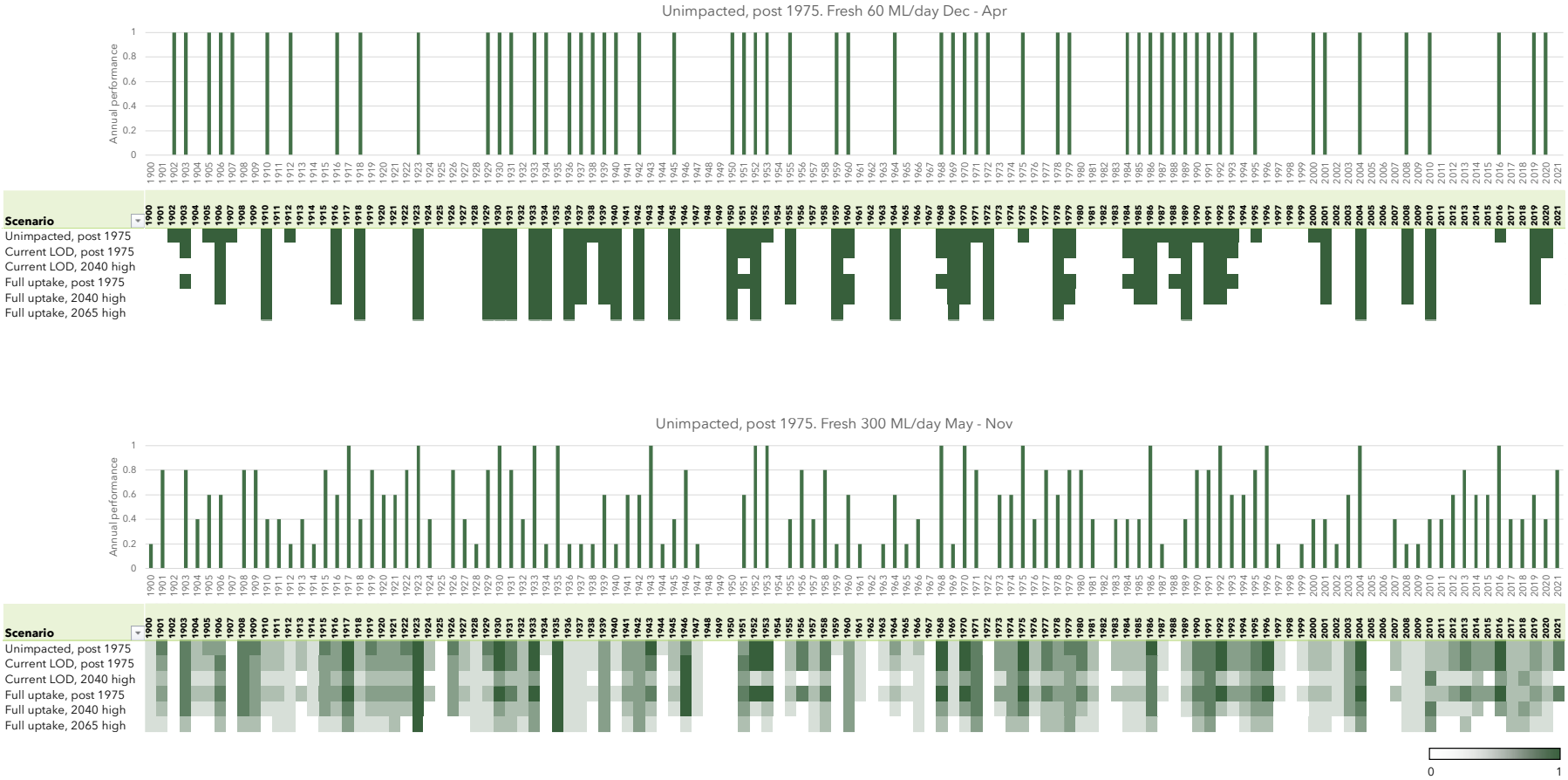

Unimpacted, post 1975. Low flow 50 ML/day Jun - Oct
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Fresh 30 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Fresh 50 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

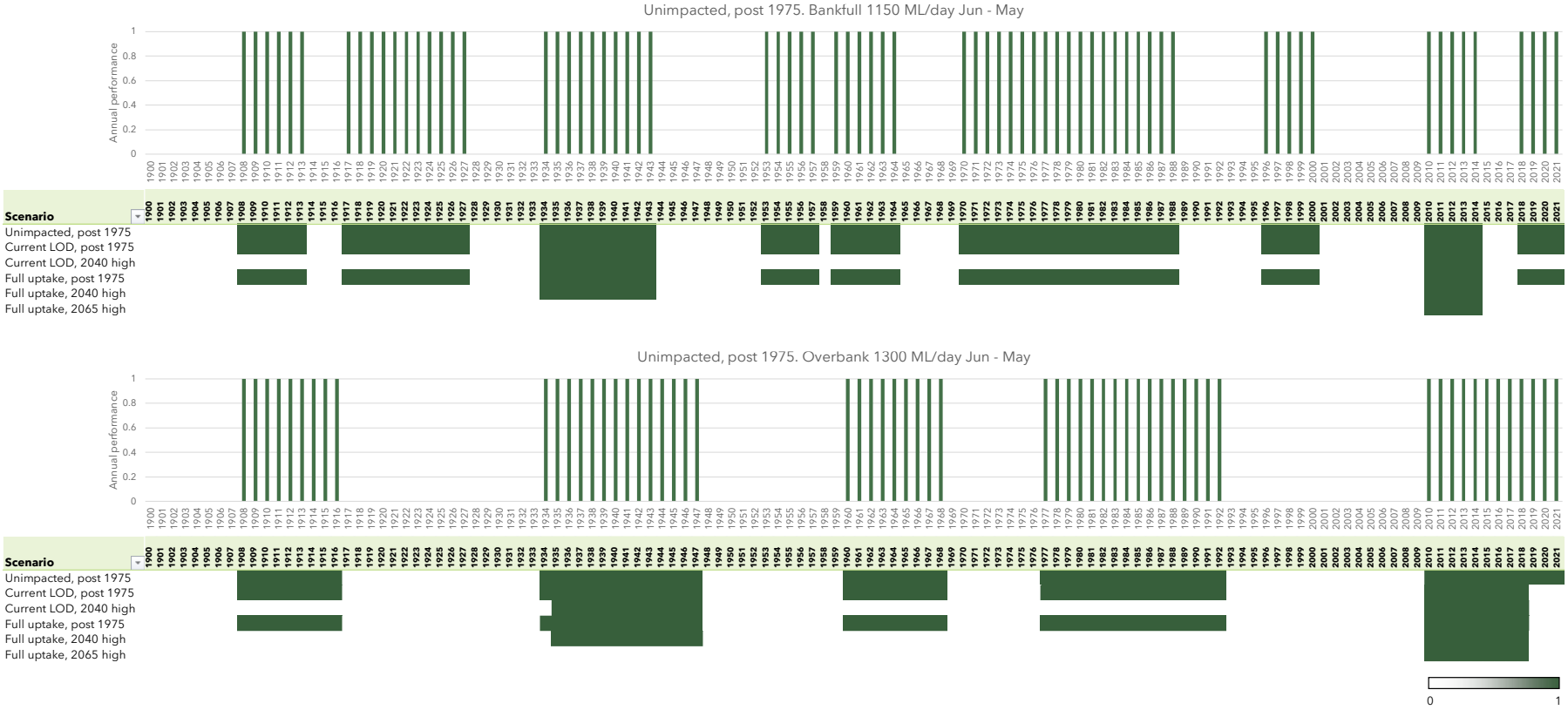

Unimpacted, post 1975. Fresh 180 ML/day May - Nov
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Bankfull 680 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Overbank 1200 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

A.6.5 Reach 3b – Performance

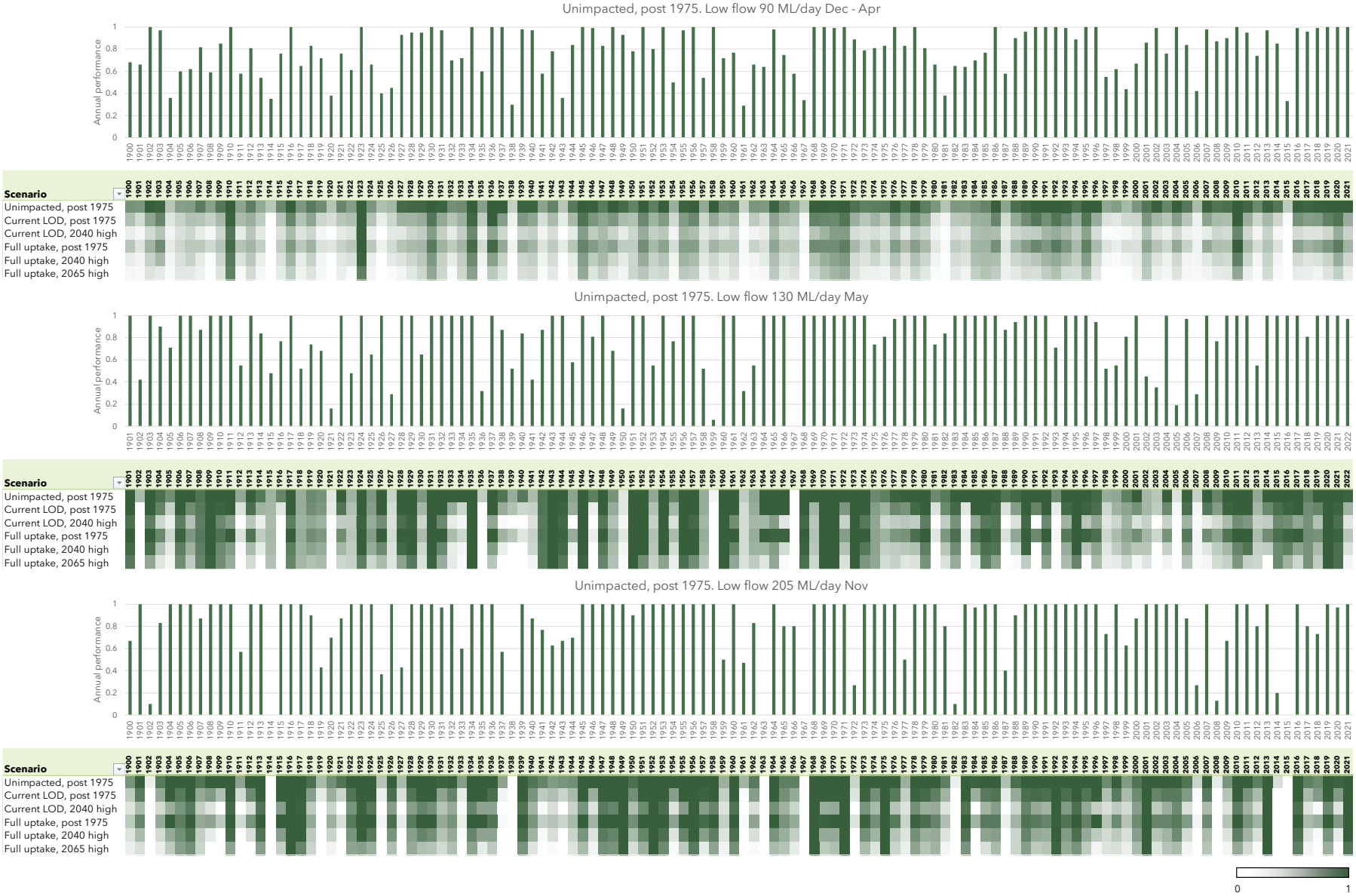


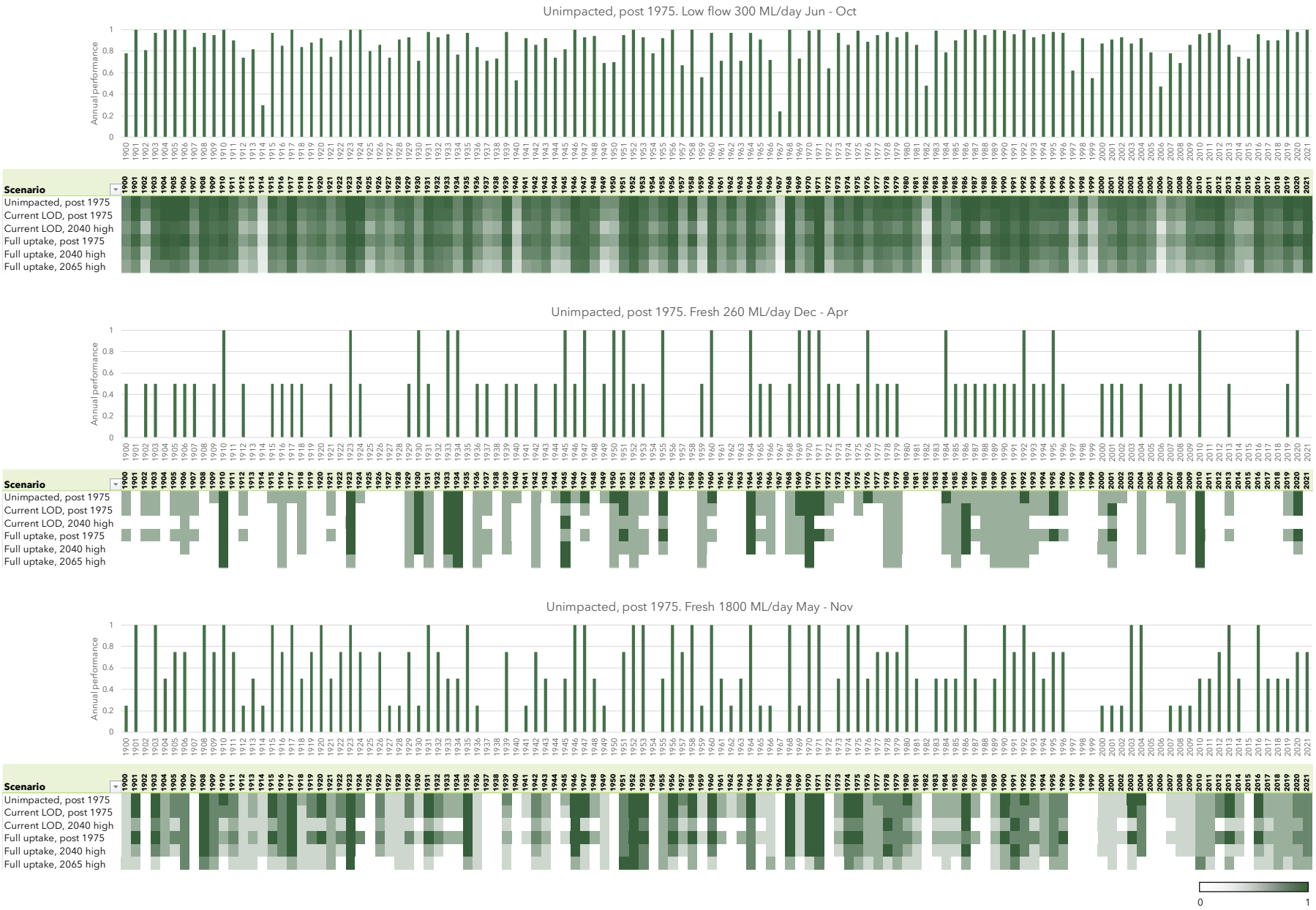

Unimpacted, post 1975. Low flow 60 ML/day Jun - Oct
Annual performance
Unimpacted, post 1975. Fresh 30 ML/day Dec - Apr
Annual performance
Unimpacted, post 1975. Fresh 40 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

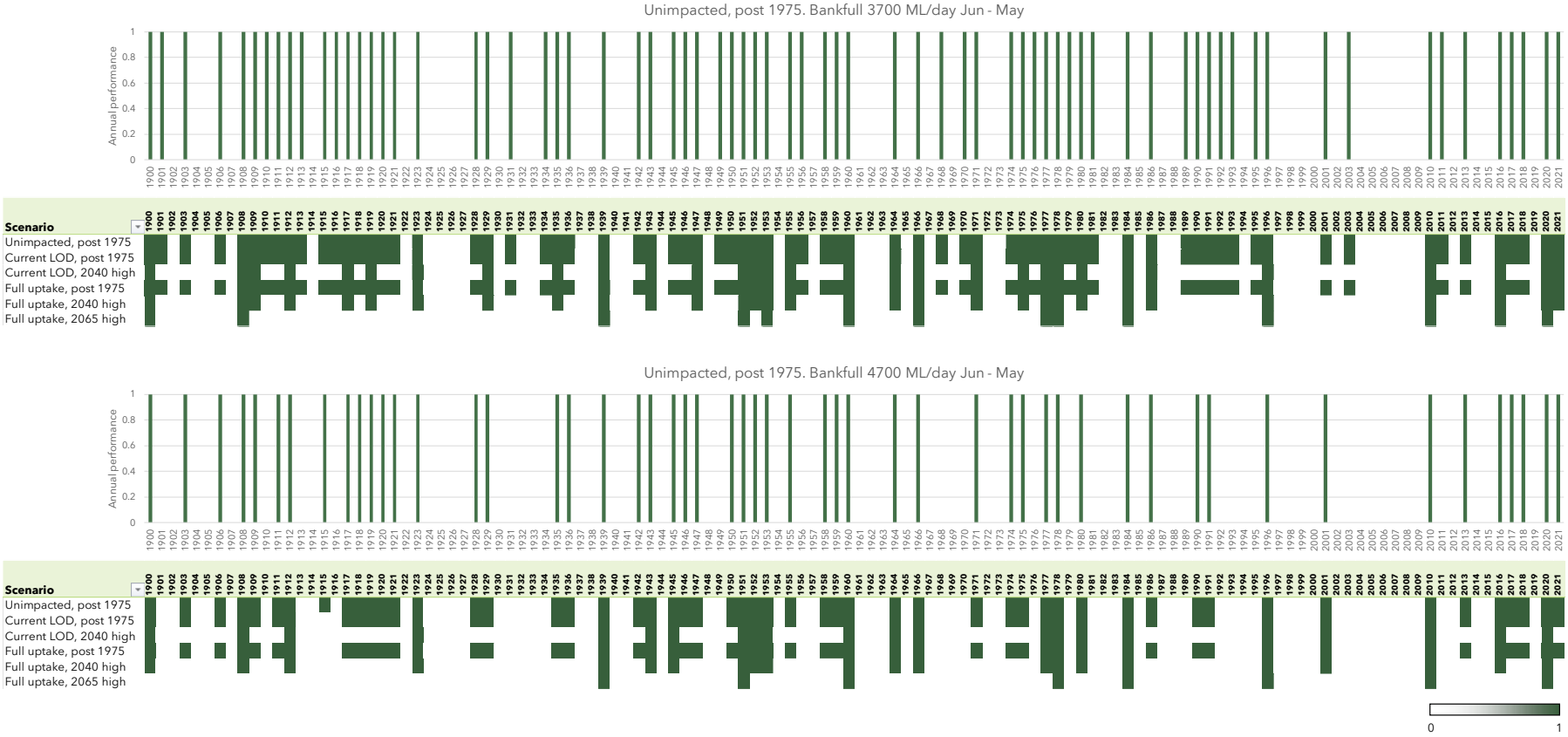

Unimpacted, post 1975. Fresh 60 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Fresh 300 ML/day May - Nov
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1


Unimpacted, post 1975. Bankfull 1150 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Overbank 1300 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

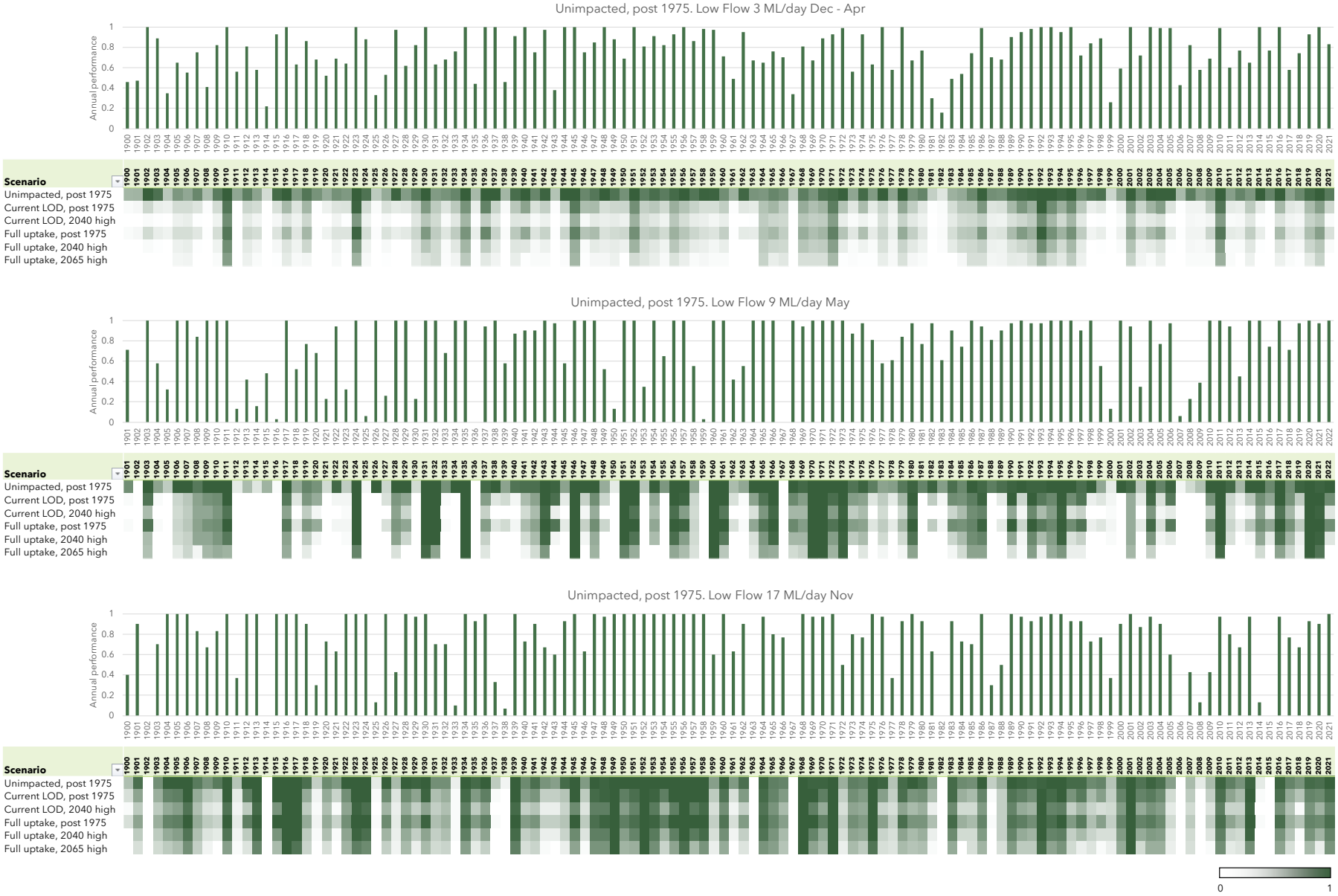
A.6.6 Reach 4 - Performance

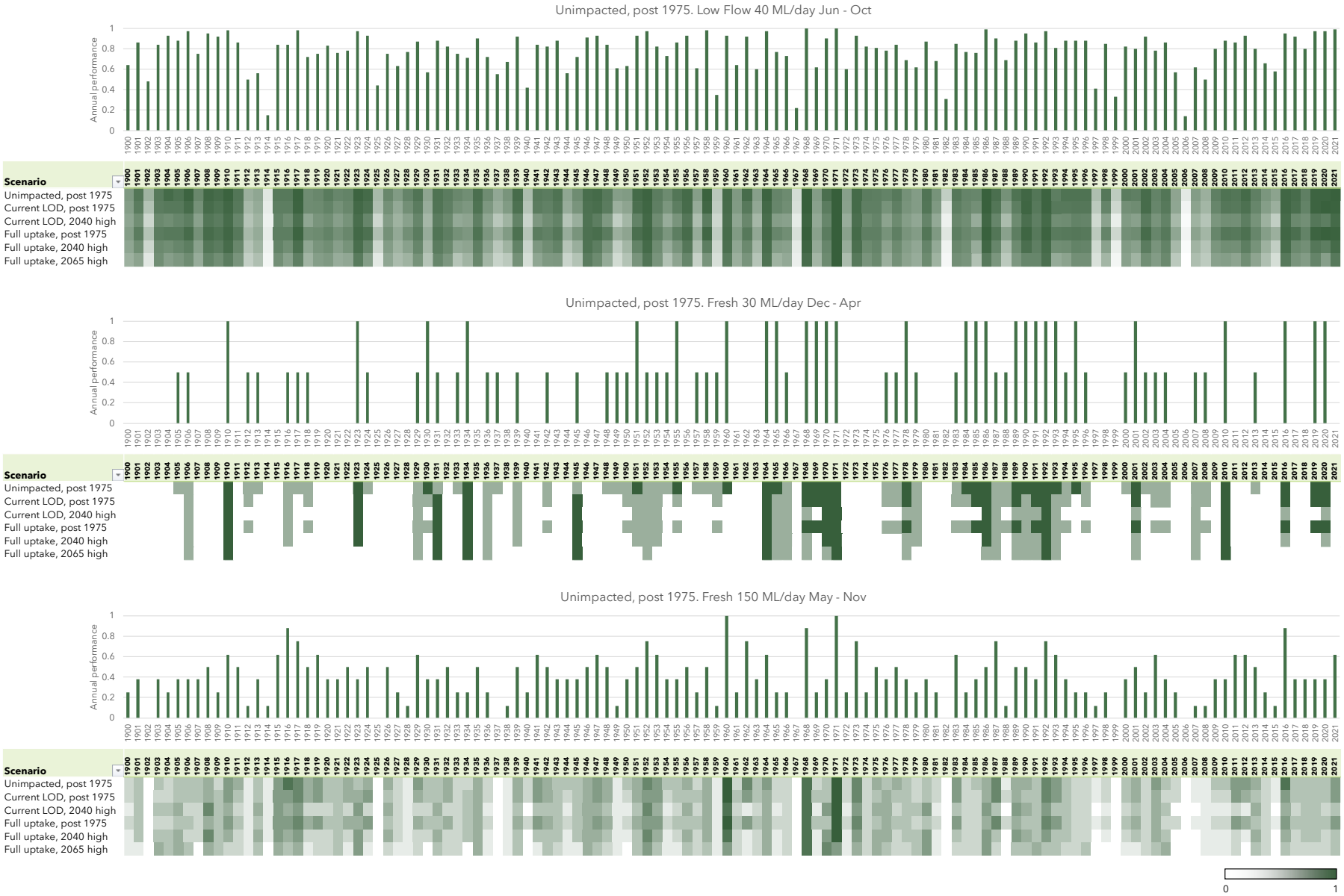


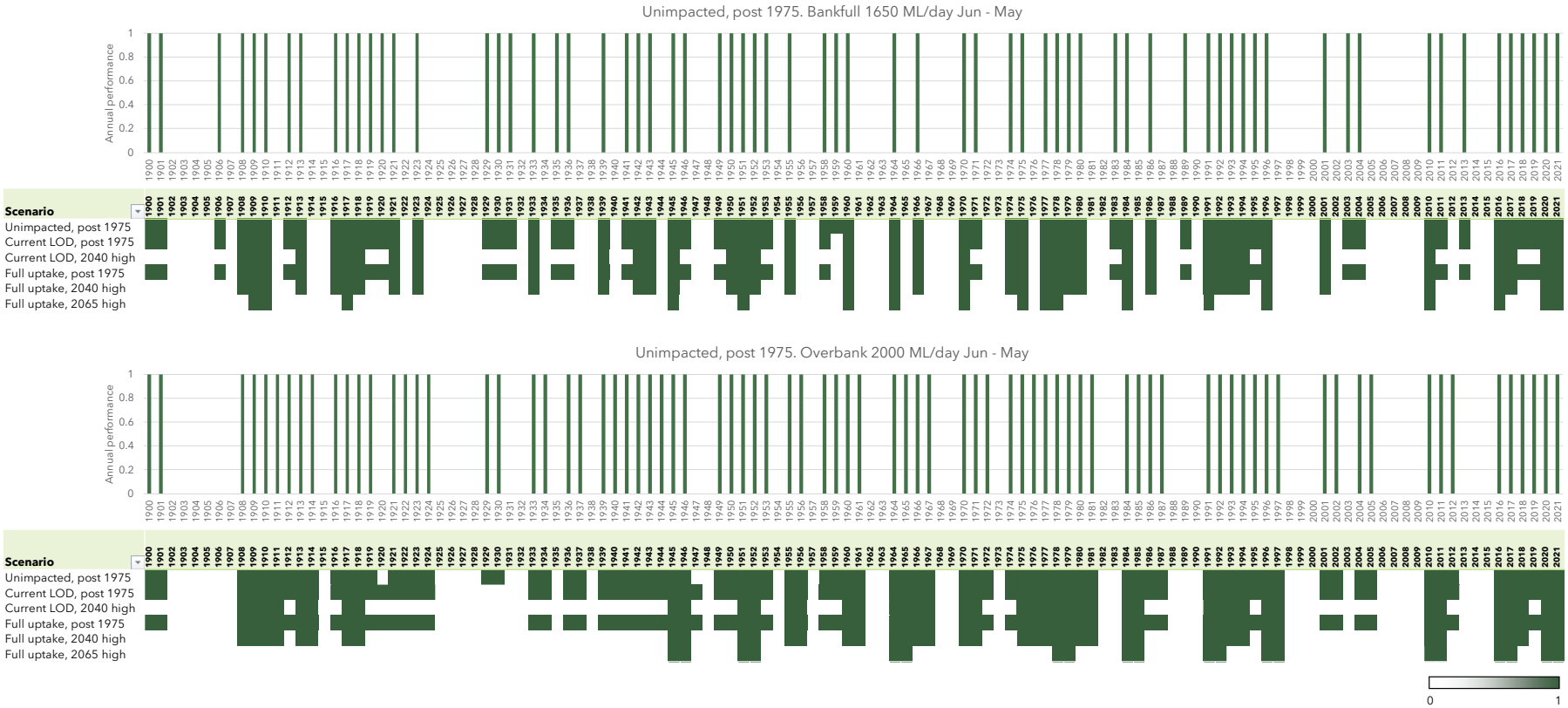

Unimpacted, post 1975. Low flow 300 ML/day Jun - Oct
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Fresh 260 ML/day Dec - Apr
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Fresh 1800 ML/day May - Nov
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1


Unimpacted, post 1975. Bankfull 3700 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Bankfull 4700 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1

A.6.7 Reach 5 – Performance




Unimpacted, post 1975. Low Flow 40 ML/day Jun - Oct
Annual performance
Unimpacted, post 1975. Fresh 30 ML/day Dec - Apr
Annual performance
Unimpacted, post 1975. Fresh 150 ML/day May - Nov
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1


Unimpacted, post 1975. Bankfull 1650 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
Unimpacted, post 1975. Overbank 2000 ML/day Jun - May
Annual performance
Scenario
Unimpacted, post 1975
Current LOD, post 1975
Current LOD, 2040 high
Full uptake, post 1975
Full uptake, 2040 high
Full uptake, 2065 high
0
1