Maribyrnong FLOWS study – Recommendations Report

FINAL

9 May 2025

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

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for Melbourne Water under the contract titled 'Maribyrnong FLOWS Review'.

Authors: **Environmental Flows Technical Panel** – Paul Boon (Dodo Environmental), Jon Fawcett (CDM Smith), Josh Griffiths (EnviroDNA), Peter Newall (Alluvium), Ian Rutherfurd (Alluvium), Zeb Tonkin (Arthur Rylah Institute), and Matt West (Wild Research).
Project team: Ying Quek, Jess Bolden, Amanda Wealands, Helen Clarke (Alluvium)

Review: Amanda Wealands, EFTP members
Approved: Amanda Wealands

Version: 3 – Final
Date issued: 9 May 2025
Issued to: Lisa Duncan, Melbourne Water
Citation: Alluvium (2025). Maribyrnong FLOWS study: Recommendations Report. Final report prepared by Alluvium Consulting for Melbourne Water. Victoria.

– Recommendations Report

Cover image: Deep Creek lower (Photo Credit: Ian Rutherfurd)

Executive summary

The Maribyrnong catchment is on Country of the Wurundjeri Woi-wurrung and Bunurong peoples, and the river and its named tributaries are areas of cultural significance and sensitivity. The Maribyrnong (Mirrangbamurn) River system provides crucial support to a range of environmental values and important ecosystem services to the adjacent agricultural and urban landscape.

The hydrological regime of Maribyrnong River has been altered by flow regulation, extraction and urban stormwater runoff. Its naturally dry landscape is facing increasing pressures from climate change, with reduced rainfall and increased temperatures expected to exacerbate cease-to-flow periods, reduce aquatic refuges, and impact species reliant on flows for survival. The river is also facing urbanisation impacts where there is an increasing risk of stormwater runoff intensifying flow variability and potential risk of pollution loads into the waterways affecting aquatic habitats.

Maribyrnong River does not have a formal environmental water entitlement. It relies instead on temporary opportunistic trades which are insufficient for long-term ecological resilience. There are also many constraints with the ability to deliver water for the Maribyrnong system.

The first environmental flows study of the Maribyrnong River was undertaken in 2006 and the last update was completed in 2016. New data, policy directions and management priorities have emerged since. The 2022 Central and Gippsland Sustainable Water Strategy (CGRSWS) set a target to recover 7 GL of water for environmental purposes in the Maribyrnong system. In response to this, Melbourne Water, as the waterway manager, required an updated study to:

- Improve understanding of environmental water requirements
- Support water allocation decision-making by Department of Energy, Environment and Climate Action
- Align its priorities with the Healthy Waterways Strategy (HWS) to ensure key ecological values are protected and enhanced.

Key ecological values and flow needs

The study identifies critical water-dependent species and habitats in the Maribyrnong system and developed specific flow objectives for:

- Native fish, including the Yarra Pygmy Perch and Short-finned Eel
- Platypus
- Growling Grass Frog
- Flow-dependent vegetation communities

Environmental flow recommendations

Based on the constraints of the system, the study sets environmental flow requirements across regulated (Jacksons Creek reaches 6 and 7) and unregulated reaches (Deep Creek reaches 1, 2 and 4), Emu Creek (reach 3) and Riddells Creek (reach 5).

Management

Current water management arrangements cannot achieve all environmental flow requirements. The establishment of an environmental entitlement; increase of outlet capacity at Rosslynne Reservoir; active management of take from unregulated waterways; protection of groundwater fed refuges, and reducing the impacts of increased stormwater are all necessary to improve achievement of environmental flow requirements.

Melbourne Water are committed (and will continue) to collaborating with Traditional Owners to manage Country and to achieve shared benefits through environmental flows.

Table 1. Summary of all flow recommendations

Flows	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
JACKSONS CREEK						
Low flows	6	Dec-May	4 ML/d	Continuous	Continuous	Refugia habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates, vegetation, and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
		Jun-Nov	20 ML/d	Continuous	Continuous	Refugia and maintain wetted areas for vegetation, fish and frogs. Plant growth and reproduction for submerged floating-leaved vegetation and emergent vegetation. Reduce thermal stratification and maintaining gross channel size.
	7	Dec-May	8 ML/d	Continuous	Continuous	Refugia habitat, water quality for platypus, Growling Grass Frog (shallow stream margin and deep pools), small-bodied native fish and diadromous species and macroinvertebrates. Provide longitudinal connectivity for platypus. Plant growth and reproduction for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
		Jun-Nov	40 ML/d	Continuous	Continuous	Refugia and provide longitudinal connectivity for Platypus, Growling Grass Frogs, vegetation and fish. Promote plant growth for submerged and emergent vegetation. Maintain gross channel size
Freshes	6	Dec-May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Connectivity of habitat and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat condition for macroinvertebrates, vegetation diversity and vertical zonation (submerged, emergent, fringing). Water quality in pools and transport of silts, salts and nutrients
		Jun-Nov	215 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools
		Jun-Nov	350 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat complexity for macroinvertebrates (which as resource for platypus, and also inundate vegetation), plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools and transport of silts, salts and nutrients
	7	Dec-May	40 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Migration of juvenile and adult diadromous species. Connectivity of habitat (Platypus, Growling Grass Frog and fish) and propagule dispersal. Habitat for macroinvertebrates (resource for platypus), vegetation diversity and vertical zonation (submerged, emergent, fringing) and to support tadpole and frog (thermoregulation and breeding opportunity). Water quality in pools and transport of silts, salts and nutrients
		Jun-Nov	400 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Longitudinal connectivity, breeding, and recruitment, brumation cues (Growling Grass Frog). Maintaining geomorphic conditions (habitat complexity for macroinvertebrates), habitat for macroinvertebrates (resource for platypus), plant growth and propagule dispersal, vertical zonation

Flows	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
High flows	6	Anytime	1,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent and fringing woody vegetation
	7	Anytime	2,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (frogs)
DEEP CREEK						
Low flows	1	Dec-May	2 ML/d	Continuous	Continuous	Refugia habitat and water quality for Yarra Pygmy Perch, small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
	2		3 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
	4		6 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation, platypus and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain groundwater (for floodplain vegetation)
	1	Jun-Nov	20 ML/d	Continuous	Continuous	Refugia habitat for Yarra Pygmy Perch and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
	2		17 ML/d	Continuous	Continuous	Refugia habitat for fish and water quality. Maintain wetted areas for vegetation (plant growth for submerged). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
	4		25 ML/d	Continuous	Continuous	Refugia habitat for fish and platypus and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent) and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance) and groundwater (floodplain vegetation)
Freshes	1	Dec- May	50 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal (adult and juvenile diadromous species), refugia habitat and water quality for small-bodied fish (Yarra Pygmy Perch) and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.
	2		17 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.
	4		100 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 3 days AVE: 3 days WET: 5 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.

Flows	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
	1	Jun - Nov	150 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for Yarra Pygmy Perch and other small-bodied native fish, connectivity and migratory cues (fish), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size
	2		175 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size
	4		250 ML/d	DRY: 3 AVE: 4 WET: 4	DRY: 6 days AVE: 6 days WET: 7 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates and its resource for platypus), vegetation diversity and vertical zonation for vegetation, flush propagules. Maintain gross channel size
High flows	1	Anytime	1,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
	2		500 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
	4		2,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
EMU CREEK						
Low flows	3	Dec-May	6 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates and vegetation
		Jun-Nov	14 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity and prevention of chytrid fungus for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates, vegetation (emergent and floodplain). Maintain gross channel size (physical disturbance) and groundwater for floodplain vegetation
Freshes		Dec-May	14 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 1 day AVE: 3 days WET: 3 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish), Growling Grass Frog breeding, thermoregulation and protection. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal.
		Jun-Nov	100 ML/d	DRY: 2 AVE: 3 WET: 4	DRY: 4 days AVE: 4 days WET: 4 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish). Breeding, thermoregulation, protection, connectivity and brumation opportunities for Growling Grass Frog. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal. Maintain gross channel size (physical disturbance)
High flows		Anytime	1,000 ML/d	2 per 3 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (Growling Grass Frogs)

Flows	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
RIDDELLS CREEK						
Low flows	5	Dec-May	2 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
		Jun-Nov	10 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
Freshes		Dec-May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 2 days WET: 4 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal
		Jun-Nov	50 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 4 days AVE: 4 days WET: 5 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal. Maintain gross channel size (physical disturbance). Connectivity for frogs
High flows		Anytime	400 ML/d	1 per 2 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation

Contents

Figures

Tables

1 Introduction

The Maribyrnong (Mirrangbamurn) catchment is on Country of the Wurundjeri Woi-wurrung and Bunurong peoples, and the river and its named tributaries are areas of cultural significance and sensitivity.

The Maribyrnong River is the second major river in the Melbourne region, after the Yarra River. The catchment extends from Mount Macedon, Lancefield and Kilmore in the north, to Yarraville in the south, and is bounded by the Hume Highway to the east and the Calder Freeway to the west. The main stem of the river flows through to discharge into Port Phillip Bay after joining the Yarra River near Coode Island in western Melbourne. The river system provides crucial support to a range of environmental values such as platypus and threatened fish species and provides important ecosystem services to the adjacent agricultural and urban landscape.

The last update to the environmental flows study of Maribyrnong River was undertaken in 2016 (Alluvium, 2016). In the recent release of the Central and Gippsland Regional Sustainable Water Strategy (CGRSWS) (DELWP, 2022a) a water recovery target of up to 7 GL is committed for the Maribyrnong system. Melbourne Water, the waterway manager for Maribyrnong catchment, requires an updated study to improve the understanding of environmental water requirements of the river system, to assist with water allocation decision-making (by DEECA) and align its priorities with Healthy Waterways Strategy (HWS).

An updated understanding of how much water is required, and under what conditions the water is needed, is essential to ensuring that environmental values are protected, maintained and/or improved in the system. This study reports the updated flow recommendations for reaches of the Maribyrnong catchment. The updated flow recommendations incorporate advances in our understanding of the system, values, vulnerabilities and ecohydrological relationships.

1.1 Structure of this report

This is the environmental flow recommendation report for the Maribyrnong FLOWS study update. The report is set out as follows:

Section 1	Introduction and study area
Section 2	Context of the study
Section 3	Values, character and vulnerability of the system: A system-level discussion of water-dependent values, threats, vulnerabilities and key environmental objectives for the setting of flows.
Section 4	An overview to environmental flow recommendations and flow component definition
Section 5	Environmental flow requirements for the regulated system (Jacksons Creek)
Section 6	Environmental flow requirements for the unregulated system (Deep Creek, Riddells Creek and Emu Creek)
Section 7	Review of Reach 8: Maribyrnong River
Section 8	Summary of flow recommendations
Appendices	1. Approach of determining flow recommendations: 2. Environmental objectives and hydraulic criteria 3. Hydraulic model development 4. Model outputs 5. Performance analysis results

1.2 Study area

The spatial scope of this project includes the main river reaches of Maribyrnong system: Deep Creek, Jacksons Creek, Emu Creek, Riddells Creek and Maribyrnong River (Figure 1). The estuarine section of the river is not included in the scope of this investigation (Table 2).

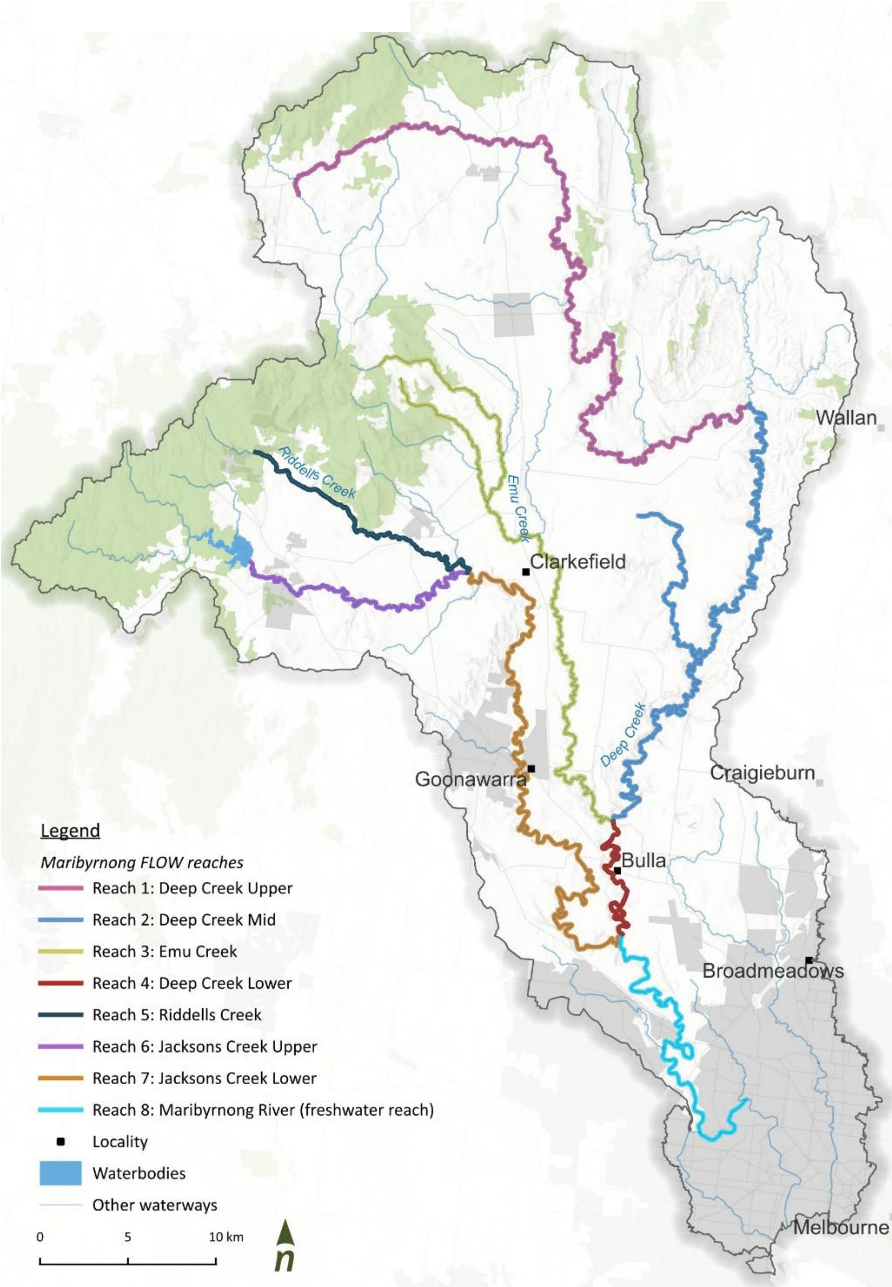


Figure 1. *Maribyrnong River catchment and flow reaches*

Table 2. Maribyrnong flow reaches

Reach number	Waterway name	Description
Reach 1	Deep Creek Upper	The headwaters of Deep Creek, upstream of Boyd Creek
Reach 2	Deep Creek Mid	The middle reach of Deep Creek, downstream of Boyd Creek and upstream of Emu Creek
Reach 3	Emu Creek	Emu Creek, upstream of its confluence with Deep Creek

Reach number	Waterway name	Description
Reach 4	Deep Creek Lower	The lower reach of Deep Creek, downstream of Emu Creek and upstream of Jacksons Creek
Reach 5	Riddells Creek	Riddells Creek, upstream of its confluence with Jacksons Creek
Reach 6	Jacksons Creek Upper	The upper reach of Jacksons Creek from Rosslynne Reservoir to Jacksons Creek's confluence with Riddles Creek
Reach 7	Jacksons Creek Lower	The lower reach of Jacksons Creek, downstream of Riddells Creek to the confluence with Deep Creek
Reach 8	Maribyrnong River (freshwater reach)	The freshwater reach of the Maribyrnong River main stem, from the confluence of Jacksons Creek and Deep Creek, to the upper extent of the Maribyrnong estuary
Reach 9	Maribyrnong River (estuary)	Out of project scope

1.3 Project engagement

The environmental flows technical panel (EFTP) members were:

- Professor Ian Rutherfurd – geomorphology
- Professor Paul Boon – vegetation
- Dr Zeb Tonkin – fish ecology
- Josh Griffiths – platypus
- Dr Matt West – frog ecology
- Dr Peter Newall – water quality
- Dr Jon Fawcett – groundwater

The following groups were engaged during the project:

Project steering committee: The purpose of the Steering Committee was to oversee project implementation, provide direction on the scope of work, and review and provide feedback for key milestones throughout the project. The Steering Committee comprised the following representatives:

- Department of Energy, Environment and Climate Action (DEECA)
- Melbourne Water (MW)
- Victorian Environmental Water Holder (VEWH)
- Bunurong Land Council Aboriginal Corporation (BLCAC)
- Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation

Project Advisory Group: The purpose of the Project Advisory Group (PAG) was to ensure that the broader stakeholder groups of the Maribyrnong system are adequately represented. This group provided a source of local knowledge and community expectations. The membership of this group included agencies, community groups and Traditional Owners.

2 Context of the study

Flow in the Maribyrnong River has been significantly altered since European colonisation and subsequent development of the catchment. Availability of water in rivers and creeks is critical to water-dependent ecological values and cultural values.

2.1 History and development of Maribyrnong catchment

Maribyrnong River is on Country with the Wurundjeri Woi-wurrung and Bunurong peoples and its name is derived from the Aboriginal phrase *Mirring-gnay-bir-nong*, meaning ‘I can hear a ringtail possum’ (Melbourne Water, 2022).

The Aboriginal people have had a deep connection with the catchment for at least the last 40,000 years. The Traditional Owners used these creeks and rivers for drinking water, supplying building materials, facilitating transport, medicine and sustaining food sources (Melbourne Water, 2022). It was a biodiversity-rich landscape with fish and eels thriving in the river, kangaroos and emus on the plains along with small marsupials of echidnas, possums, waterbirds and lizards.

Early European pastoralists in early 1800s and settled into the open grazing country of Maribyrnong’s upper reaches. More European settlers arrived and established towns we know now as Gisborne, Sunbury and Diggers Rest and they called the Maribyrnong River the Saltwater River for its tidal nature in its lower reaches (Melbourne Water, 2022). As the grazing landscape transformed into an industrial hotspot, demand for water increased and the naturally cease-to-flow conditions caused pollution issues (eMelbourne, 2008). In 1857 Victoria’s first irrigator, David Milburn developed a hand pump to draw water from the river to irrigate market gardens in Keilor. This was the first water extraction ever used in the Maribyrnong system.

The lower reaches of Maribyrnong River have since developed into an industrial powerhouse, contributing pollution but also amenity values to people living in the area. The increase in development and population growth in Maribyrnong catchment led to greater demand for water use and the construction of Rosslynne Reservoir in early 1970s (Melbourne Water, 2013) for drinking water and irrigation purposes. The reservoir has since significantly altered the flow regime in Jacksons Creek to meet the demands for water for consumptive and irrigative purposes.

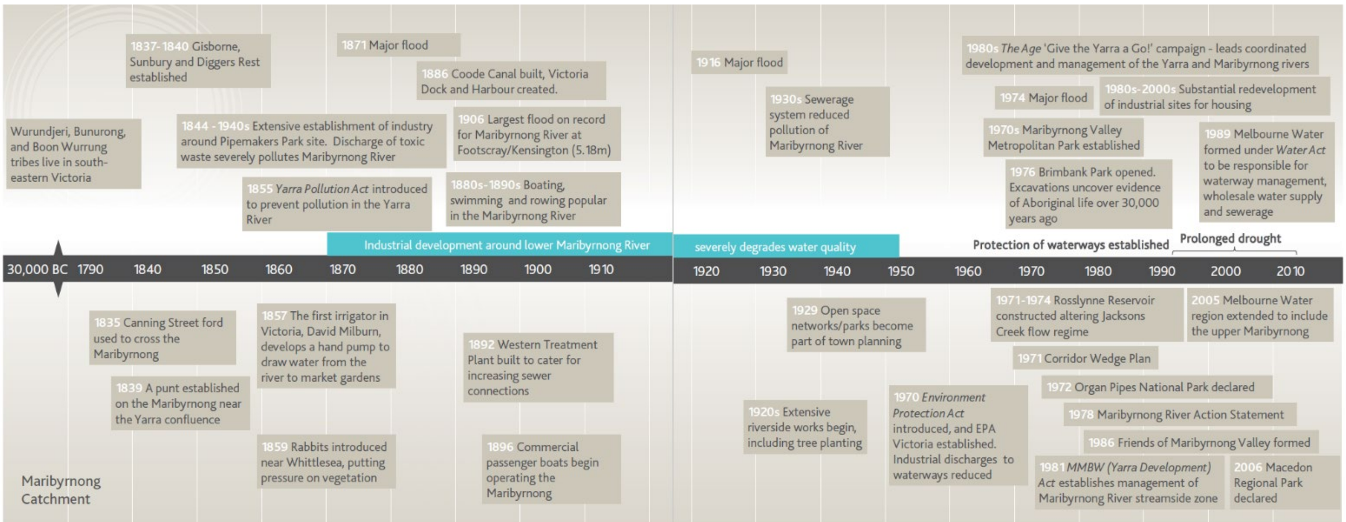


Figure 2. *Timeline of the development of Maribyrnong catchment (Melbourne Water, 2013)*

2.2 Flow availability and regulation in Maribyrnong catchment

Two points are critical in understanding the natural (pre-development) flow regime in the Maribyrnong River system. First, the upper reaches of Maribyrnong catchment naturally cease to flow during summer / autumn periods. Flow is driven by climate conditions, especially rainfall and evapotranspiration, and it is highly seasonal in this region of Victoria (Alluvium, 2025).

Second, flow in the river is strongly influenced by groundwater inputs. The relative importance of groundwater increases where surface flows are more episodic in nature. During droughts the ecological values within habitat refuges are maintained primarily by groundwater inflows.

Deep Creek is a recognised groundwater-dependent drought refuge, ranked as high priority groundwater dependent ecosystem (Melbourne Water, 2021a). During drought and other extended dry periods, groundwater contributes almost all the surface flow in Deep Creek (Cartwright and Gilfedder, 2015). This makes groundwater inflows critical to the protection of refugia in this part of the Maribyrnong River system. During winter and during wet periods, however, surface runoff significantly contributes to flow.

Jacksons Creek between Rosslynne Reservoir and the township of Sunbury (reaches 6 and 7) is also a recognised groundwater-dependent drought refuge (Melbourne Water, 2021).

Rosslynne Reservoir and other flow regulations

Flows in the Maribyrnong system have been altered greatly by the construction of Rosslynne Reservoir and the subsequent introduction of flow regulations. Rosslynne Reservoir is the only major storage in the Maribyrnong catchment. It is located on the upper reaches of Jacksons Creek, northwest of Gisborne, and supplies irrigation and domestic water to the townships of Sunbury and Macedon Ranges. Passing flows provide water to Jacksons Creek year-round, which largely eliminates cease-to-flow events. This changes the flow regime in Jacksons Creek such that flows are now greater in summer / autumn (due to irrigation demand) than in winter / spring, a reversal in the natural seasonality.

This alteration of flow downstream is exacerbated by the outlet capacity of Rosslynne Reservoir and the passing flow requirements (Alluvium, 2025). Rosslynne Reservoir currently has a maximum release capacity of 20 ML/day (VEWH, 2024), and this limits the rate at which environmental water can be released. Operationally, the maximal release is about 15 ML/day (L. Duncan, Pers. Comm. Oct 2024).

There is no formal Environmental Entitlement (EE) in the Maribyrnong system. Over the past 10 years Melbourne Water has worked with the Victorian Environmental Water Holder (VEWH) and irrigation entitlement holders to secure up to 315 ML/year for environmental releases in Jacksons Creek via temporary trades (Jacobs, 2013). Most recently, the traded volume for 2022 – 2023 was 321.9 ML (N. Longden, Pers. Comm. April 2025). Due to administration requirements, the temporary nature of these trades and the lack of carryover, water may not become available for trade until January, which limits its use to summer/autumn flow components.

A minimum passing flow requirement of 1 ML/day in Jacksons Creek (at the Gisborne and Sunbury gauging stations) was included in the consumptive Bulk Entitlements held in Rosslynne Reservoir (Attachment 1). Additional passing flow rules apply when there is more than 2,200ML in Greater Western Water's capacity share of the reservoir:

- the lesser of 3 ML/day and natural flow at the Gisborne gauging station,
- the lesser of 10 ML/day and modified natural flow at the Sunbury gauging station, and
- the lesser of 5 ML/day and the modified natural flow at the Keilor gauging station
- when the reservoir has not overflowed on/before October 1 and cumulative inflow is greater than 10,500 ML:
    - 20 ML/day passing flows at Gisborne gauging station for 10 consecutive days.

The passing flow requirements are met at Sunbury gauging station during winter and spring by inflows from the Riddells Creek and the Mount Macedon catchments. During summer and autumn, Riddells Creek usually ceases to flow and the passing flow requirements must be met by releases from Rosslynne Reservoir into Jacksons

Creek. As a result, flow in Upper Jacksons Creek downstream of Rosslynne Reservoir is seasonally reversed, and are relatively consistent across the year (Alluvium, 2025). Long travel times between Rosslynne Reservoir and the Sunbury gauge and complex groundwater interactions in Reaches 6 and 7 can result in surface water losses in Jacksons Creek, requiring the release of significant volumes of water to meet passing flow requirements.

Other (smaller) regulating structures in the Maribyrnong system occur in Deep Creek, Bolinda Creek, Main Creek, Turritable Creek, Willimigongon Creek, Barringo Creek and Middle Gully / Railway Creek (Alluvium, 2025). These smaller structures also harvest and store water under the Bulk Entitlements for consumptive purposes in the catchment (Attachment 1). Other licensed water extraction from the catchment, for example for stock and domestic use may also reduce flows in the catchment as discussed in the Long Term Water Resource Assessment (DELWP, 2020). Licensed volumes in the Maribyrnong catchment are provided in Attachment 1. Southern Rural Water (SRW) is currently investigating the impacts of farm dams and unlicensed take on the flow regime in Maribyrnong catchment to address this knowledge gap.

Unregulated groundwater extractions

During periods of low surface flow, groundwater inputs supplement baseflows and during low surface flow periods groundwater inputs can maintain aquatic refuges.

The Maribyrnong system is currently subject to local groundwater extractions for stock and domestic use, licensed (non-urban) use and urban supply to Lancefield in the Lancefield GMA (DEECA, 2023) Groundwater entitlements in Deep Creek within the Lancefield Groundwater Management Area (GMA) are managed by Southern Rural Water in accordance with the Lancefield Local Management Plan (Southern Rural Water, 2023). Section 51 take and use licences in Jacksons Creek and other parts of the Maribyrnong catchment outside of GMAs are managed by Southern Rural Water. Increasing groundwater extractions during dry periods lower groundwater levels and decrease groundwater inflows to stream refuges. With combined effect of surface water extractions and harvesting of peak flows in the catchment, it may reduce the recharge of aquifers and reduce groundwater availability. There is no strong empirical evidence that current groundwater extraction currently poses a threat to stream refuges, although GHD (2012) did suggest that such impacts were possible.

2.3 Broader factors affecting flows

Urbanisation

Urbanisation is a major current and future challenge for the Maribyrnong system, as it increases the demand for consumptive water, generates increased polluted runoff from stormwater flowing off increased areas of impervious surfaces. The population of the Maribyrnong catchment is expected to nearly double over coming decades, from 584,000 in 2016 to 1,140,000 in 2050 (DELWP, 2022b). The associated increase in impervious area and stormwater runoff is expected to generate a 26% increase in stormwater runoff by 2050 in Maribyrnong catchment, and this will influence flooding and almost certainly cause ecosystem damage without having sufficient management controls in place (DELWP, 2022b). Large scale stormwater harvesting projects are being investigated as a solution to the damaging effects of uncontrolled stormwater flows and to address environmental flow shortfalls in the catchment.

Climate change

Climate change is projected to significantly alter the hydrology of the Maribyrnong catchment (Alluvium, 2025).

Upper reaches of Deep Creek and Riddells Creek are projected to experience decreased yields, and longer and more frequent dry spells. Dry spells will affect all flow components, however their greatest impact will be on low magnitude flow components (low flows and freshes). The number of days of cease-to-flow conditions in the upper reaches is almost certain to increase markedly under likely future climate conditions (Alluvium, 2025).

Jacksons Creek upper (reach 6) is heavily regulated, with a significant portion of the flow regime already dominated by releases from Rosslynne Reservoir and Greater Western Water's wastewater treatment plants. This reach is therefore likely to be quite resilient to changes in low flows, a function of the passing-flow requirements from Rosslynne Reservoir (Alluvium, 2025) and treated wastewater releases.

Future climate change is predicted to reduce overall flows in the Maribyrnong system, leading to the following impacts on habitat extent and on water quality:

- Reduced extent, abundance and depth of pool habitat
- General tendency for aquatic habitats to become shallower
- In some cases, the loss of specific flow-dependent habitats such as riffles, backwaters, inundated benches and deep channels.

Decreasing frequency and duration of freshes could increase the likelihood of water stagnation and reduce concentrations of dissolved oxygen in pools. This will markedly reduce the quality of habitat for sensitive macroinvertebrates taxa (resulting in changes in macroinvertebrates species composition), fish, and the species that rely on these habitats as refuges (Alluvium, 2025).

Of course, there is a multitude of other potential or likely impacts of climate change, including increasing air and water temperatures and an increase in the frequency and intensity of extreme events that could affect the Maribyrnong system. For example, increased severity of storm events may increase stormwater runoff particularly in urban areas and degrade water quality through the corresponding movement of urban pollutants, sediment and nutrients through waterways.

2.4 Potential opportunities for management

Decreased flow and increases in the range and magnitude of other ecological stressors will have major impacts on the environmental values of the Maribyrnong system. With the current stressors as highlighted in Section 2.2 and 2.3, it is imperative for water managers to plan and adapt for the new 'norm' of the system and future trajectories of the system under changing climate. Below are some of the potential opportunities that are being considered to provide water recovery to the system.

Future environmental water recovery

The 2022 CGRSWS includes a target to recover up to 7 GL of water in the Maribyrnong system (Policy 8-6, Action 8-11). This additional water would open the possibility of having a permanent environmental entitlement. Substituting use of river water with manufactured water, and increasing use of stormwater, recycled water or efficiency measures to reduce water extraction for towns are some of the options being investigated to meet the recovery target. Melbourne Water is currently working with Greater Western Water to determine the feasibility of using recycled water from wastewater treatment plants and large-scale stormwater harvesting in the Maribyrnong catchment for environmental benefit.

Greater Western Water is also exploring options to reduce its reliance on river entitlements and return water to the environment.

Rosslynne Reservoir upgrade

The outlet at Rosslynne Reservoir has a current maximum release capacity of 20 ML/day (VEWH, 2025, Southern Rural Water, 2025), with which limits the rate at which environmental water can be released when the reservoir is completely full, and operationally, the maximal releases approximate 15 ML/day (L. Duncan Pers. Comm. Oct 2024). The current storage capacity and infrastructure of Rosslynne Reservoir is not practical or feasible for delivering some recommended flow components. DEECA and Melbourne Water are investigating options to increase the capacity of the outlet, with Southern Rural Water investigating the cost for upgrading Rosslynne Reservoir.

Alternative / manufactured water sources

Jacksons Creek is heavily modified, with extensive agricultural operations (broadacre cropping and livestock grazing) and urban development within the catchment (Melbourne Water, 2021). The Central and Gippsland Sustainable Water Strategy outlined a policy to substitute river water with manufactured water in the long term to meet the recovery target of up to 7 GL/year (Policy 4-3; DELWP, 2022a). Manufactured water includes desalinated water, recycled water and treated stormwater. The CGRSWS identified the need to transition away from relying on river water to meet the increasing water demand in future and there are opportunities for these manufactured water for the environment.

Stormwater harvesting (treatment and release) in Sunbury is under investigation as a potential source of environmental water for Jacksons Creek. Streamology (2024) recently recommended maximum flows for Jacksons Creek to manage threats from urbanisation and corresponding stormwater runoff and maximise environmental benefits achieved through stormwater harvesting ventures.

Improved groundwater monitoring

Groundwater aquifers are vulnerable to groundwater extraction and in some cases but to a lesser degree, surface water harvesting. It is important to have a more complete understanding of groundwater flow within aquifers that support stream refuges, especially during the extremes of drought. A critical data requirement is groundwater levels adjacent to the refuge, that can be monitored alongside stream flow and pool depth. Melbourne Water's established GDE groundwater monitoring within the catchment provides an example of this approach, however, depending on identified specific refuges, additional groundwater bores may be required to expand the groundwater monitoring network, and inform the protection of refuges during low flows and cease-to-flow periods.

A voice for Traditional Owners in environmental water management

"*Healthy country is to keep planting and putting our species back in, to see our species growing in the ground. To see water flowing and hear the sounds of animals and birds. Hopefully our people can get out there and do that and work with stakeholders that manage biik wurrdha [Jacksons Creek]. Here our ancestors would have caught eels, made spears, scarred trees for shields and canoes. Bunjil our creator and Waa the protector put these resources here for them. We respect these creation ancestors."* (WWCHAC, 2021 pp 14)

The Maribyrnong (Mirrangbamurn) River is culturally significant to Traditional Owners and flows through Wurundjeri Woi-Wurrung and Bunurong Country. The entire watercourse (mainstem and named tributaries) is recognised as a site of cultural heritage sensitivity (ACHRIS, 2024). The cultural values study at Jacksons Creek (WWCHAC) notes that Woi-wurrung people do not perceive the land, vegetation and wildlife within the landscape as isolated elements. Rather, they view the aesthetic of a landscape holistically through the ecological biodiversity required for healthy Country.

Water is Life sets out government commitments and policy pathways to increase Traditional Owner and First Nations access to water, water management and water decision-making within the existing water entitlement framework. Wurundjeri Woi-Wurrung Aboriginal Corporation (WWCHAC) and Bunurong Land Council Aboriginal Corporation (BLCAC) provided nation statements for *Water is Life* (DELWP, 2022b). WWCHAC articulated sovereign rights and obligations to care for, manage and be decision-makers for Country. These rights extend to cultural, environmental, social and economic uses of water. WWCHAC want to partner with Government to enable Wurundjeri Woi-wurrung control of water on Wurundjeri Woi-wurrung Country, including to co-govern environmental water entitlements. BLCAC want to actively manage cultural landscapes and be involved in and have control of decisions regarding the management of water on Country, its use and distribution.

WWCHAC and BLCAC self-determined their respective involvement in this FLOWS study. Melbourne Water are committed (and will continue) to collaborating with Traditional Owners to manage Country and to achieve shared benefits through environmental flows.

3 The values, character and vulnerability of the system

The Maribyrnong River system is massively altered from its pre-European condition, with its hydrology under increasing pressures from climate change, urbanisation, and growing agricultural demands. Ongoing urbanisation and climate impacts will continue to threaten the current ecological values and create a complex challenge for waterway managers to balance competing demands for water and for the environment.

Many of the Maribyrnong's waterways are deeply incised and its naturally dry landscape requires substantial volumes of water to increase water levels in the river channel. The challenge to increase water level in the channel is particularly evident in dry conditions where the surface-groundwater interaction result in 'losses' of instream flows to the groundwater system. The lack of a formal environmental water entitlement and constrained infrastructure to deliver environmental water further limit the system's capacity to achieve the required flow habitats to improve waterway health.

In the context of this altered (and still developing) catchment, restoring the system to a pre-European ecological condition is not feasible. The vision and goals for the catchment outlined in the co-designed Catchment Program for the Maribyrnong Catchment Region (Melbourne Water, 2018) aligns and reflects this challenge and reality:

> *Vision: A Maribyrnong whose ecological health has significantly improved since 2018. It is accessible, used and valued by the community. Its collaborative management reflects the contributions of Traditional Owners and the broader community.*
>
> *Goal (Environmental): Management is helping create a preferred future for the Maribyrnong's environments by assisting species and habitats to change, adapt, move or be replaced as the catchment and climate change. The Maribyrnong River and their tributaries are important bio-links – corridors of secure, high quality habitats that allow plants and animals to move and adapt to changes in catchment conditions and climate. Water quality and flows provide for healthy and diverse populations of plants and animals. Stormwater is managed to enhance rather than destroy waterway health.*
> *(Melbourne Water 2018)*

The environmental flow objectives for this study have been developed with reference to this vision and goal, and to be relevant and suitable for the next 10 year period. While focused on the next decade of management, the objectives consider and reflect the condition trajectories and future vulnerabilities for flow-dependent values as the system adapts to changing climate and urbanisation pressures into the future.

Through site visits with EFTP, workshops with Melbourne Water, the Project Advisory Group and Steering Committee, the study identified the following key flow-dependent environmental values of the Maribyrnong catchment:

- Fish including Yarra Pygmy Perch and Short-Finned Eel
- Frogs including Growling Grass Frogs
- Platypus and other aquatic mammals such as Rakali
- Flow-regime dependent instream and bank vegetation
- Macroinvertebrates

Geomorphology and water quality are key supporting conditions to these environmental values.

The environmental objectives of these key water dependent values have been developed by the EFTP and the project team, in consultation with Melbourne Water and other stakeholders (Alluvium, 2025). The environmental objectives of these key environmental values and supporting conditions are summarised in Figure 3, with the relevant reaches they apply to. These values are selected as the focal species as they are the most important values for the Maribyrnong system. It is expected the flow objectives and recommended flow regime will also support other species and mammals such as rakali. A full list of the key water dependent values and the environmental objectives can be found in Attachment 3.

Values	Objective	Reach 1	2	3	4	5	6	7	8
	Maintain population abundance and extent of Yarra Pygmy Perch	■							
	Maintain diversity and extent of small-bodied native fish populations and diadromous species	■	■	■	■	■	■	■	■
	Improve habitat condition to support Growling Grass Frog populations			■				■	
	Maintain conditions to support current platypus populations				■			■	■
	Maintain condition, extent and diversity of flow-dependent vegetation	■	■	■	■	■	■	■	■
	Maintain habitat conditions to support for macroinvertebrates	■	■	■	■	■	■	■	■
Supporting conditions	Prevent terrestrialisation of the channel by inundation-intolerant plant species	■	■	■	■	■	■	■	■
	Facilitate downstream transportation of silt, salt and nutrients through the river system into Port Phillip and ultimately the sea	■	■	■	■	■	■	■	■
	Maintain suitable dissolved oxygen concentrations in deep-water habitats such as pools	■	■	■	■	■	■	■	■
	Maintain extent of ecological habitat for aquatic, riparian and terrestrial fauna	■	■	■	■	■	■	■	■

Figure 3. *Overall environmental objectives at Maribyrnong catchment*

3.1 Fish

Yarra Pygmy Perch (*Nannoperca obscura)* is highlighted as one of the most vulnerable species found in very limited areas within the Maribyrnong system, specifically only at Upper Deep Creek (Reach 1). Other threatened species such as Australian Mudfish (*Neochanna cleaveri*) and Australian Grayling (*Prototroctes maraena*) were in previous records. While Australian Grayling does occur in Reach 8 of the Maribyrnong River, and as an amphidromous species might otherwise be expected to migrate upstream to freshwater reaches, establishment of populations of Australian Grayling is considered unlikely for this study due to the presence of instream barriers. Melbourne Water is currently addressing the issue of man-made instream barriers and there may be future opportunities to consider re-establishing Australian Grayling populations in some reaches beyond this flow study.

Native fish are a very important environmental value in the Maribyrnong system and are strongly dependent on flows and flow regimes for completion of their life cycles. For this study, native fish are classified into six groups based on their presence within different parts of the Maribyrnong system, their use of the estuary and their migration patterns, all of which affect their environmental flow requirements (Lloyd et al., 2012, Alluvium 2025). **Freshwater resident** and **estuarine dependent (freshwater and migratory) fish** are of particular interest for this FLOWS study as these species are dependent upon freshwater flows in the Maribyrnong system. For all other groups see further details on the Site and Issue paper (Alluvium, 2025).

Freshwater fish spend their entire life cycle in freshwater reaches and are therefore dependent upon freshwater habitats, including riffles, runs and pools. Four freshwater native fish species have been recorded in the Maribyrnong system, including the FFG Act and EPBC Act listed species Yarra Pygmy Perch.

Estuarine dependent fish (freshwater and marine) depend on the estuary for at least one stage of their life cycle, for example, spawning, as a nursery ground, for feeding and for passage between marine and freshwater ecosystems. Estuarine dependent fish (freshwater) are considered *diadromous* – that is, they migrate between freshwater and saltwater ecosystems. These species are further classified as *amphidromous*, *catadromous* and *anadromous* depending on the direction and purpose of the migration, as defined below.

> **Catadromous fish** – species that complete most of their life cycle in freshwater ecosystems and migrate downstream to breed in the estuary. Catadromous species in the Maribyrnong system include Southern short-finned eel (*Anguilla australis*) and Tupong (*Pseudaphritis urvillii)*.
>
> **Anadromous fish** – species that complete most of their life cycles in marine or estuarine ecosystems that migrate upstream to breed in freshwater ecosystems. Short headed lamprey (*Mordacia mordax)* is an anadromous species in the Maribyrnong system.
>
> **Amphidromous fish** – Species that migrate between freshwater and estuarine/marine ecosystems, but not explicitly for the purpose of breeding. For example, a species may spawn in freshwater, eggs and larvae are carried with flows downstream to estuarine and marine ecosystems. Individuals then migrate back upstream into freshwater systems to mature and eventually spawn. Australian mudfish (*Neochanna cleaver)* is an amphidromous native fish species in the Maribyrnong system.

Vulnerability and threats

Fish values in Deep Creek Upper and Jacksons Creek were categorised as declining and unlikely to meet the long-term Healthy Waterways Strategy targets in the Maribyrnong catchment (Melbourne Water, 2024). Yarra Pygmy Perch population is currently restricted to Upper Deep Creek (Reach 1) and continues to decline across known locations over the last decade.

Yarra Pygmy Perch has limited ecological niche, being restricted in its distribution across Victoria and is highly fragmented with low levels of genetic diversity (Brauer et al. 2013, Hammer et al. 2010, Saddlier and Hammer 2010). It has specific habitat requirements and exhibit low tolerances to changed habitat condition (e.g. habitat loss, decreased water quality from nutrient and stormwater runoff). Habitat availability and populations of Yarra Pygmy Perch were reduced during the Millennium Drought (Jones 2008). With predictions of climate change increasing the number and duration of cease-to-flow events, and decreasing magnitude of low flow events across Maribyrnong, the climate risk and vulnerability assessment (Alluvium 2025) identified low adaptive capacity and high hydrological vulnerability for specialist fish species such as Yarra Pygmy Perch under high climate change scenarios (Alluvium, 2025). It is therefore a priority for management to protect Yarra Pygmy Perch populations and their habitat requirements during dry (cease-to-flow) period. With waterways in the Maribyrnong system ceasing to flow regularly, refuge pools are significant habitat to support isolated fish populations across the landscape.

Other small-bodied generalist fish species such as Australian Smelt, Flat Head Gudgeon and Common Galaxias (also diadromous) occupy a range of habitat and water quality conditions. They have a broad ecological niche and broad tolerance to changing conditions. Small-bodied generalist fish species are dependent on flows to recolonise areas after a major disturbance. Under climate change scenarios where the flow regime is likely to experience increased cease-to-flow events and duration, as well as reduction in fresh events, freshes are likely to be shorter and the period between these events are likely to be longer.

Diadromous fish species such as Short-finned Eel, Tupong and Common galaxiid and Australian Grayling are also generalist species that occupy a broad range of habitat. They exhibit the ability to migrate and re-colonise from the marine environment even if habitat was lost under catastrophic event, however they are also vulnerable with the availability of freshes to allow connectivity between the estuarine and freshwater environment. Australian Grayling is restricted to Reach 8 of Maribyrnong River and establishment of populations of Australian Grayling is considered unlikely with presence of instream barriers impeding their migration across the reaches.

The Site and Issue paper (Alluvium 2025b) also identified the other threatening processing to native fish populations in the Maribyrnong system:

- **Barriers to fish passage:** Large natural instream fish barriers exist on Jacksons Creek upstream of Sunbury. These barriers are unlikely to be rectified as they are natural. Fish passage may therefore be restricted without installation of fishways on natural barriers to better facilitate upstream fish passage
- **Extreme low flows and reduced overall flow volumes** reduce habitat quality and quantity and reduce longitudinal connectivity across all reaches
- **Degraded riparian zone and instream vegetation** and limited instream woody habitat for small bodied fish
- **Agricultural and urban runoff impacts** on water quality and flow variability in Deep Creek Lower and Jacksons Creek
- Lack of riparian zone leading to **high water temperatures** during summer low flow periods at Emu Creek (though conditions are favourable by Growling Grass Frogs)
- **Presence of pest fish species** that pose a threat to native fish populations and the presence of other fauna values (such as frogs) through predation, and impacts on instream vegetation and water quality

3.2 Frogs

There are three listed amphibian species in the Maribyrnong catchment: Growling Grass Frog *(Litoria raniformis*), and the Brown Toadlet (*Pseudophryne bibronii*) and Southern Toadlet (*Pseudophryne semimarmorata*). Growling Grass Frog are listed as Vulnerable under both the FFG and EPBC Acts and the other two are listed as Endangered under the FFG Act.

Growling Grass Frog (GGF) is highlighted as one of the key values for the Maribyrnong catchment. Jacksons Creek and Emu Creek are known to contain important populations and habitat required for GGF persistence (Jacobs, 2021). Jacksons Creek is a designated high priority reach, while Emu Creek was identified in 2022–2023 surveys as supporting multiple populations of GGF, making it a key stronghold for the species (TactEcol, 2023). Areas of known GGF populations within Jacksons Creek and Emu Creek are also recognised as areas of strategic importance under the Melbourne Strategic Assessment Growling Grass Frog Masterplan (DELWP, 2017). In Emu Creek, there were low numbers of riparian trees shading the stream. The reduced canopy cover can help to increase ambient air and water temperatures and in turn reduce chytrid fungus infections and provides basking sites and terrestrial habitat (Roznik, et al. 2015; Heard, et al. 2018). In-stream vegetation provides favourable habitat for breeding and foraging.

Vulnerability and threats

Growling Grass Frog was previously common in south-eastern Australia and is now listed as vulnerable in both EPBC Act and FFG Act owing to loss of habitat, predation by introduced species and infection with chytrid fungus. Prior to 2010, Growling Grass Frogs were observed in all Maribyrnong sub-catchments. Since 2010, Deep Creek Upper and Boyd Creek no longer have positive records for Growling Grass Frogs (Melbourne Water, 2024).

Eight Maribyrnong sub-catchments historically supported *Pseudrophryne* spp. (Brown Toadlet *Pseudophryne bibroni* or Southern Toadlet *Pseudophryne semimarmorata*). After 2010, seven of these sub-catchments (Taylors Creek, Maribyrnong River, Emu Creek, Deep Creek Lower, Deep Creek Upper, Jacksons Creek, Boyd Creek) no longer have positive records for *Pseudrophryne* spp (pg. 58, Melbourne Water, 2024).

Jacksons Creek was found to have a declining frog condition and Deep Creek Lower had potentially declining frog condition based on the 2022 Healthy Waterways Strategy mid-term review (Melbourne Water, 2024). Declines in frog populations were widespread across the Port Phillip and Westernport region, not just within Maribyrnong catchment. Multiple processes and threats likely contribute to decreased frog population size, distribution and fluctuations. The threats include habitat loss and degradation with lack of permanent / semi-permanent water in the landscape during breeding and metamorphosis, introduced predators such as predatory fish and competitor species, disease caused by chytrid fungus. Many of these threats to frogs are exacerbated by during urbanisation, with additional impacts of increased impervious surfaces leading to increased stormwater runoff and poorer water quality in streams and off-stream habitat. The explanation for the decline in Jacksons Creek frog condition is unclear, but the above listed threats are likely contributing factors.

3.3 Platypus

In the Maribyrnong catchment, extensive live trapping and eDNA surveys have revealed that platypus populations are now largely restricted to the lower and middle reaches of Jacksons Creek (Reaches 7), lower Deep Creek (Reach 4) and the upper Maribyrnong River (Reach 8). The lower and middle reaches of Jacksons Creek, mainly downstream of Sunbury township (Reach 7), support the core platypus population in the Maribyrnong Catchment. Recent surveys report some of the highest capture rates in the greater Melbourne area, and eDNA sampling detected platypus at 5 of 7 sampling points.

Platypus in Lower Deep Creek are not as extensive or abundant as the Jacksons Creek population. Recent live-trapping surveys near Bulla have indicated a declining population and eDNA sampling record occasional detections only. These declines are associated with poor platypus habitat suitability due to surface flow cessation that further restrict connectivity between populations. The lower and middle reaches of Jacksons Creek and Lower Deep Creek are both areas of high management priority for platypus, with mid-term review recommendations that focus on improving habitat quality and strengthening connectivity.

While historically platypus populations extended into the middle and upper reaches of Deep Creek, following the Millenium drought they have largely disappeared from these reaches. The HWS mid-term review states that the long-term trajectory targets for platypus in upper Deep Creek and Emu Creek sub-catchments are not likely to be met. In the Upper Deep Creek reduced flows, fragmentation and poor riparian vegetation have largely contributed to declines in platypus population. Significant declines in capture rates (as an index for abundance) have been recorded in live-trapping surveys (undertaken between 2002-2014), and with no eDNA detections recorded since early 2022, platypuses are considered functionally extinct in this reach (although low numbers may persist). In Emu Creek, lack of suitable habitat due to low flows and lack of instream and riparian vegetation have been associated with no positive detections in this reach. In the last 20 years, there has been no evidence of a resident platypus populations being supported in Emu Creek.

Vulnerabilities and threats

Under the FFG Act, platypus (*Ornithorhynchus anatinus)* is classified as vulnerable. Declining populations of platypus are associated with several threats that include poor flow regimes, particularly cease to flow events which pose a high threat in reaches of Deep Creek and Jacksons Creek. In Upper Deep Creek permanent populations of platypus are no longer supported due to inability to maintain adequate habitat over summer and autumn periods. While vegetation and macroinvertebrates can tolerate cease to flow events, overland movement of platypus between pools expose platypus to predation by introduced fauna including dogs and foxes. The predicted future reduction in rainfall (due to climate change) and subsequent increase in cease to flow events across Maribyrnong waterways is expected to have significant impact on platypus populations.

Urbanisation is also a threat as it may increase stormwater run-off and impact flow variability. This is particularly a concern in lower Jacksons Creek due to extensive urban development in Sunbury. In summer / autumn increased flows or flashes > 1 m can result in the drowning of juvenile platypus. Fragmentation and restricted distribution of platypus habitat are worsened by poor instream habitat and variable flow regimes that present a moderate threat. Other threats that impact platypus populations to a lower extent include poor in-stream complexity and genetic diversity issues, such as in-breeding.

3.4 Vegetation

The Maribyrnong catchment straddles three bioregions: the Victorian Volcanic Plain (VVP) bioregion, the Central Victorian Uplands (CVU) bioregion, and in the lower parts of the catchment a very small portion of the Gippsland Plain (GipP) bioregion. Despite the long-standing and extensive land use changes discussed in the Site and Issue Paper (Alluvium, 2025), a total of 39 Ecological Vegetation Classes (EVCs) have been mapped as present across the catchment (DEECA, 2023b). Of these, 12 are clearly water-dependent EVCs. The Bioregional Conservation Status (BCS) ratings of these vegetation communities includes Rare, Vulnerable or Endangered categories.

The Maribyrnong catchment supports 80 threatened flora species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) (see Attachment 5 in Alluvium 2025). Eighteen of these are likely to be water-dependent owing to their growth in wetlands, in seepage areas, drainage lines or riparian areas. In almost all cases, the flow-requirements of these listed species have not been determined, chiefly because they are rare and therefore difficult to study. Robust information on flow requirements is limited to a few commonly occurring and widespread species (e.g. Common Reed, *Phragmites australis*). The problem faced when attempting to develop flow recommendations is that environmental water is required not only to support common or widely distributed vegetation types but also threatened vegetation types and even individual listed species. For example, EVC 68 Creekline Grassy Woodland and EVC 83 Swampy Riparian Woodland have a BCS of Endangered in the Central Victorian Uplands. The canopy layer in the former EVC is River Red Gum (*Eucalyptus camaldulensis*) and in the latter is Swamp Gum (*Eucalyptus ovata*) and Eurabbie (*Eucalyptus globulus* ssp. *bicostata*). The water requirements of River Red Gum are well known, but those of Eurabbie are very poorly understood.

The Site and Issue Paper (Alluvium, 2025b) identified four broad vegetation functional groups, based on the typologies developed by Brock and Casanova (1997) and Casanova (2011). Each of these vegetation types plays an important role in the structure and function of a waterway.

- Submerged aquatic vegetation: submerged and floating-leaved vegetation in the thalweg of the stream, including Eelweed (*Vallisneria australis*) and various pondweeds (*Potamogeton* spp.).
- Emergent vegetation: a wide range of non-woody fringing vegetation found along the water's edge and beyond with species such as reeds (e.g. *Phragmites australis*), rushes and sedges (e.g. *Juncus* and *Carex* spp.).
- Riparian vegetation: a mix of fringing woody vegetation such as eucalypts (e.g. *Eucalyptus camaldulensis*), paperbarks (*Melaleuca* spp.), tea-trees (*Leptospermum* spp.) and bottle-brushes (*Callistemon* spp.), water-dependent ferns, grasses and understorey component.
- Floodplain vegetation: vegetation consisting of woody taxa (e.g. River Red Gum *Eucalyptus camaldulensis* and Swamp Gum *Eucalyptus ovata*) on the floodplain and mostly non-woody taxa in floodplain wetlands (e.g. *Phragmites australis*).

This study does not directly address terrestrial vegetation types as they are not water-dependent and are outside the influence of environmental flow delivery. Terrestrial vegetation (i.e. vegetation that is intolerant of prolonged inundation), however, is relevant when it comes to limiting the colonisation of the stream channel by non-aquatic plants, a process known as terrestrialisation.

Water-dependent vegetation is a critical value in the Maribyrnong system for a number of reasons:

- Vegetation provides much of the structural and habitat diversity enjoyed by native aquatic and terrestrial fauna, for example nesting and roosting sites for birds in the riparian zone, shelter for native animals on the floodplain, in-stream habitat for large-bodied fish etc.
- Vegetation, water-dependent or terrestrial, is the ultimate source of the organic carbon that drives food webs in aquatic systems. It also plays a critical role in nutrient spiralling and other biogeochemical processes in streams, wetlands and floodplains.
- Vegetation provides the foundation of the regional landscapes that drive social and economic uses, e.g. a foundation of recreational angling and other forms of nature-based tourism such as bird watching. It is highly likely that water-dependent vegetation, especially riparian vegetation, has a net positive influence on people's mental health.

Vulnerability and threats

Assessments of the current condition of vegetation in the Maribyrnong system are varied, in part because of changing approaches to monitoring vegetation conditions. On the basis of the latest vegetation vision assessment (completed in 2021), the condition of some survey sites at the headwaters of Maribyrnong catchment and upper reaches of Jacksons Creek and Deep Creek are rated at least 'High'; however, over half of the survey sites were rated 'Medium' or lower at most assessment sites. The site visit by the Environmental Flows Technical Panel (EFTP) in 2024 (Alluvium 2025b) identified several threatening processes to the vegetation condition in Maribyrnong catchment:

- Degradation of the riparian and floodplain zone, especially in Emu Creek and Upper Deep Creek
- Terrestrialisation of stream channel during low flow / cease-to-flow periods in almost all reaches

- Abundance of weeds in the riparian / floodplain zone, with presence of invasive plants in lower Deep Creek and Jacksons Creek.

The climate risk and vulnerability assessment (Alluvium, 2025) identified high hydrological vulnerability for EVC 83 Swampy Riparian Woodland. This is because shorter periods of seasonal inundation and smaller peak flows are projected to occur under climate change. Several water-dependent EVCs (e.g. EVC 641 Riparian woodland, EVC 851 Streambank shrubland and EVC 56 Floodplain Riparian Woodland) were assessed as having medium-level hydrological vulnerability. This is because the dominant canopy tree, River Red Gum (*Eucalyptus camaldulensis*) requires inundation for sexual recruitment, growth of juveniles and good condition of adult trees. Some of the EVCs present in the catchment have perennial shrubs in the understorey that may require regular watering. but in general, these EVCs can adapt to periods of irregular inundation / watering. One other EVC, EVC 68 Creekline Grassy Woodland, has a low hydrological vulnerability as its indicative plant species can draw upon other sources of water. It needs to be stressed that there are many limitations to assessing climate vulnerability of vegetation, as outlined in the climate risk and vulnerability assessment (Alluvium, 2025).

3.5 Macroinvertebrates

Aquatic macroinvertebrates play an important role in the ecosystem as they act as an essential food source to local platypus, fish and frog populations (DEECA, 2021-22). The Maribyrnong catchment supports a broad range of aquatic macroinvertebrates, that includes freshwater shrimp (*Paratya australiensis*) and various species of burrowing crayfish, caddisflies, butterflies, and beetles. It also supports populations of the Large River Damselfly (*Caliagrion billinghursti*) that is found in the Maribyrnong River and is listed as Vulnerable under the FFG Act and in the IUCN Red List.

In 2000, a study was undertaken by Rankin and Bate on macroinvertebrates and water quality of waterways in the Maribyrnong system. The results of the study revealed the presence of diverse macroinvertebrates communities in the upper catchment, indicating a likely trend towards less diverse and less pollution-intolerant communities in the lower reaches, particularly in the urban tributaries. Turbidity was the water quality variable most significantly aligned with reduced species diversity. Other factors that were associated with poorer water quality, and invertebrate communities were streamside vegetation, local erosion and sediment deposition.

In the HWS mid-term review (period covering 2018 to 2023) no macroinvertebrates sites in the Maribyrnong catchment were classified as ‘improving’ (Melbourne Water, 2024). One largely forested, four urbanising and two urban sites were classified as declining. All main-stem Maribyrnong River and Deep Creek sites had ‘declining’ macroinvertebrates trends over the historical time period. Habitat suitability modelling predicts macroinvertebrates condition declines in Jacksons, Emu and Upper Deep Creek sub-catchments.

As part of the HWS mid-term evaluation three sites were selected for detailed analysis to understand the declining trends. The sites were located at Baringo Creek (Jacksons Creek sub-catchment), Deep Creek (Deep Creek Upper sub-catchment) and Maribyrnong River (Maribyrnong River sub-catchment). In the sites selected for Deep Creek and Jacksons Creek declines in macroinvertebrates populations were associated with reduced stream flows and urban development.

Vulnerabilities and threats

The most significant threats to macroinvertebrates populations are threats that impact their habitat quality, this includes climate change, urban development and reduced stream flow. Recent projections of habitat suitability considering projections of climate change and urban development (Chee *et al*., 2023), predict that the catchment will experience higher temperatures with reduced rainfall in winter and spring (June to November) and increased water shortages.

Overall, the application of these climate projections to habitat suitability models reveal a high probability of change of species based on their ability to tolerate these conditions i.e., sensitive taxa will be the most vulnerable. The results indicate a significant increase in 'very poor' habitat, with losses in 'poor,' 'moderate,' and 'good' habitats, and a smaller loss in 'very good' habitat. As habitat quality declines, macroinvertebrates species in 'moderate' and 'good' habitats are expected to decrease, particularly those less tolerant of low-quality conditions such as sensitive *Ephemeroptera* (mayflies) and *Trichoptera* (caddisflies). Species in 'poor' habitats that are less sensitive may also be lost from their current reaches and potentially from the stream entirely.

Macroinvertebrates species that are adapted to poorer water quality and less diverse habitat include Coleoptera, Odonata, Diptera and Hemiptera taxa.

Higher temperatures across the catchment will also mean an overall decrease in flow. Reduced stream flow will result in decreased abundance, diversity and quality of physical habitat. Low flows or cease to flow conditions will also reduce mixing of waters in pools causing anerobic conditions that effect the water quality and sensitive taxa. The quality and diversity of benthic habitat is also dependent on the flushing of silts and organic sediments, this can be prevented by low flow events.

Urban development with improper planning and design can also have significant flow regime and water quality impacts on macroinvertebrates. Increased flows on impervious surfaces deliver rainfall directly to streams reducing their water quality and causing short-term high flow events and long-term low flows and/or cease-to-flow events, resulting in increased physical erosion and habitat loss.

3.6 Supporting conditions

Geomorphology

The relationships between flows and channel form in the Maribyrnong system are strongly controlled by underlying geology, especially the relatively young basalt flows that influence almost all streams. Most of these streams are incised into resistant bedrock. Where the channel is completely incised into basalts (e.g. the full length of Emu Creek) the morphology is that of a simple, flat channel. Such channels are also resistant to any change in erosion rates.

In downstream reaches, as the channel becomes larger, it is often cut through the basalt into underlying Silurian sedimentary rock, which is more easily eroded. In many reaches, the relationship between channel form and specific flows is complicated. For example, reaches may have multiple surfaces/benches within the channel, and a single 'bankfull' elevation may be difficult to define. For this reason, higher flows in some reaches that exceed freshes but do not fill the channel have been termed 'high flows'.

Many of these streams are 'underfit'. This means that the small modern river is now confined within a larger trench cut by larger rivers in the geological past. Being underfit explains some of the unusual stream morphology, such as long-straight sections filled with reeds. Underfitting complicates the potential for higher flows to do geomorphic work along the entire length of the channel.

Most channels in the Maribyrnong system do not carry much coarse sediment. This is because the basalt rocks quickly break down into sand and silt, with the gravels carried in the channel often derived from other rock types, such as quartz dykes. Only one of the field sites (Reach 4) had large gravels, where Lower Deep Creek is cut into Devonian granites. This means that there is less chance of pools filling with sediment over time.

The deposition of sediment plays an important role in providing material in which the seeds of terrestrial vegetation can germinate (Greet et al., 2024). The movement of sediment through the reach therefore remains an important function of flows.

The diversity and complexity of habitats that support ecological values, such as pools, riffles and benches, are maintained by the geomorphic processes that shape the channel and floodplain. The physical form of a stream depends on its flow regime, the characteristics and supply of its bed and bank sediment, the riparian and instream vegetation and valley controls (such as confinement and valley slope).

Water quality

Water quality is a critical component of river environments. It determines the habitat suitability for aquatic species through tolerance ranges (e.g. salinity, pH, dissolved oxygen, temperature, and light availability), as well as adverse processes (e.g. high nutrient concentrations causing eutrophication, leading to harmful fluctuations in dissolved oxygen, pH, and light availability).

The frequent low flows and cease-to-flow periods in the Maribyrnong system make it vulnerable to poor water quality and adverse processes through insufficient flushing of pools, stratification of pools, and increased likelihood of algal blooms. Each of these are likely to impact dissolved oxygen concentrations with potential harmful effects on the fish and aquatic macroinvertebrates assemblages. High phosphorus and nitrogen concentrations measured at several sites within the Maribyrnong system combined with concerningly low concentrations of dissolved oxygen further indicate that the river system is vulnerable to serious water quality impacts.

Maintenance of dissolved oxygen concentrations, avoidance of eutrophication and stratification and the flushing of silts, salts and nutrients are critical in the Maribyrnong catchment especially for unregulated river reaches where threatened species are known to occur.

Using flushing flows to remove/dilute of pollutants, nutrients, salts, warm water, and fine sediments, as well as creating sufficient turbulence across pools to promote mixing and minimising stagnation and eutrophication will therefore be an important component in the maintenance of the fish and aquatic macroinvertebrates fauna. Using flow regimes in conjunction with sound riparian and whole-of-catchment management approaches will also help management of water quality to accommodate and adjust to changing climatic conditions.

4 Approach to developing environmental water requirements

This study has applied the FLOWS method approach to determining environmental flow requirements (DEPI, 2013). The process that has been applied for this study, to determine environmental flow recommendations for the Maribyrnong system, followed 4 key steps (Figure 2):

1. Identify water-dependent values in the system and development of ecological objectives to support those values based on overarching objectives and alignment with broader strategies (e.g. HWS), consultations with Project Advisory Group (PAG), Environmental Flows Technical Panel (EFTP) and the Steering Committee
2. Develop the required ecological – flow functions from ecological conceptual models and objectives with technical expertise and knowledge from EFTP
3. Develop flow components and hydraulic criteria to determine the magnitude of the flow recommendations
4. Use hydraulic modelling (2D) and hydrological analysis to understand system hydrology in order to determine frequency, duration, timing and climate conditions of the flow recommendations

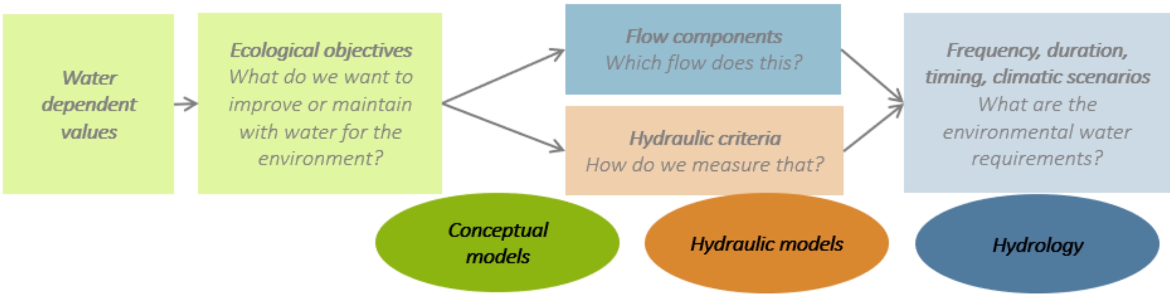


Figure 4. *Approach to understanding environmental water requirements (adapted from DEPI, 2013)*

Site visit was conducted over two days on 22 and 23 July 2024 with some of our environmental flows technical panel (EFTP) (Vegetation, Aquatic Fauna and Geomorphology experts), Melbourne Water, Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation and Narrap Rangers. The site visits and previous desktop assessments enabled technical panel members to identify key water-dependent values and conditions based on site observations.

An online flow-recommendation workshop was then held with the EFTP (16 December 2024) and there were subsequent individual meetings with EFTP members to further develop appropriate flow functions, hydraulic criteria and flow recommendations. These flow recommendations were then fine-tuned using hydrologic analysis (e.g. flow duration curves, spells analysis) with modelled natural and current from Maribyrnong Source model and validated with EFTP members.

Discussions with Melbourne Water and EFTP members identified the need to delineate the Maribyrnong system into two management systems based on different management drivers and objectives, and the mechanisms available for water managers to deliver environmental water. Section 5 and 6 present the outcomes of these deliberations, by grouping reaches together according to the degree of regulation. Flow recommendations are similarly organised, by flow components with similar flow objectives and flow functions.

- **Unregulated systems** (Deep Creek Reaches 1, 2 and 4, Emu Creek Reach 3; and Riddells Creek Reach 5) are defined as reaches where there are no large dams or weirs to regulate flow (DELWP, 2022a), even if there are smaller regulating structures (e.g. on-farm storages) may be in place for stock and domestic use. This study has developed flow recommendations for unregulated system with a focus on protecting existing ecological functions for priority water-dependent values. The approach considers the impact of loss of flows (e.g. climate change and pumping) and urbanisation under the context of current management levers.
- **Regulated systems** (Jacksons Creek Reaches 6 and 7; and Maribyrnong River Reach 8) are regulated systems where availability of water supply is currently limited by Rosslynne Reservoir outlet capacity. Management levers are influenced by potential upgrade of Rosslynne Reservoir outlet and

achievement of future environmental water recovery volumes whilst maintaining the access to temporary trade.

In developing the flow recommendations for Jacksons Creek, the EFTP also considered recommendations from the Maribyrnong River and Waterways Association (MRWA, 2024), and the maximum flow recommendations developed by Streamology for Reach 7 only (Streamology, 2024).

Further details on the approach to developing the flow recommendations are provided in Attachment 2. The environmental objectives and hydraulic criteria are provided in Attachment 3. Hydraulic model establishment and outputs are in Attachments 4 and 5, respectively.

It should be noted that the updated flow recommendations have not been designed to be 'climate ready' under future climate change. In the early phase of this project a climate change and vulnerability assessment was completed to understand the impacts of climate change on the values and if existing flow recommendations can be made 'climate ready'. However, the project team and EFTP highlighted the complexity of incorporating uncertainty in these species' trajectory into the future and consider the lifespan of this FLOWS study being 10 years. It is acknowledged that waterway conditions and flow regime will change under future climate change and the impacts to values are discussed, on a high level, in Section 3. The study therefore develops a suite of flow recommendations fit for purpose for the current climate based on best available information and latest understanding of the existing key values and their potential trajectory of the values in the future.

Defining flow components

The paper presents the flow recommendations with flow components as defined below:

Base flows	**Summer / Autumn low flows** are the flows occurring in the dry period between December - May that maintain water flowing through the channel, keeping in-stream habitats wet and pools full. **Winter / Spring low flows** are persistent increase in low flows that occurs with the onset of the wet period (June – November)
Freshes	**Summer / Autumn freshes** are freshes occurring between December – May that are frequent, small, and short duration flow events that last for one to several days as a result of localised rainfall during the low flow period. **Winter / Spring freshes** refer to sustained increases in flow during the higher flow period in June – November as a result of sustained or heavy rainfall events.
High flows	**High flows** are 'channel-forming' flows required to erode the toe of the river banks. Rivers of the Maribyrnong system are incised and require extremely high flow magnitude to fill the channel as 'bankfull'. As such, we have presented flow recommendations as higher flow freshes that can be delivered anytime throughout the year where possible.

5 Environmental flow requirements for the regulated system: Jacksons Creek and Maribyrnong River

5.1 Overview

The hydrology of Jacksons Creek has been radically changed by the operation of Rosslynne Reservoir. Current flows through the year are largely consistent (Figure 5), due to consistent releases from the reservoir and the capture of higher magnitude flows within the reservoir.

The flow regime at Upper Jacksons Creek (Reach 6) has been altered and it no longer ceases to flow (Figure 5). The current flows during summer / autumn are now generally higher than those of winter / spring, and are sustaining more flows throughout the year than what it was naturally (Figure 5). Current flows in winter / spring are also sustaining low flows longer than it was naturally (Figure 5). The effect of the operation and extraction of water has also decreased the magnitudes of higher flows and these higher flows are now occurring less frequently in both seasons (Figure 5). These effects are contributing to the 'seasonal reversal' effect that are common in many regulated systems.

Reach 7 does not experience seasonal reversal as it also receives inflows from Riddells Creek (Figure 6). Prior to the construction of Rosslynne Reservoir, Jacksons Creek experienced frequent cease to flow events during summer and autumn, whereas today, passing flows ensure season-long low flows (except for when entitlements are qualified and no passing flows are provided, for example during droughts when no water is available for release or when there is a storage level trigger reducing passing flows). This has 'reset' the reach to a new hydrological regime.

The flow recommendations have not been designed to return the hydrology of Jacksons Creek to a pre-development condition. Rather, they seek to support existing values and critical ecological functions.

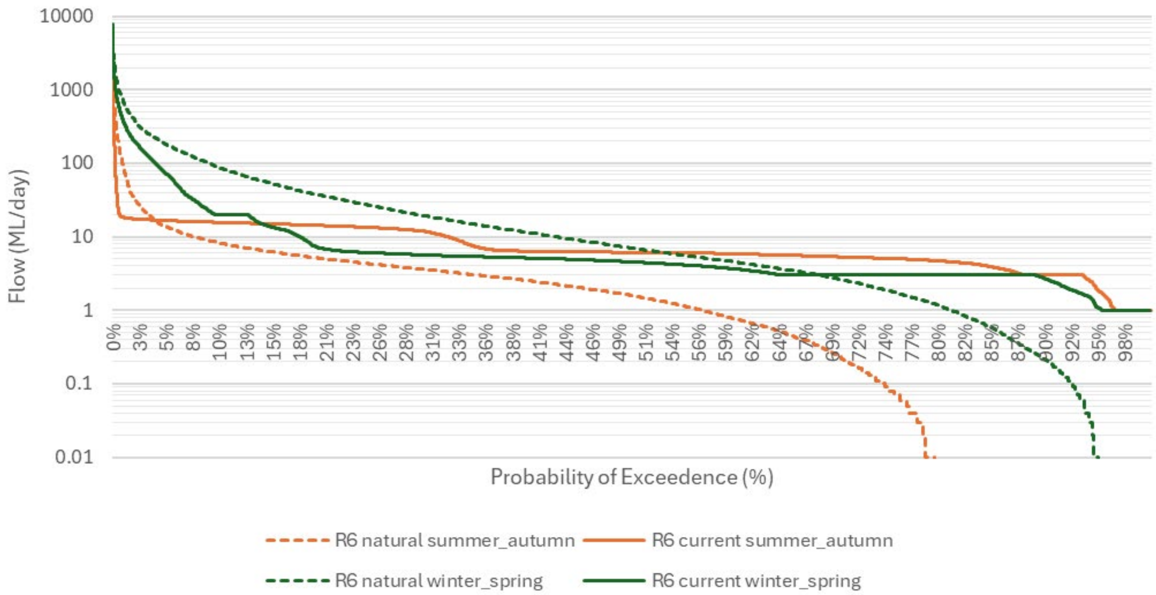


Figure 5. *Flow duration curves of Reach 6 using modelled natural and current seasonal flows*

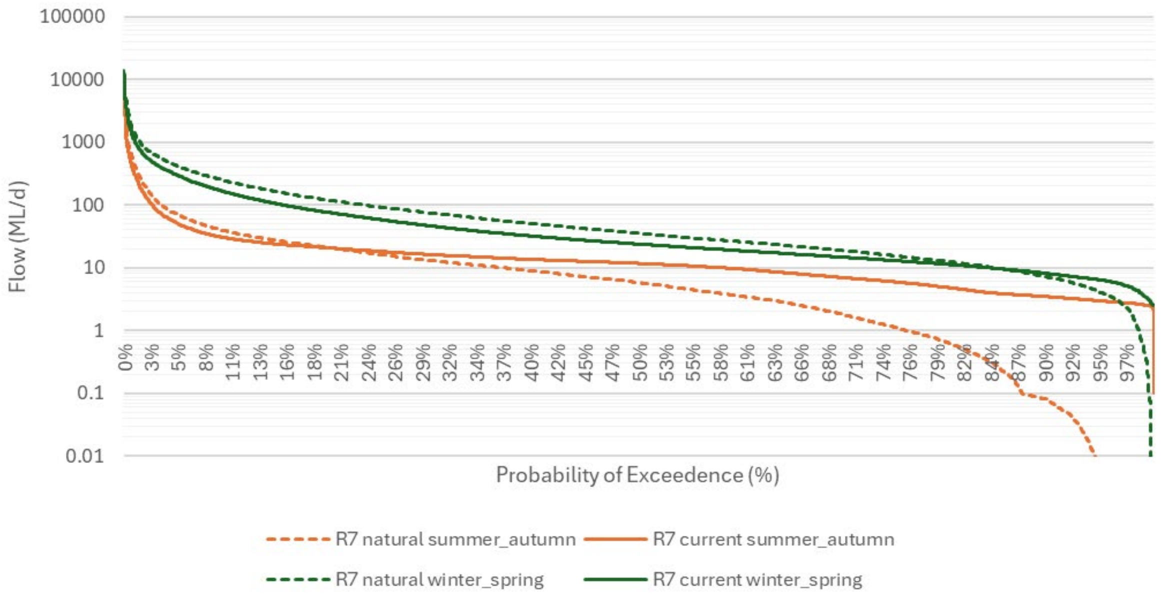


Figure 6. *Flow duration curves of Reach 7 using modelled and current seasonal flows*

The Maribyrnong River is a regulated reach downstream of the confluence of Jacksons and Deep Creek. It is strongly influenced by the hydrology of Jacksons Creek. It also receives inflows from the unregulated reaches of Deep Creek, Emu Creek and Riddells Creek (Figure 7). A comprehensive update of the existing flow recommendations for the Maribyrnong River was not in the scope of this study. There are limited opportunities to deliver the magnitude of flows that would be able to influence this reach. Reach 8 flow recommendations have been considered for general alignment with those for upstream reaches, for example, to achieve consistency in the frequencies and durations of freshes and higher flows across the system.

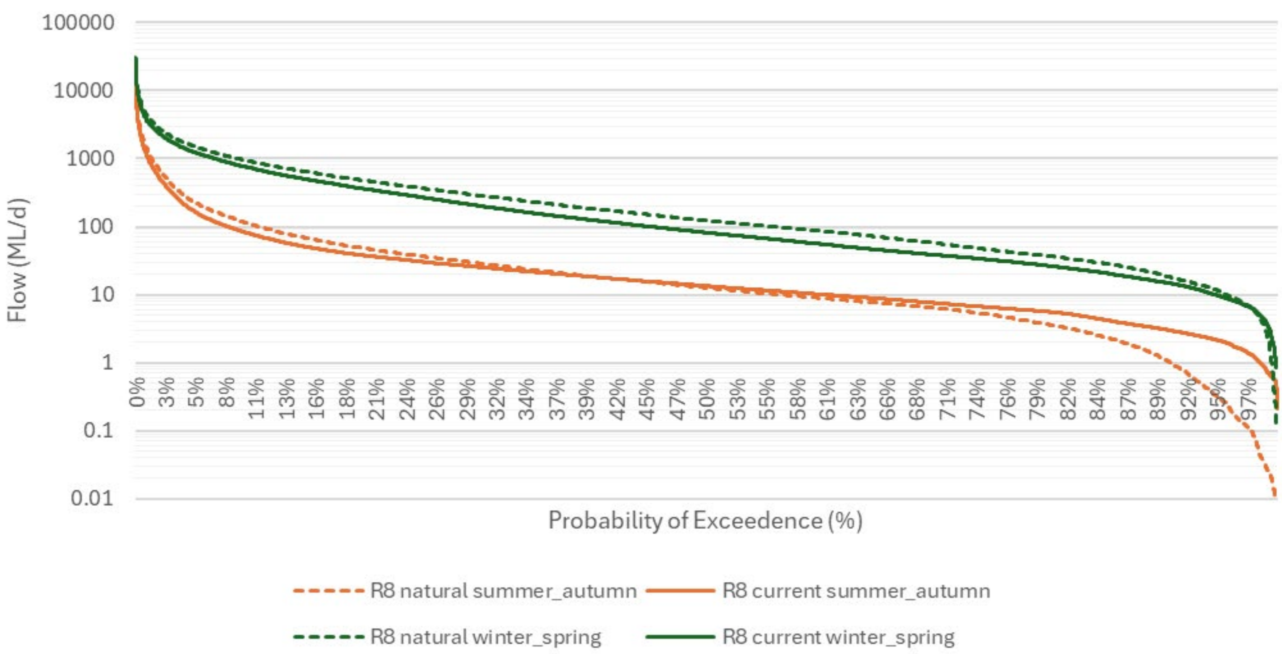


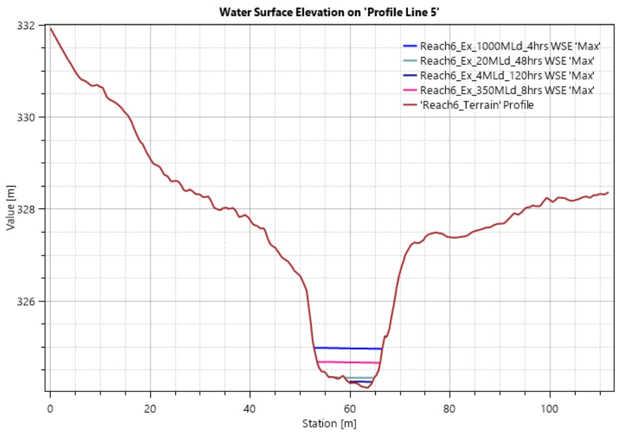
Figure 7. *Flow duration curves of Reach 8 using modelled and current seasonal flows*

5.2 Habitat characteristics of the regulated reaches

Reach 6 (Jacksons Creek Upper)

Reach 6 is deeply incised with exposed basalt bedrock, providing little opportunity for flows to move laterally. There are series of small run-riffle-pool sequence throughout the reach and also pockets of small permanent pools on basalt banks up to 1 m deep. A small narrow floodplain was present, mostly vegetated with pasture grasses and exotic species (e.g. Gorse, Artichoke Thistles and Blackberries). Dense Phragmites swards are encroaching on the channel which reduces the habitat diversity of this reach. There is evidence of replanting with native vegetation (e.g. *Allocasuarina verticillata* Drooping She-oak) on the floodplains. Small bodied native fish and short-finned eel are likely to reside in this reach in some of these deep and small pools for breeding but more likely to move to other habitat within and beyond the reach in higher flow events. Both Platypus and Growling Grass Frogs are less likely to be found in this reach due to altered flow regime, lack of deep pool habitat and poorer water quality from agricultural and urban runoff from Gisborne. Urban runoff may affect the health of macroinvertebrates populations in this reach where macroinvertebrates condition is declining, as discussed in the Site and Issue paper and the 2022 Healthy Waterways Strategy mid-term review (Alluvium, 2025b; Melbourne Water, 2024).

Jacksons Creek (Reach 6) is a recognised groundwater-dependent drought refuge. During summer / autumn periods (December to May), aquatic habitat, especially some of the deeper sections of the channel is maintained by groundwater. During dry periods, the water quality may be affected by groundwater inflows, and may become more saline, depending on the season's rainfall and stream flow dynamics. However, there is a lack of information to describe more fully the influence of groundwater on riverine water quality.



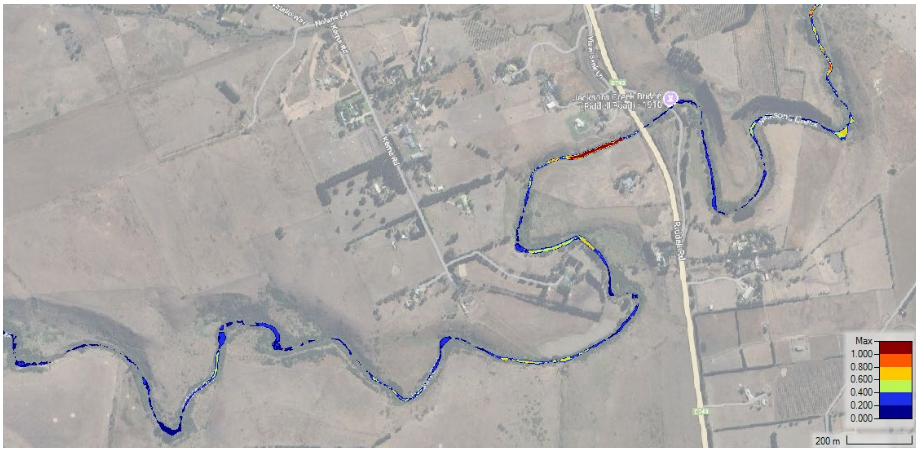


Figure 8. *Top left: Reach 6 site, Top right: typical cross section of Reach 6 showing highly incised channel. Bottom: Screenshot of the maximum channel depth (m) when 4 ML/d is modelled (creek flows downstream from left to right of this image).*

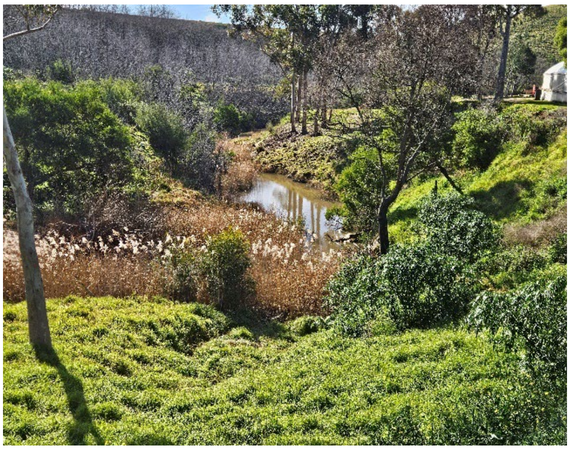
Reach 7 (Jacksons Creek Lower)

Reach 7 is a highly confined, incised reach with high capacity for flow. Reach 7 is downstream of Reach 6 and receives unregulated inflows from Riddells Creek. Impacts of Rosslynne Reservoir are less pronounced than that of Reach 6. Reach 7 has larger channel capacity, providing a range of habitat for range of water-dependent species. In Summer / Autumn period (Dec – May), the stream bed is characterised by shallow pools (about 1 m depth) (Figure 7) and sections where the bed is colonised by macrophytes. Reach 7 is adjacent to Sunbury township and so is at risk from serious impacts arising from rapid urbanisation and other land use changes.

Despite the land use changes, Platypus, Growling Grass Frogs, small bodied native fish and Short-finned Eel are key values in this reach. Reach 7 is one of the last remaining reaches of the Maribyrnong system that supports healthy populations of Platypus compared to other reaches in the Maribyrnong system. Platypus are consistently recorded here downstream of the Sunbury Treatment Plant, which may help provide consistent flows (i.e. less flow variability, reduced cease-to-flows) during dry periods to enable connectivity opportunities for Platypus to move across the reach (foraging) and increase productivity. Within this reach there is mosaic of vegetation with patches of Phragmites spotted along the fringing beds, though floodplain conditions are degraded.

Reach 7 has a variety of pool habitat between 0.5 m – 1.0 m deep and shallow margins for aquatic fauna (Figure 9). There are also a number of aquatic habitats on the floodplain in parts of Reach 7 beyond the riparian areas. These pool habitats and shallow margins support a small population of Growling Grass Frog to breed and forage. Warmer waters in some small and shallow in-channel pools help suppress chytrid fungal threats. Reach 7 also supports small-bodied native fish populations and short-finned eels in some of these deep and small pools for breeding but more likely to move to other habitat in higher flow events.

Similar to Reach 6, Jacksons Creek (Reach 7) is a groundwater-dependent drought refuge. During Summer / Autumn periods, aquatic habitat, especially some of the deeper sections of the channel is maintained by groundwater. During dry periods, the water quality may be affected by groundwater inflows and become more saline, depending on the season's rainfall and stream flow dynamics. However, there is lack of information to ascertain the influence of groundwater on riverine water quality.



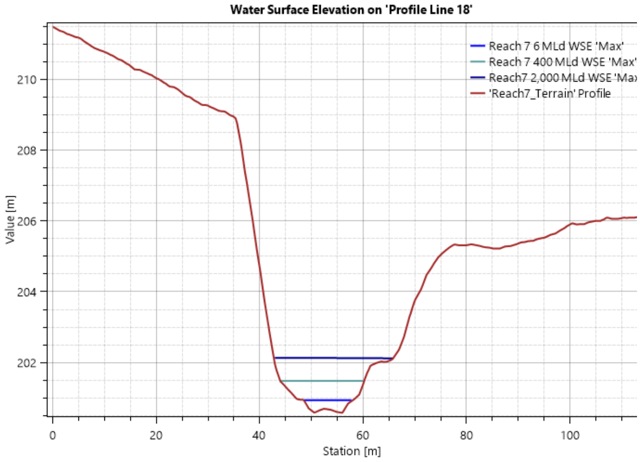


Figure 9. *Top left: Reach 7 site, Top right: typical cross section of Reach 7 showing highly incised channel. Bottom: Screenshot of the maximum channel depth (m) for a modelled flow of 6 ML/d showing a mix of habitats and areas of deep pools.*
Note: The green to red areas are the deeper pools and the blue areas are shallower sections) Note: location of the site visit is downstream of the hydraulic model. Creek flows downstream from left to right of this image.

Reach 8 (Maribyrnong River)

Reach 8 is a large river channel that connects the estuary and upstream reaches through established urban areas of Melbourne. Channel capacity in Reach 8 is much larger than for the other reaches under investigation in this study, which means it is difficult or impossible to provide most of the environmental flow components (e.g. bankfull flows) in this reach. The river provides habitat for small-bodied native fish and other diadromous species and supports riparian and floodplain vegetation that seems to be in good condition. Platypus persist in the upper sections of this reach from the confluence of Jacksons and Deep Creeks down to the M80 Ring Road.

5.3 Base flow requirement

Summer / Autumn low flows (December to May)
The primary function of low flows in Summer / Autumn periods in Jacksons Creek is to maintain a minimum baseflow, which will then result in longitudinal connectivity and the maintenance of aquatic refugia. This includes the provision of pool habitats with permanent deep zones and shallow margins in part of Jacksons Creek where pool habitat is present. Summer / Autumn low flows will provide connectivity along most of Jacksons Creek and the Maribyrnong River, which facilitates the dispersal of biota between pools, and prevents encroachment of terrestrial vegetation into the channel.

In effect, persistent Summer / Autumn low flows in these reaches eliminate cease-to-flow events, providing suitable habitat and food for water-dependent plants and animals, as well as maintaining water quality (e.g. DO and salinity) and providing food resources. The maintenance of pools requires sufficient inflows to promote mixing and prevent thermal stratification.

Shallow pools and stream margins are used by Growling Grass Frog to keep warm, and the higher water temperatures help suppress chytrid fungal infections. In contrast, Platypus prefer a combination of deep pool habitat and shallower riffles. Aquatic and fringing vegetation allow for growth and reproduction of macroinvertebrates, provides quality foraging habitat, and protects frogs, tadpoles and small-bodied native fish from predation.

Hydraulic criteria for the <u>maintenance of longitudinal connectivity and pool habitat in the Summer / Autumn low flow period</u> include:

- Maintain depth in pools greater than 0.5 m
- Prevent thermal stratification of pools and maintain water quality through the provision of 0.1 m/s velocities in at least some part of the pools
- Prevent cease to flow periods (ensure there is 0.05 m – 0.1 m above riffles, to allow for animal movement)

Winter / Spring low flows (June to November)
The primary function of Winter / Spring low flows in Jacksons Creek is to protect and maintain the habitat used by fish, frogs, platypus and other water-dependent fauna by maintaining water quality and suitable conditions for macroinvertebrates. Low flows, delivered in winter / spring, serve to maintain wetted areas, provide connectivity throughout the reach and support the dispersal of biota between habitats.

Connectivity is particularly important for large aquatic fauna (e.g. Platypus), as overland travel exposes species to predation. Low flows in Winter / Spring period provide adequate depth and permanence of water in the channel, to prevent further encroachment of terrestrial and riparian plants into aquatic habitats, while maintaining depth and wetted perimeter to support submerged, floating leaves, and fringing vegetation.

Winter / Spring low flows in Jacksons Creek are expected to assist in the recharge/maintenance of groundwater aquifers during the winter / spring period. These aquifers help to maintain groundwater water-dependent vegetation on the floodplain and support the maintenance of refugia in dry times though groundwater inflows.

Key hydraulic criteria for <u>low flows in winter / spring (Jun-Nov)</u> include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.1 m/s in at least some part of pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Maintaining 0.1 m over riffles

Environmental flow recommendations – base flows in Jacksons Creek
Ensuring longitudinal connectivity throughout December to May is critical to the survival of Platypus in Jacksons Creek. Reach 7 supports one of the last remaining refuges for Platypus in Maribyrnong Catchment and cease-to-flows are likely to cause detrimental impact on Platypus populations. The highest priority is to deliver low flows

(Dec – May) is to ensure there is a minimum baseflows throughout at Reach 7 to protect the existing Platypus populations.

Table 3. Environmental flow recommendation for base flows in the regulated reaches

Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
6	Dec-May	4 ML/d	Continuous	Continuous	Refugia habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates, vegetation, and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, Fr7, **M3**, **P1**, V1, V4, V7, **WQ2,**
	Jun-Nov	20 ML/d	Continuous	Continuous	Refugia and maintain wetted areas for vegetation, fish and frogs. Plant growth and reproduction for submerged, floating-leaved vegetation and emergent vegetation. Reduce thermal stratification and maintaining gross channel size.	**Fi1**, Fr7, **P1**, V1, V4, V7, **WQ2**, G1
7	Dec-May	8* ML/d	Continuous	Continuous	Refugia habitat, water quality for platypus, Growling Grass Frog (shallow stream margin and deep pools), small-bodied native fish and diadromous species and macroinvertebrates. Provide longitudinal connectivity for platypus. Plant growth and reproduction for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **Fr1**, **Fr4**, **Fr7**, M3, **P1**, **P3**, **V1**, **V4**, V7, WQ2
	Jun-Nov	40** ML/d	Continuous	Continuous	Refugia and provide longitudinal connectivity for Platypus, Growling Grass Frogs, vegetation and fish. Promote plant growth for submerged and emergent vegetation. Maintain gross channel size	Fi1, Fr1, Fr4, Fr7, P1, P3, **V1,** V4, V7, WQ2, G1

*Summer / Autumn low flows in Reach 7 do not exceed the recommended maximum flows for reach 7 of 9.3 ML/d (Streamology, 2024).
**40 ML/d is a maximum base flow following the recommendation of the maximum Winter / Spring low flows magnitude from Streamology (2024).
^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.

<u>Notes on availability of flows in dry years</u>
In considering the needs for key environmental values at Jacksons Creek, maintaining deep pools in Jacksons Creek and preventing cease to flow periods is essential. The availability of flows at Jacksons Creek, especially at Reach 6 is driven by the releases from Rosslynne Reservoir. In drier years the storage levels at Rosslynne Reservoir will decrease and this will impact on the ability to deliver existing passing flow requirements, thereby decreases the volume of water available for the environment. In very dry years, there may not be sufficient water in storage to deliver passing flows nor water for the environment.

The availability of flows increases further away from the Reservoir at Reach 7 where there are other inflows such as Riddells Creek, stormwater runoff and flow releases from upstream treatment plants such as Sunbury Sewerage Treatment Plant and Gisborne Water Treatment Plant. These additional inflows could improve flow availability at Reach 7 in dry years.

5.4 Fresh flow requirements

Summer / Autumn freshes

Freshes in summer / autumn are important for Jacksons Creek as it provide additional depth across the reaches to replenish water in pool / riffle / run habitats within the reaches and encourages connectivity along the reaches. Summer / Autumn freshes provide additional opportunities for dispersal of biota (fish, platypus, frogs) between refuges in Jacksons Creek, and for migratory species (e.g. short-finned eel and Tupong), to move between freshwater reaches and the estuary (downstream of Reach 8).

Freshes inundate benches and semi-aquatic vegetation beds to enhance the diversity and extent of aquatic habitats for macroinvertebrates. The variability in depth along the river's edge supports vegetation diversity and zonation up the bank and further sustains macroinvertebrates populations. The higher velocities of freshes promote increased mixing and flushing of pools, to maintain water quality for macroinvertebrates and other biota, and promote the oxygenation of pools at depth.

Summer / Autumn freshes help to flush propagules (seeds and plant fragments) of terrestrial vegetation from the channel, reduce likelihood of germination and colonisation of the channel. Freshes also promote the dispersal of propagules from water-dependent plants.

Hydraulic criteria for freshes during the low flow season include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.3 m/s in at least some part of pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Providing 0.1 m depth over riffles to provide connectivity and thereby enable dispersal of biota between habitats and trigger downstream migration of adult diadromous fish species (primarily short-finned eels)
- Providing an increase of 0.15 – 0.3 m depth above those achieved by low flows

Timing for Summer / Autumn freshes should be aligned with downstream migration cues of adult diadromous species (Table 4). The provision of freshes from September to January will support the upstream migration of juvenile diadromous species from the estuarine reach and also encourage dispersal of Growling Grass Frog during their active and breeding season from September to April. Freshes in late March / April in Reach 7 also cues Growling Grass Frog to seek suitable (above full water level) sites for brumation / sheltering over winter.

Table 4. Migration and movement timing for fish and frogs in the Maribyrnong system

Flow season	Low					High						Low
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Downstream migration												
Short-finned eels	■	■	■	■	■							■
Tupong					■	■	■	■				
Common Galaxias			■	■	■							
Upstream migration												
Juvenile diadromous species	■								■	■	■	■
Movement												
Growling Grass Frog	■	■	■	■					■	■	■	■

Summer / Autumn freshes should also be aligned with specific requirements for vegetation and macroinvertebrates to promote downstream movement of propagules, plant reproduction and maintenance of macroinvertebrates habitat (Table 5).

Table 5. Specific timing for freshes (other than Dec-May / Jun – Nov) for vegetation and macroinvertebrates

Flow season	Low					High						Low
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vegetation – submerged and floating leaved vegetation												
Downstream movement of propagules									■	■	■	
Vegetation – fringing woody vegetation												
Promote plant reproduction (sexual and asexual)	■	■							■	■	■	■
Downstream movement of propagules	■	■							■	■	■	■
Vegetation – floodplain vegetation												
Engage flood-runners to inundate floodplain									■	■	■	
Macroinvertebrates												
Maintain habitat condition	■	■							■	■	■	■
Breeding and recruitment									■	■	■	

Winter/ Spring freshes

Winter / Spring freshes generate sufficient shear stresses to keep fine sediment from infilling and clogging gravel beds, and support large macroinvertebrate populations which are an essential food source for platypus, fish and frogs. The scouring of sediment assists in the prevention of terrestrialisation of the stream by removing a key substrate for germination, and maintaining gross channel size.

Periodic freshes recharge pools, flushing, mixing and reoxygenating water at depth. These functions are essential for maintaining the condition, extent of aquatic fauna, and for maintaining the diversity of submerged and floating leaved vegetation. Freshes inundate instream benches and other features, increasing wetted areas, entraining carbon and other nutrients, and facilitating the downstream movement of plant propagules. The variability in depth at the margins improves the condition, extent and diversity of emergent (fringing woody and non-woody) vegetation, and promotes vertical zonation of different plant taxa up the bank.

Winter / Spring freshes provide important cues for breeding, and migration of aquatic species. The provision of freshes from September to January will support the upstream migration of juvenile diadromous species from the estuarine reach, downstream migration of adult diadromous species, and encourage dispersal of Growling Grass Frog between sites (Table 4). Specific timing for fish, frogs, vegetation and macroinvertebrates are listed in Table 4 and Table 5.

Hydraulic criteria for Winter / Spring freshes include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.3 m/s in pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Providing 0.1 m depth over riffles for reach-long connectivity, thereby supporting the species dispersal and migration
- Providing an increase of 0.15 – 0.3 m channel depth above that achieved by Winter / Spring low flow, to increase vegetation diversity and zonation on the bank, and to cover benches and point bars in the channel.
- Generating shear stresses that are sufficient to erode the margins of the channel (10 – 15 Pa, noting that these shear stresses are sufficient to scour cohesive sediments and gravels) to turn over the stream bed and limit colmation (clogging of gravels).

Environmental flow recommendations – freshes in Jacksons Creek

The most important consideration for delivering freshes is to promoting **Platypus dispersal** to new foraging habitat, **minimise flow variability** to protect macroinvertebrates and enabling sediments to mobilise and prevent habitat degradation for Platypus.

Recent research has demonstrated that increasing flow variability (urban stream syndrome) has significant negative impacts on viability of platypus populations (Griffiths et al. 2019; Griffiths et al. 2024). There are serious concerns around the impact of substantial urban growth in the Sunbury region and the potential impacts on lower Jacksons Creek. As this area supports the remaining core platypus population, it is critical that further changes to flow regimes are avoided to sustain platypuses in the catchment.

Table 6. Environmental flow recommendation for freshes in the regulated reaches

Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported^	Hydraulic criteria^
6	Dec – May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Connectivity of habitat and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat condition for macroinvertebrates, vegetation diversity and vertical zonation (submerged, emergent, fringing). Water quality in pools and transport of silts, salts and nutrients	**Fi2**, **Fi3**, **M2**, V2, V3, V5, WQ1
	Jun – Nov	215*** ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools	Fi2, Fi3, **Fr6**, M1, M2, M4, **V2**, **V3**, **V5**, WQ1
		350[#] ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat complexity for macroinvertebrates (which as resource for platypus, and also inundate vegetation), plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools and transport of silts, salts and nutrients	Fi2, Fi3, Fr6, **M1**, M2, M4, V2, V3, V5, WQ1, **P4**, **G2**
7	Dec – May	40* ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Migration of juvenile and adult diadromous species. Connectivity of habitat (Platypus, Growling Grass Frog and fish) and propagule dispersal. Habitat for macroinvertebrates (resource for platypus), vegetation diversity and vertical zonation (submerged, emergent, fringing) and to support tadpole and frog (thermoregulation and breeding opportunity). Water quality in pools and transport of silts, salts and nutrients	Fi2, **Fi3**, Fr3, **Fr5**, M2, P2, **V2**, **V3**, **V5**, WQ1
	Jun – Nov	400**[#] ML/d	DRY: 1 AVE: 2	DRY: 2 days AVE: 3 days	Longitudinal connectivity, breeding and recruitment, brumation cues (Growling Grass Frog). Maintaining geomorphic	Fi2, Fi3, Fr3, Fr5, Fr6, Fr8,

Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported^	Hydraulic criteria^
			WET: 3	WET: 3 days	conditions (habitat complexity for macroinvertebrates), habitat for macroinvertebrates (resource for platypus), plant growth and propagule dispersal, vertical zonation	**M1**, M2, M4, **P2,** V2, V3, V5, WQ1, **G2**

Note: Frequency and duration of freshes in Reach 6 are based on those of Reach 7.
^ Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
# see notes below on flow constraints
*The maximum summer / autumn fresh recommended by Streamology is 40 ML/day (Streamology, 2024).
** The maximum Winter / Spring fresh magnitude recommended by Streamology is 1000 ML/d (Streamology 2024)
***215 ML/d is an interim Winter / Spring fresh magnitude based on the existing flow constraint at Reach 6. This flow magnitudes fulfills the requirements for most environmental objectives except geomorphic processes required to scour the pools and channel, keeping fine sediment from infilling gravels and limit colmation. See #Notes below for the reasoning for the flow constraints.

#Notes on flow constraint at Reach 6 and implications for Reach 7:

Streamology (2025) recently undertook a maximum beneficial flows study to understand the options to optimise flow deliveries within the system. They identified the risk of flooding at a recreation reserve in Gisborne located at the upper end of Reach 6 if a flow magnitude of more than 215 ML/d was to be delivered from Rosslynne Reservoir. This is well below the recommended fresh flow magnitudes of 350 ML/d at Reach 6 and 400 ML/d at Reach 7, as well as the high flows of more than 1,000 ML/d for both reaches (also discussed in Section 5.5). Lowering the flow recommendations for Reach 6 and 7 to 215 ML/d will severely compromise the geomorphic values as the reaches require higher flows to create channel disturbance, prevent terrestrial vegetation encroachment into aquatic habitat, erode river banks for woody habitat and limit colmation. These geomorphic processes are critical to providing necessary habitat and biological process for all flow-dependent values and therefore while there is current constraint to deliver water in the system these flow recommendations should still be required for critical ecological processes. This study recommends two flow magnitudes: an interim flow magnitude of 215 ML/d and an ideal flow magnitude 350 ML/d for Winter / Spring fresh flow recommendations.

Notes on climate variable flow recommendations:
The frequency and duration of Summer / Autumn freshes and Winter / Spring freshes are determined by spells analysis using the modelled natural and current hydrologic data. These were further adjusted by EFTP to consider the environmental objectives and primary functions of the key water dependent values.

In drier years, delivering multiple fresh events may not be possible (based on modelled natural and current hydrologic data and constraints from Rosslynne Reservoir). Provision of one fresh event is then to enhance water mixing, prevent stratification and re-oxygenate pool habitat for key environmental values (e.g. Platypus, Growling Grass Frogs, small-bodied fish). Maintaining minimum connectivity and allowing short periods of disturbance would also be ideal for Platypus in drier years to move across refuge pools.

In wet years there are opportunities to deliver more than one fresh event. However, the duration of the event should be considered carefully to maintain existing Growling Grass Frog populations. Growling Grass Frogs are at risk of disease and require a combination of rock structures and areas to bask, presence of shallow margins and relatively saline water bodies to protect them from chytrid fungus. While they can cope with multiple freshes, longer duration may not be suitable. They will also be reliant on off stream pools (and flooded areas) for breeding during wet years.

Alignment of Reach 6 and Reach 7
The frequency and duration of freshes in Reach 6 were set to be the same as those in Reach 7, in order to achieve alignment between reaches. The frequency and duration of freshes in Reach 6 is higher than would be achieved naturally, however the flow recommendations were set to provide function and support of existing values, rather than returning flows to a 'natural' regime.

5.5 High flows (Anytime)

Higher flows in these streams are critical for scouring deeper pools, depositing sediment on bars and riffles, and eroding riverbanks to deliver woody habitat into the stream. These flows play a critical role in scouring channels and maintaining pools and substrate. It is important to note that, at present, these higher flows are not much affected by dams, extraction or other forms of flow regulation in the Maribyrnong catchment. At the same time, there is little capacity to influence these larger flows.

Due to the incised and 'stepped' nature of Maribyrnong channels, the magnitude of flows big enough to qualify as 'bankfull' events is impossible to determine, and even very large magnitude flows often fail to completely fill the channel. The term 'high flows' has therefore been used in place of the term 'bankfull' flow.

Additional (or 'channel-forming') flows are required to erode the toe of riverbanks. The required shear stresses are typically in the range of 15 – 25 Pa (Khorsandi et.al. 2004; Allmanova et. al. 2021, and Papanicolau et. al. 2007) although they may be higher in the cohesive sediments of Maribyrnong streams (I. Rutherfurd, Pers. Comm. Dec 2024). High flows have several functions: (1) the undermining of trees, which subsequently fall into the river to become woody habitat, (2) the scouring of the bed and banks to prevent encroachment by terrestrial vegetation, (3) the inundation lower parts of the bank to support fringing woody vegetation (3) the entrainment of nutrients and carbon from banks, and (4) the transport of sediment.

Woody habitat is essential as a substrate for biofilms, and subsequent support of macroinvertebrates, which are a critical food source for higher organisms including fish, frogs and mammals. Woody habitat also provides critical habitat and cover for fish.

Managed (deliberately released) high flows should be avoided during the platypus breeding season (October – January, inclusive), to protect recruitment. Managed high flows and rapid changes in flow magnitudes from stormwater runoff should be avoided from September – March (inclusive), to support Growling Grass Frog breeding and recruitment.

The key hydraulic criterion for high flows is:

- Generating channel forming shear stresses (15 – 25 Pa), sufficient to erode the toe of banks and deliver large wood to the channel.

Table 7. Minimum high flows recommendations, regulated reaches (anytime)

Reach #	Magnitude#	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
6	1,000 ML/d#	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent and fringing woody vegetation	**M5, V6, G3**
7	2,000 ML/d*	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (frogs)	Fr2, **M5, V6, G3**

*The maximum high flows magnitude recommended by Streamology is 3500 ML/d. (Streamology 2024).
^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.

Note: The frequency of these high flows is not developed with climate conditions. This is based on the expectations that such flows are required regardless of whether a particular year is dry, average or wet. It is acknowledged there could be multiple events of such events occurring in a year and flows of this magnitude can also typically occur in average and wet years.

#Note on flow constraint at Reach 6

As discussed in Section 5.4, Streamology (2025) identified the risk of flooding at a recreation reserve in Gisborne located at the upper end of Reach 6 if a flow magnitude of more than 215 ML/d was to be delivered from Rosslynne Reservoir. This is well below the recommended high flows of more than 1,000 ML/d for both reaches. Lowering the flow recommendations for Reach 6 and 7 to 215 ML/d will mean it is impossible to deliver water to reaches 6 and 7. This will severely compromise the geomorphic values as the reaches require higher flows to create channel disturbance, prevent terrestrial vegetation encroachment into aquatic habitat, erode river banks for woody habitat and limit colmation. These geomorphic processes are critical to providing necessary habitat and biological process for all water-regime dependent values and therefore while there is current constraint to deliver water in the system these flow recommendations should still be required for critical ecological processes.

5.6 Other flow and complementary management actions required to achieve environmental flow recommendations in Jacksons Creek

Upgrade of infrastructure to meet delivery needs

The outlet capacity at Rosslynne Reservoir is currently 20 ML/day, which precludes the delivery of Winter / Spring freshes and high flows in Reach 6. The capacity upgrade of the outlet at Rosslynne Reservoir is essential for the delivery of Winter / Spring low flows, Winter / Spring freshes and high flows in Reaches 6 and 7. Upgrading the outlet capacity to 350 ML/day would enable the delivery of recommended Winter / Spring low flows, Winter / Spring freshes and high flows in Reaches 6 and 7. It is expected that high flows magnitudes would exceed the capacity of an upgraded outlet. high flows would instead be delivered naturally following large rainfall events via overtopping of the reservoir's fixed crest spillway.

Environmental entitlement

The Maribyrnong system does not currently have an environmental entitlement. Through Policy 8-6 of the Central and Gippsland Region Sustainable Water Strategy, the Victorian Government will return up to 7 GL of water to the Maribyrnong system. Water is to be recovered through the substitution of river water with manufactured water, and increasing use of stormwater, recycled water or efficiency measures to reduce water extraction from rivers for cities and towns.

Reducing the impacts of urbanisation (stormwater flow management)

Additional management objectives include the prevention of degradation of flows (impacts to magnitudes, rates of rise and fall, water quality) due to urbanisation. Excessive flow variability, exceedance of rates of rise and fall, and magnitudes that exceed scouring thresholds displace macroinvertebrates are all more likely with stormwater runoff, and expected to have a major negative impact on Platypus and Growling Grass Frog populations.

Use of different water sources (manufactured water) to deliver environmental flows

It is acknowledged that water released from the Sunbury Wastewater Treatment Plant maintains platypus populations during drought, by maintaining pool depths. Stormwater harvesting and the use of recycled water (of suitable quality) for environmental watering will play important roles in protection of refugia and the recovery of water for the environment. Releases should be managed as to avoid the delivery of too much water with inappropriate rates of rise and fall, in the wrong place at the wrong time. Moreover, managed delivery of high flows should be avoided during the platypus breeding season (October to January, inclusive) and Growling Grass Frog breeding season (September to March, inclusive), to support platypus and Growling Grass Frog recruitment.

Maximum flows

Maximum flow recommendations have been developed for Reach 7 of the Maribyrnong, to inform stormwater management and the use of harvested stormwater for environmental purposes, and to prevent detrimental outcomes from excess urban runoff (Streamology, 2024). The recommendations above align with the maximum flow recommendations. It is noted that magnitudes of summer / autumn fresh recommendation (40 ML/day) and winter / spring low flow recommendations (40 ML/day) are at the maximum recommended flow magnitudes for these flow components.

Fish barriers

Several barriers, both natural and anthropogenic, are present in the Maribyrnong system. If weirs and other man-made barriers were to be removed from the system, the environmental objectives for fish and flow recommendations remain applicable. Outcomes for species capable of climbing remaining natural barriers (eels and some galaxiids) would improve as there would be fewer barriers overall to negotiate. However, it is the technical panel's view that the remaining natural barriers would still impede passage by non-climbers, such as Tupong and Australian Grayling.

6 Unregulated system – Deep Creek, Riddells Creek and Emu Creek

This section describes the unregulated parts of the Maribyrnong River system for Deep Creek (Reaches 1, 2 and 4), Riddells Creek (Reach 5) and Emu Creek (Reach 3). In the unregulated parts, though there are local onstream storages and dams, there are no large onstream storages for holding water. This means that managers of unregulated reaches have few options to deliver water to each of the identified reaches. The corollary is that flow recommendations for unregulated reaches of an otherwise strongly regulated river system refer mostly to the setting of restrictions and bans on extraction to maintain what flows are there naturally and to prevent alterations to flow that would have serious detrimental impacts on the water-dependent values of the individual reaches. This action may also involve restrictions on the setting of new licences (through Permissible consumptive volumes (PCVs)), diversions and other permissions for take and a local groundwater pumping regime in the reach.

In summary, the recommendations provided below serve mostly to protect the existing flow regime from alterations. The environmental flows recommended here provide a desired flow regime that support the ecological functions, highlighting important components that should be ‘protected’ from allocation and extraction for consumptive or other purposes.

6.1 About the flow functions in unregulated reaches

Base flows

Summer / Autumn low flows (December to May)
All unregulated reaches in the Maribyrnong system naturally cease to flow for at least some days during Summer / Autumn periods. During December to May, cease-to-flow periods are common in upper reaches (1, 3 and 5). When these events occur the watercourse evolves into a series of discontinuous pools, often known also as a ‘chain of ponds’ system. Pools can be in the form of waterholes, riverine pools and even temporary habitat such as wet patches under the banks, logs, and rocks. Some of these refugia are deep enough to persist during dry and even drought periods. Often this persistence arises from substantial groundwater inflows. Deep pools and other drought refugia are critical to the survival of aquatic species s during dry periods, particularly those that are restricted within the Maribyrnong system such as Yarra Pygmy Perch in Upper Deep Creek (Reach 1) and Growling Grass Frogs in Emu Creek (Reach 3). Refugia are also critical to support the re-building of populations during wetter periods (Bond et al. 2008).

The primary function of Summer/ Autumn low flows in unregulated reaches is to maintain the extent, depth and water quality of pool refugia, which is critical for the maintenance of all water-dependent values. These pools require sufficient inflows to promote mixing, oxygenation at depth and prevent thermal stratification for supporting habitat for water-dependent values. However, in an unregulated system these flows cannot be “delivered”.

The provision of suitable depth and water quality supports aquatic and fringing vegetation, and it also supports macroinvertebrates and small bodied native fish. In Emu Creek, frogs breed in pools and vegetated shallow margins during summer/autumn seasons and deeper pools help to protect tadpoles from desiccation. Frogs also prefer floating and submerged vegetation such as Water Ribbons that provide ideal breeding and foraging habitat and protective cover from predators, especially during summer.

Hydraulic criteria for the maintenance of refugia in more-or-less permanent pools include:

- Maintaining depth in pools greater than 0.5 m
- Preventing thermal stratification of pools, and maintain water quality in pools through the provision of 0.1 m/s velocities in at least some part of the pools

Winter / Spring low flows *(June – November)*
Winter / Spring low flows delivered in June to November, serve to maintain wetted areas, provide connectivity throughout the reach and support the dispersal of biota between habitats. Winter / Spring low flows provide

adequate depth and permanence of water in the channel, to prevent further encroachment of terrestrial and riparian plants into aquatic habitats, while maintaining depth and wetted perimeter to support submerged, floating-leaved, and fringing vegetation. Winter / Spring low flows therefore help to maintain gross channel size while simultaneously extending the potential range for aquatic and submerged vegetation.

Winter / Spring low flows provide wet margins and greater extents and depth of pool habitats than low flows in Summer / Autumn period. Higher and faster flows promote the efficient mixing of pools, preventing thermal stratification and increasing oxygenation at depth. Winter / Spring low flows provide a greater extent of riffle and run habitats which are important for both macroinvertebrate populations, and the species that depend on macroinvertebrates as a food source. The increased wetting of margins further supports the zonation of vegetation communities on the bank, increasing diversity and macroinvertebrates support.

Key hydraulic criteria for Winter / Spring low flows include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.1 m/s in at least some part of pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Maintaining 0.1 m depth over the thalweg

Freshes

Summer / Autumn freshes (December – May)
The key functions of Summer / Autumn freshes are to enhance filling, mixing and flushing of refuge pools, to improving water quality, oxygenation at depth and to preventing stratification. It is noted that while whole-of-reach connectivity may not be achievable, the provision of depth over *at least some* riffles enables the dispersal of small-bodied native fish between pools and other habitats. The hydraulic variability provided by Summer / Autumn freshes also inundate benches and aquatic vegetation beds and wetted areas, thereby promoting vegetation diversity and facilitate vertical plant zonation on banks. This variability enhances the diversity and extent of aquatic habitats for macroinvertebrates, as does the provision of riffles.

Freshes in late March / April in Emu Creek (Reach 3) may encourage Growling Grass Frogs to seek suitable (above full water level) sites for brumation / sheltering over winter. It also encourages dispersal of populations between habitat sites during their active / breeding season between September to April. The timing of other freshes should align with timing for movement and migration for fish species (see Table 4).

Summer / autumn freshes help to flush propagules (seeds and plant fragments) of terrestrial vegetation from the channel, reduce likelihood of germination and colonisation of the channel. Freshes also promote the dispersal of propagules from water-dependent plants, which provide habitat for water-dependent fauna.

Hydraulic criteria for Summer / Autumn freshes include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.3 m/s in at least some part of pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Providing 0.1 m depth over riffles to provide connectivity and thereby enable dispersal of biota between habitats and trigger downstream migration of adult diadromous fish species (primarily short-finned eels)
- Providing an increase of 0.15 – 0.3 m depth above those achieved by low flows.

Winter / Spring freshes (June – November)
Winter / Spring freshes during winter/spring support several functions, including physical disturbance, the inundation of in-stream features, longitudinal connectivity and including the provision of migratory cues. Winter / Spring freshes provide shear stresses in the range of 10 – 15 Pa, which erode the margins of the channel, mobilise sediment, turn over the riverbed and limit the clogging of gravels. This function is important to support drift and dispersal of macroinvertebrate populations which are also a food source for fish, frogs and other higher consumer species. The scouring and movement of sediment prevents colonisation of the channel by

terrestrial macrophytes (which colonise areas of accumulated sediment) and thereby helps to maintains gross channel size.

Winter / Spring freshes inundate benches, point bars and other physical features in the waterway, extending wetted habitat, supporting emergent and bank vegetation and entraining nutrients and carbon to the channel. The higher flows also facilitate the downstream movement of plant propagules. The increased depth over riffles and runs supports fish dispersal and migration while simultaneously increasing and diversifying habitats for macroinvertebrates.

Periodic freshes further recharge pools, flushing, mixing and reoxygenating water at depth. These functions are essential for maintaining the condition, extent of aquatic fauna, and for maintaining the diversity of submerged and floating leaved vegetation.

Winter / Spring freshes provide important cues for breeding and migration of aquatic species. The provision of Winter / Spring freshes supports the upstream migration of juvenile diadromous species and the downstream migration of adult tupong (Table 4).

Key hydraulic criteria for Winter / Spring freshes include:

- Maintaining pool depths greater than 0.5 m
- Maintaining flows of > 0.3 m/s in pools to enhance water mixing, prevent stratification and thereby maintain sufficient dissolved oxygen at depth
- Providing 0.1 m depth over riffles for reach-long connectivity, thereby supporting the species dispersal and migration
- Providing an increase of 0.15 – 0.3 m depth above that achieved by low flows in Winter / Spring, to increase vegetation diversity and zonation on the bank, and to cover benches and point bars in the channel.
- Generating shear stresses that are sufficient to erode the margins of the channel (10 – 15 Pa, noting that these shear stresses are sufficient to scour cohesive sediments and gravels) to turn over the stream bed and limit colmation (clogging of gravels).

High flows (Anytime)

As in the regulated reaches, high flows (or 'channel-forming') flows are required to erode the toe of river banks of unregulated reaches. The required shear stresses are typically in the range of 15 – 25 Pa, although they may be higher in the cohesive sediments of Maribyrnong streams. High flows have several functions: (1) the undermining of trees, which subsequently fall into the river to become woody habitat, (2) the scouring of the bed and banks to prevent encroachment by terrestrial vegetation, (3) the inundation of lower parts of the bank to support fringing woody vegetation (4) the entrainment of nutrients and carbon from banks, and (5) the transport of sediment.

Woody habitat is essential for supporting biofilms and macroinvertebrates, which are a critical food source for higher organisms including fish, frogs and mammals.

High flows can technically occur anytime, and in reaches 1-5 would be delivered naturally following large rainfall events. 'Managed' high flows should be avoided in Reach 3 during September – March to avoid disturbance of Growling Grass Frogs during the breeding season, however acknowledging that naturally occurring events cannot be avoided. Similarly, managed high flows should be avoided during September – January to support recruitment of platypus.

The key hydraulic criterion for high flows is:

- Generating channel forming shear stresses (15 – 25 Pa), sufficient to erode the toe of banks and deliver large wood to the channel.

6.2 Upper Deep Creek environmental flow recommendations

Habitat characteristics – Upper Deep Creek (Reach 1)

Reach 1 is a known groundwater dependent ecosystem (Bureau of Meteorology, 2025), with groundwater inflows supporting baseflows and maintaining refuges during dry periods. During extended dry periods, groundwater levels are expected to lower due to evapotranspiration and increased extractive demands, resulting in decreased discharges to Deep Creek.

There are three large and deep habitat pools (> 1.5 m) in the modelled reach, separated by short rock bars (Figure 10). Water Ribbons provide ideal cover for Yarra Pygmy Perch and frogs, and adjacent low-lying shallows provide frog habitat though they also prefer warmer temperatures and limited canopy shading which are absent at this reach. There are also in-stream / stream-adjacent patches of phragmites which are not favoured by frogs hence it is less likely for frogs to reside here. While platypus are still occasionally recorded in Reach 1, it is very unlikely that a sustainable, resident population now exists. Current flow conditions appear unsuitable to support a platypus population (due to extensive cease to flow events).

Deep Creek Upper is a significant habitat for Yarra Pygmy Perch. Deep pools (maintained by groundwater) provide refuge for this species especially during the drought period. As discussed in Site and Issue paper (Alluvium, 2025b), groundwater contributes nearly 100% of the surface flows in Deep Creek in drought and dry periods. To protect Yarra Pygmy Perch in drier years, Melbourne Water undertook emergency watering of these habitat pools back in 2016 and 2019 to ensure there is sufficient water in these habitats. Maintaining the pool water quality, including oxygen concentrations, is therefore critical for these habitats.

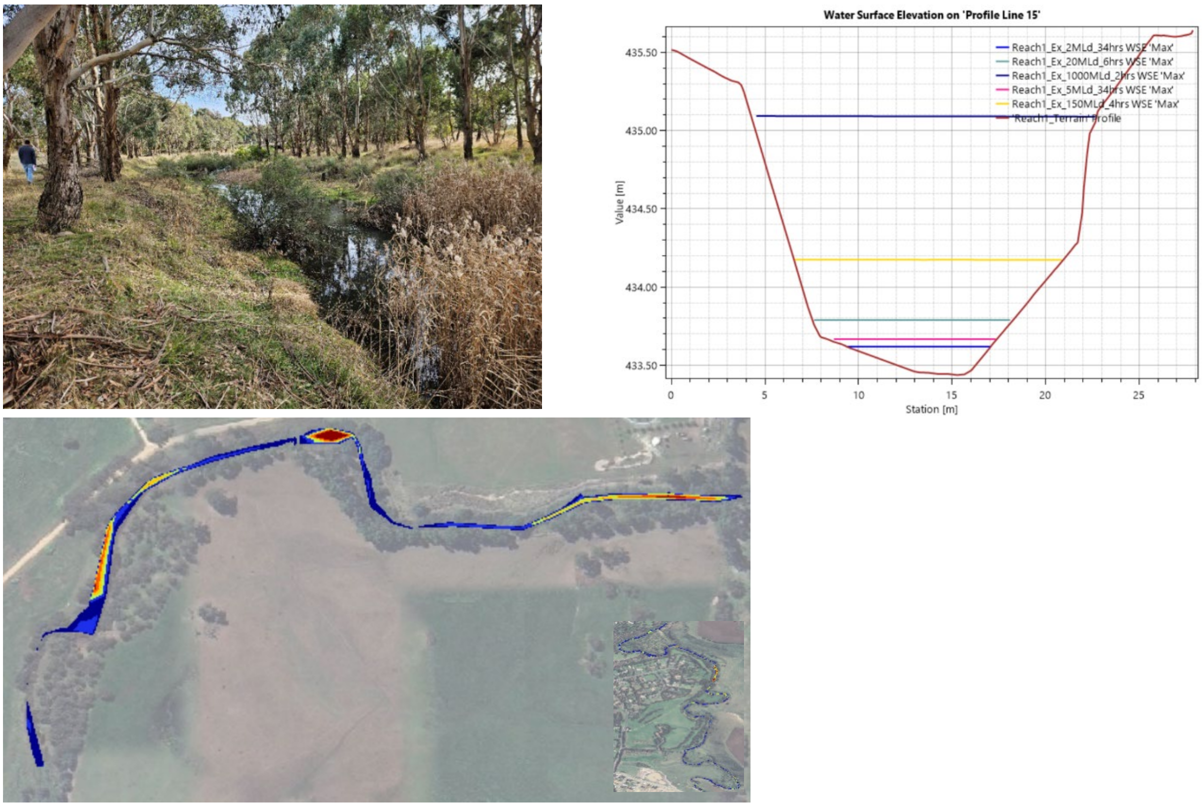


Figure 10. *Top left: Reach 1 site, Top right: typical cross section of Reach 1. Bottom: Screenshot of the maximum channel depth (m) when 2 ML/d is modelled (creek flows downstream from left to right of this image).*

Reach 1 environmental flow recommendations

Yarra Pygmy Perch are a priority value in Reach 1. The **protection of key refugia** is a management priority during dry (cease-to-flow) periods to prevent local extinction of threatened Yarra Pygmy Perch.

Table 8. Environmental flow recommendations for Upper Deep Creek (Reach 1)

Flows	Seasons	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
Base flows	Dec-May	2 ML/d*	Continuous	Continuous	Refugia habitat and water quality for Yarra Pygmy Perch, small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **M3,** V1, V4, V7, **WQ2**
	Jun-Nov	20 ML/d*	Continuous	Continuous	Refugia habitat for Yarra Pygmy Perch and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	Fi1, **V1**, V4, **V7**, WQ2, G1
Freshes	Dec-May	50 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal (adult and juvenile diadromous species), refugia habitat and water quality for small-bodied fish (Yarra Pygmy Perch) and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, Fi3, Fi4, M2, **V2, V3, V5**, WQ1
	Jun - Nov	150 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for Yarra Pygmy Perch and other small-bodied native fish, connectivity and migratory cues (fish), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size	Fi2, **Fi3**, Fi4, M1, M2, **M4, V2, V3, V5**, WQ1, G2
High flows	Anytime	1,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**

^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
*Low flow recommendations should be managed carefully with complementary measures in place. See Section 6.7 for more details.

<u>Notes on climatic variable flow recommendations:</u>
In dry years, the extent and depth of all refuge pools should be maintained, acknowledging that there may be some pools lost at times. Extraction bans and cease-to-pump rules are currently applied at Deep Creek when the gauged flow is less than 0.5 ML/d, to reduce the risk of cease-to-flows impacts on Yarra Pygmy Perch at Reach 1. This will also apply to flows in dry years. Flows may need to be supplemented with groundwater pumping rather than surface water.

In wet years, connectivity becomes a significant focus, supporting the recovery trajectories of environmental values post-drought, and delivering the magnitudes, frequencies and durations of freshes and larger flows. Recovery trajectories can be maximised through the provision of complementary actions, such weed control and fish stocking.

6.3 Deep Creek Mid environmental flow recommendations

Habitat characteristics –Deep Creek Mid (Reach 2)

Reach 2 is a deeply incised channel (2-3 m wide) and relatively simple river channel with no riffles observed. Some pools are observed separately by longer runs (Figure 11). There is a large amount of fallen trees (large wood) in the stream channel with an abundance of leaf litter on the banks. This reach includes stretches of endangered Swampy Riparian Woodland (EVC 83) and Riparian Woodland (EVC 641) along the channel banks, with densely vegetated tall (adult) canopy layers e.g. mature river red gum. Instream large wood offering substrate for biofilms and habitat for macroinvertebrates and fish. Water ribbons (*Cycnogeton procerum*) provide further submerged habitat to support small-bodied fish. It is unlikely that this reach provides favourable habitat conditions for frogs and platypus due to long cease to flow periods and less available off-stream habitat for frogs. While platypus are still occasionally recorded in Reach 2, it is very unlikely that a sustainable, resident population now exists. Current flow conditions appear unsuitable to support a platypus population (due to extensive cease to flow events).

Most of Reach 2 is considered highly likely to be a Groundwater Dependent Ecosystem. Groundwater inflows are likely important in maintaining refuges, particularly during dry times. During extended dry periods, groundwater levels are expected to be lower due to evapotranspiration and increased extractive demands, resulting in decreased discharges to Deep Creek.

Refuge pools are key habitats within this reach, supporting a range of water-dependent biota (fish, macroinvertebrates, submerged and floating vegetation) particularly during dry times.

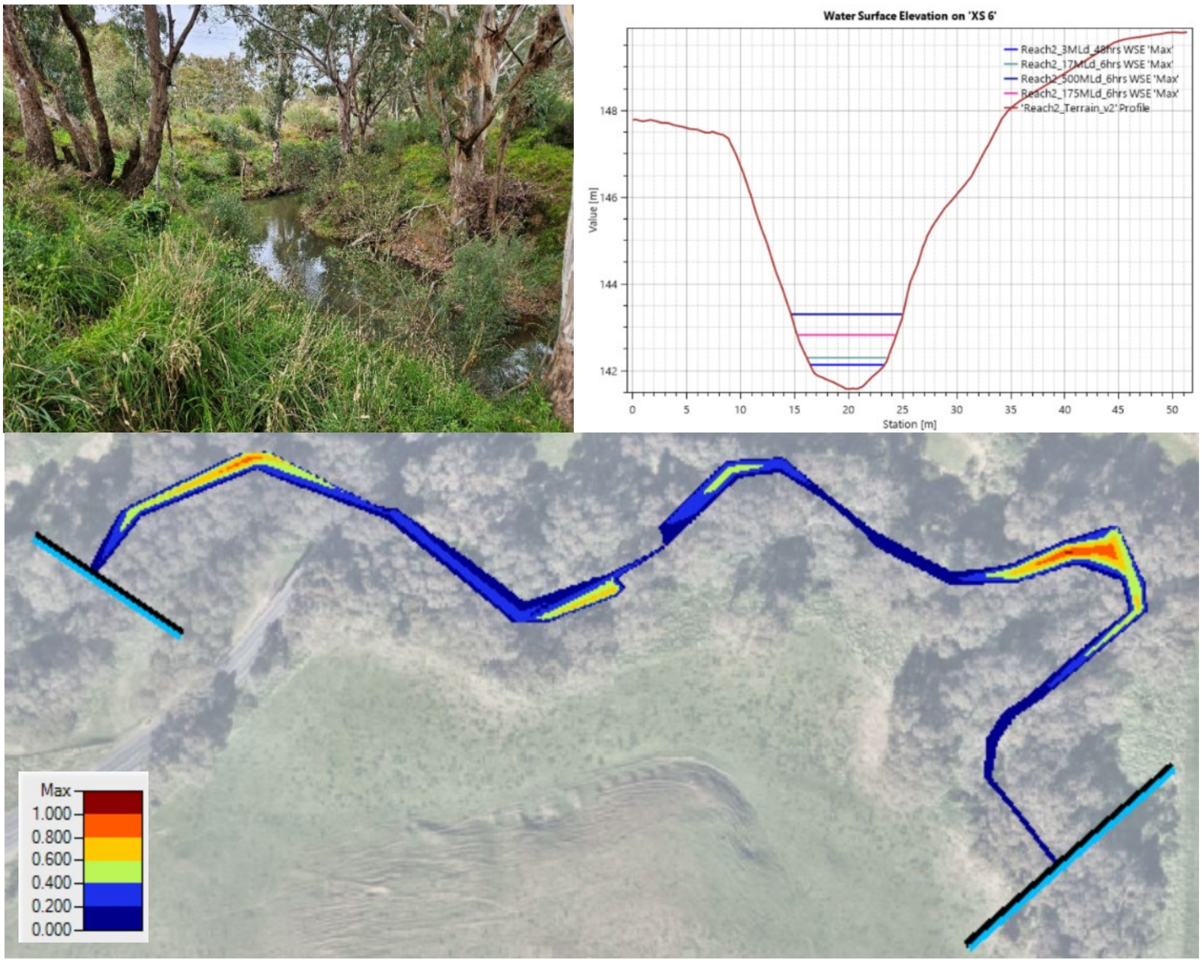


Figure 11. *Top left: Reach 2 site, Top right: typical cross section of Reach 2. Bottom: Screenshot of the maximum channel depth (m) when 3 ML/d is modelled (creek flows downstream from left to right)*

Reach 2 environmental flow recommendations

This reach is not a priority reach for ecological values compared to its upstream reach (Yarra Pygmy Perch in Reach 1) and downstream reach (Platypus in Reach 4), even though there are important values such as small-bodied native fish and vegetation values. Reach 2 delivers flows to Reach 4 where platypus are observed and flows being delivered in Reach 2 should also be met in Reach 4. Given the similarity with the environmental objectives with Reach 1, the flow recommendations were developed to align with Reach 1 flow recommendations, specifically its frequency and duration of flow delivery (Table 9).

Table 9. Environmental flow recommendation for Mid Deep Creek (Reach 2)

Flows	Seasons	Magnitude	Frequency	Duration	Key values and functions supported^	Hydraulic criteria^
Base flows	Dec-May	3 ML/d*	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **M3**, V1, V7, **WQ2**
	Jun-Nov	17 ML/d*	Continuous	Continuous	Refugia habitat for fish and water quality. Maintain wetted areas for vegetation (plant growth for submerged). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	**Fi1**, **V1**, **V7**, **WQ2**, G1
Freshes	Dec-May	17 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, **Fi3**, M2, **V2**, **V3**, **V5**, WQ1
	Jun - Nov	175 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size	Fi2, Fi3, Fr6, **M1**, M2, M4, V2, V3, V5, WQ1, **G2**
High flows		500 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5**, **V6**, **G3**

^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
* Low flow recommendations should be managed carefully with complementary measures in place. See Section 6.7 for more details.

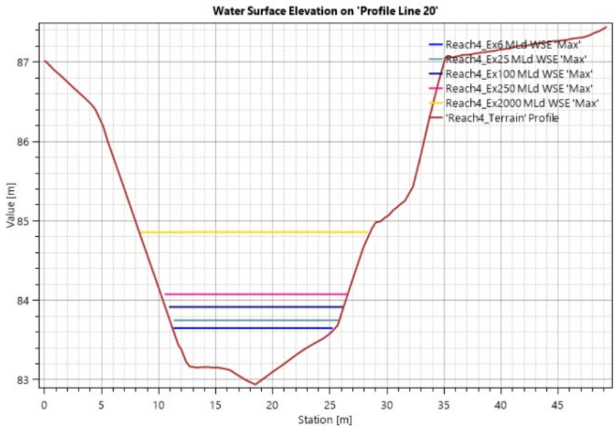
6.4 Deep Creek Lower environmental flow recommendations

Habitat characteristics – Lower Deep Creek (Reach 4)

Deep Creek Lower exhibits a rare section of stream where the bed and banks are granite instead of basalt. The stream channel is diverse with deep permanent pools and riffles. It provides a range of habitats for submerged, emergent plants and aquatic fauna. Some riffle runs with terrestrialisation of bars on stream with *Leptospermum* sp. Vegetation value is high with diverse floodplains of multiple levels and presence of native riparian vegetation (River Red Gum).

Platypuses are still recorded in the lowest sections of Reach 4 as far upstream as Wildwood Rd (likely in low abundance), but extensive cease-to-flow events restrict colonisation beyond this. This reach is also unlikely to support Growling Grass Frog populations nor is designated conservation area under the Melbourne Strategic Assessment (MSA).

Most of Reach 4 is highly likely to be a groundwater dependent ecosystem (GDE). Groundwater inflows are likely important in maintaining refuges, particularly during dry times. During extended dry periods, groundwater levels are expected to lower due to evapotranspiration and increased extractive demands, resulting in decreased discharges to Deep Creek.



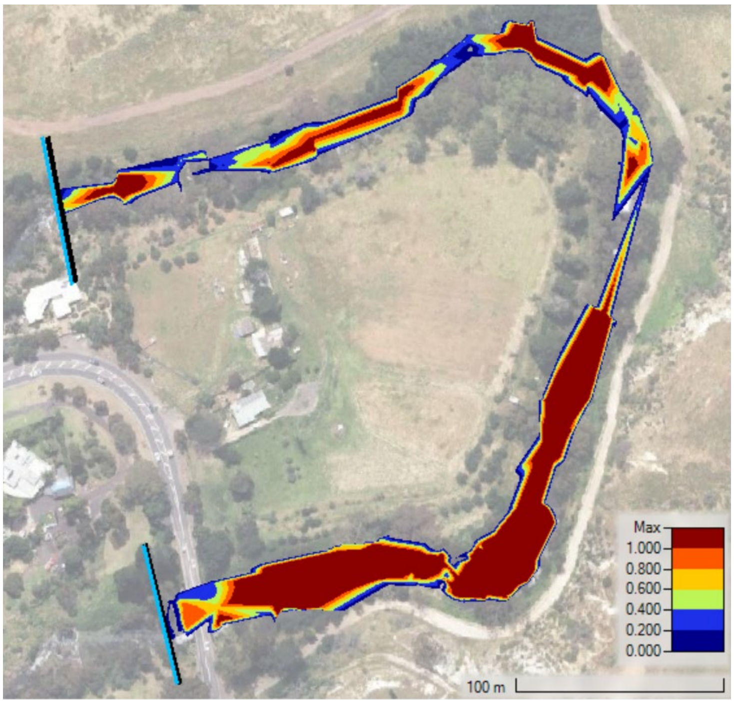


Figure 12. *Top left: Reach 4 site, Top right: typical cross section of Reach 4. Bottom: Screenshot of the maximum channel depth (m) when 6 ML/d is modelled.*

Reach 4 environmental flow recommendations

Vegetation is the priority value in Reach 4 and so is Platypus. Maintaining the condition and extent of water-dependent vegetation, and improving the condition of the reach to strengthen the resilience of Platypus populations are the management priority for this reach.

Table 10. Environmental flow recommendations for Lower Deep Creek (Reach 4)

Flows	Seasons	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
Base flows	Dec-May	6 ML/d*	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation, platypus and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain groundwater (for floodplain vegetation)	**Fi1**, Fr7, **M3**, P1, V1, V7, V8, **WQ2**
	Jun-Nov	25 ML/d*	Continuous	Continuous	Refugia habitat for fish and platypus and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent) and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance) and groundwater (floodplain vegetation)	Fi1, Fr7, P1, **V1**, **V7**, V8, WQ2, G1
Freshes	Dec-May	100 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 3 days AVE: 3 days WET: 5 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, **Fi3**, M2, **V2**, **V3**, **V5**, WQ1
	Jun - Nov	250 ML/d	DRY: 3 AVE: 4 WET: 4	DRY: 6 days AVE: 6 days WET: 7 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates and its resource for platypus), vegetation diversity and vertical zonation for vegetation, flush propagules. Maintain gross channel size	Fi2, Fi3, Fr6, **M1**, M2, M4, **P4**, V2, V3, V5, WQ1, **G2**
High flows	Any	2,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**

^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
* Low flow recommendations should be managed carefully with complementary measures in place. See Section 6.7 for more details.

<u>Notes on climatic variable flow recommendations:</u>
The frequency and duration of Summer / Autumn freshes and Winter / Spring freshes are determined by spells analysis using the modelled natural and current hydrologic data. These were further adjusted by EFTP to consider the environmental objectives and primary functions of the key water dependent values.

In dry years, delivering multiple fresh events through potential stormwater harvesting and other alternative water sources may not be possible. Provision of one fresh event is then to enhance water mixing, prevent stratification and re-oxygenate pool habitat for key environmental values (e.g. Platypus, small-bodied fish). Maintaining minimum connectivity and allowing short periods of disturbance would also be ideal in drier years to connect refuge pools.

In wet years, there are opportunities to deliver more than one fresh event. As Platypus are known to occur at this reach, magnitudes and rates of rise and fall should be carefully considered to avoid increases in flow variability (e.g. from urbanisation) as it would encourage platypus to move across the other reaches (e.g. Jacksons Creek).

6.5 Emu Creek environmental flow recommendations

Habitat characteristics - Emu Creek (Reach 3)

Emu Creek is a degraded incised channel with some presence of pools up to 0.5m deep (Figure 13). The riparian and floodplain zones are heavily degraded with low levels of shrubs and canopy cover and patches of dense Phragmites are present in the stream. The lack of instream aquatic vegetation or a healthy, wide riparian zone and related lack of shading provided by riparian trees does not provide suitable habitat and resource for small-bodied native fish, which are likely to suffer thermal stress and be subject to very high predation pressure.

In contrast, elevated stream temperatures arising from the shallowness of Emu Creek and the distinct lack of shading, combined with elevated water column salinity from weathering of basalts and likely agricultural activities seem to favour Growling Grass Frog despite the apparent absence of other water-dependent values. **Growling Grass Frog** is therefore identified as the key value of Emu Creek, with strong populations persisting in this landscape and records of juveniles were found in recent years.

There is no evidence that Emu Creek ever supported a resident platypus population although occasional dispersing transient individuals are found in the lowest sections when flowing.

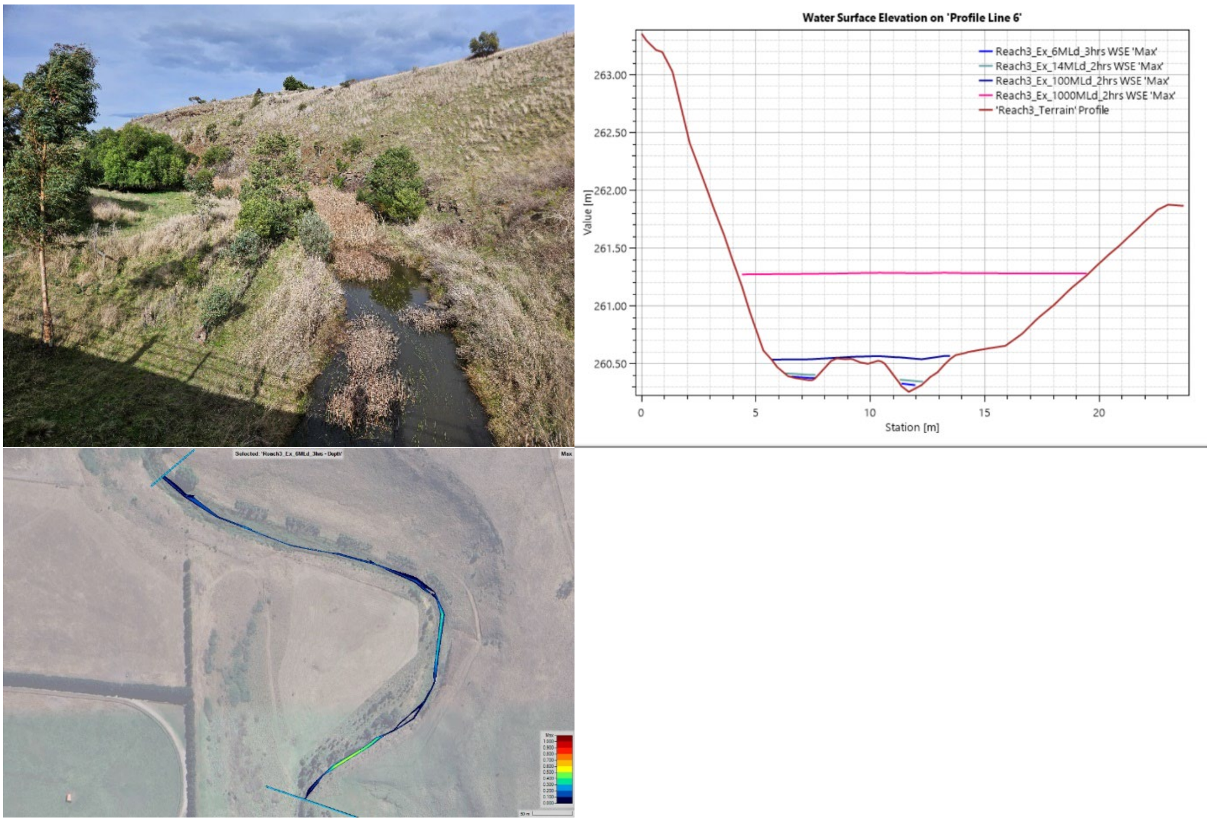


Figure 13. *Top left: Reach 3 site, Top right: typical cross section of Reach 3. Bottom: Screenshot of the maximum channel depth (m) when 6 ML/d is modelled (creek flows downstream from top to bottom).*

Reach 3 environmental flow recommendations

Growling Grass Frog are the priority value in this reach. Growling Grass Frog are dependent upon the maintenance of refuge pools, particularly during the breeding season. Extended cease-to-flow (i.e. 3-5 years) periods with pool drying during the breeding seasons is predicted to cause local extinction of what is considered to be a stronghold population. The provision of pool habitat and stable slow-moving waters is therefore important for Growling Grass Frog, particularly during extended dry periods.

Sudden flashy water flows are undesirable for Growling Grass Frog during the breeding season, however they are expected to tolerate an increase in flows in some years when water levels build up slowly and drop slowly.

Environmental flow recommendations that support the environmental objectives for Emu Creek are described in Table 11.

Table 11. Environmental flow recommendations for Emu Creek (reach 3)

Flows	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
Base flows	Dec-May	6 ML/d*	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates and vegetation	**Fi1**, **Fr4**, **M3**, **V4**, V8, **WQ2**
	Jun-Nov	14 ML/d*	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity and prevention of chytrid fungus for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates, vegetation (emergent and floodplain). Maintain gross channel size (physical disturbance) and groundwater for floodplain vegetation	**Fi1**, **Fr1**, **Fr4**, **Fr7**, M3, **V4**, V7, V8, WQ2, G1
Freshes	Dec-May	14 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 1 day AVE: 3 days WET: 3 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish), Growling Grass Frog breeding, thermoregulation and protection. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal.	Fi2, Fi3, Fr3, **Fr5**, M2, **V3**, **V5**, WQ1
	Jun – Nov	100 ML/d	DRY: 2 AVE: 3 WET: 4	DRY: 4 days AVE: 4 days WET: 4 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish). Breeding, thermoregulation, protection, connectivity and brumation opportunities for Growling Grass Frog. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal. Maintain gross channel size (physical disturbance)	Fi2, Fi3, Fr3, **Fr5**, Fr6, Fr8, M1, M2, M4, **V3**, **V5**, WQ1, G2
High flows	Anytime	1,000 ML/d	2 per 3 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (Growling Grass Frogs)	Fr2, **M5**, V5, **V6**, **G3**

^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
* Low flow recommendations should be managed carefully with complementary measures in place. See Section 6.7 for more details.

<u>Notes on climatic variable flow recommendations:</u>

The frequency and duration of Summer / Autumn freshes and Winter / Spring freshes are determined by spells analysis using the modelled natural and current hydrologic data. These were further adjusted by EFTP to consider the environmental objectives and primary functions of the key water dependent values.

In dry years, delivering multiple fresh events may not be possible. Provision of one fresh event is then to enhance water mixing, prevent stratification and re-oxygenate pool habitat for key environmental values (e.g. Growling Grass Frogs). Growling Grass Frog prefer deep pools to prevent tadpoles from drying out. In high temperature days, Growling Grass Frog need deeper and cooler water to thermoregulate and escape very hot water. A 0.5 m pool habitat with stagnate water could pose a high risk for Growling Grass Frogs, however if there is sufficient velocity (> 0.1 m/s) this will help to oxygenate the pool water and reduce the risk.

In wet years, there are opportunities to deliver more than one fresh event. As Growling Grass Frogs prefer stable and slow-moving waters, sudden flashy flows with abnormally sharp rise and falls in water levels should be avoided.

6.6 Riddells Creek environmental flow recommendations

Habitat characteristics - Riddells Creek (Reach 5)

Riddells Creek has physical diversity and structure, with sequences of runs, riffles and pools (albeit not very deep) all present in the reach. Fringing backwaters provide habitat for frogs and other biota that prefer slower moving water, while rock ledges and bars provide features for submergence by freshes and higher flows. Complex surfaces adjacent to Riddells Creek (benches, floodplain and terraces) make ‘bankfull’ flows difficult to define. The reach 5 site visited by the EFTP was degraded from a vegetation perspective, however diverse remnant native vegetation was noted e.g. presence of River Red Gum, Woolly Tea-tree, Prickly Moses, *Bursaria sp*. and *Ranunculus sp.*

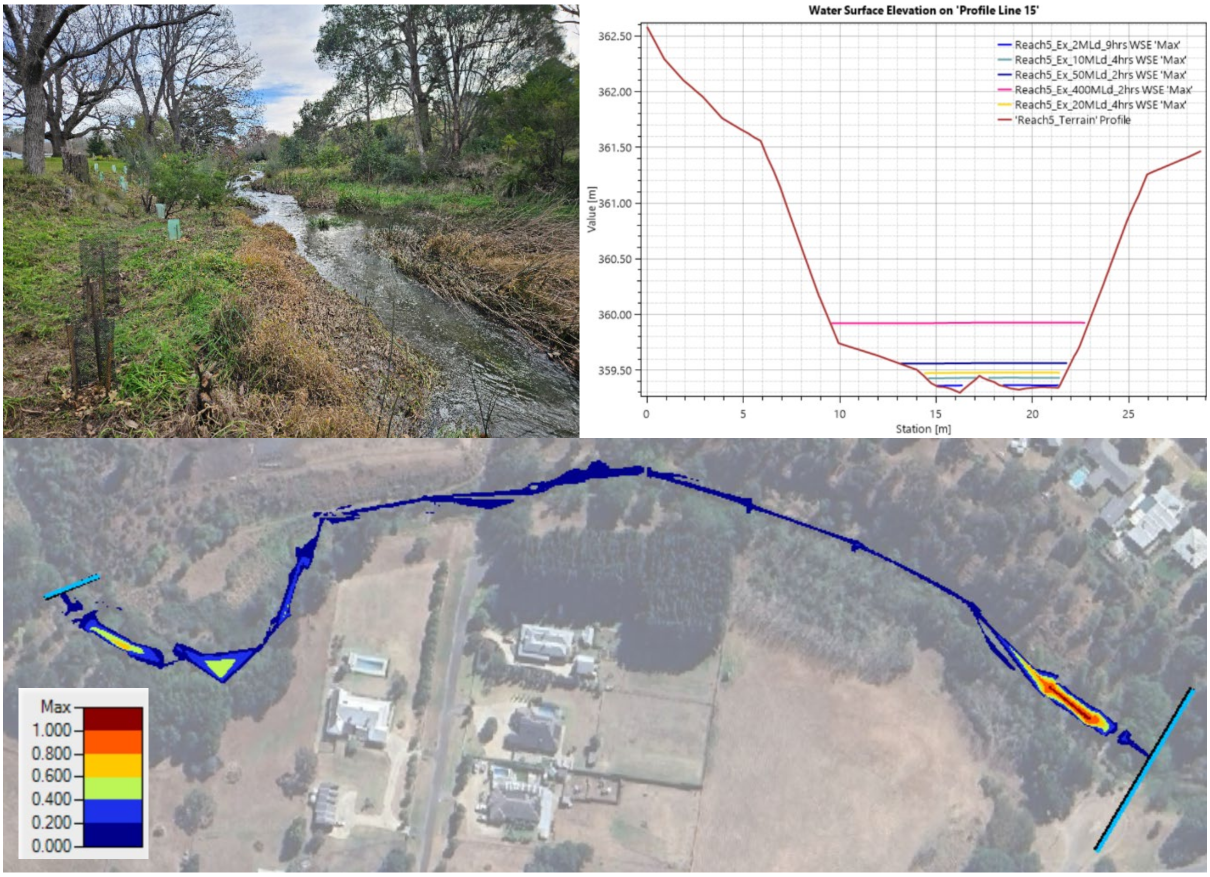


Figure 14. *Top left: Reach 5 site, Top right: typical cross section of Reach 5. Bottom: Screenshot of the maximum channel depth (m) when 2 ML/d is modelled. Flow is from left to right.*

Reach 5 environmental flow recommendations

Reach 5 was noted to have a diversity of aquatic habitats for plants and animals. As such, the priority values for Reach 5 is flow-dependent vegetation and macroinvertebrates, and maintaining this flow-dependent vegetation (aquatic vascular plants, fringing non-woody emergent plants, riparian shrubs and tree) are management priority for this reach.

Table 12. Flow recommendations for Riddells Creek (Reach 5)

Flows	Season	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria^
Base flows	Dec-May	2 ML/d*	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1, Fr7**, M3, V1, V4, V7, WQ2
	Jun-Nov	10 ML/d*	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	Fi1, Fr7, **V1**, **V4**, **V7**, WQ2, G1
Freshes	Dec - May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 2 days WET: 4 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal	Fi2, **Fi3**, M2, **V3**, **V5**, WQ1
	Jun - Nov	50 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 4 days AVE: 4 days WET: 5 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal. Maintain gross channel size (physical disturbance). Connectivity for frogs	Fi2, **Fi3**, **Fr6**, M1, M2, **M4**, **V3**, **V5**, WQ1, G2
High flows	Anytime	400 ML/d	1 per 2 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5**, **V6**, **G3**

^Design / controlling hydraulic criteria when deriving the flow magnitude is highlighted in bold.
* Low flow recommendations should be managed carefully with complementary measures in place. See Section 6.7 for more details.

6.7 Other flow and complementary management for the unregulated reaches

In the unregulated reaches of the Maribyrnong system, in general terms the best use of environmental water is for the protection of refuges, particularly during summer / autumn. The protection does not have to occur via surface flows. Indeed, in reaches where pools are primarily groundwater fed (e.g. Deep Creek reaches 1 and 2), pools would benefit from being maintained through a local groundwater pumping regime (pool top-ups with freshwater may have unintended impacts on pool salinity and temperatures which are naturally higher due to groundwater inputs). A refuge pool-based water balance model would enable managers to understand pool gains / losses, and the volumes of water that would be required to top up key pools during dry years.

Managing cease-to-flow events and low flows

It is acknowledged that cease-to-flow events occur in these unregulated systems and the events are expected to become more frequent and prolonged in the future (Alluvium, 2025; Chee et al., 2025). Cease-to-flow events can increase water temperature, inhibit mixing within the water column, and reduce dissolved oxygen concentrations due to the loss of turbulence. Low dissolved oxygen concentrations can lead to anaerobic conditions at the stream bed, which are conducive to the release of phosphorus from sediment particles. Stagnant, nutrient-rich water substantially increases the likelihood of algal blooms and instream macrophyte infestations. Blooms of algae and submerged macrophytes can exacerbate the impacts of oxygen loss, leading to hyperoxic conditions during the daytime (photosynthetic period) and hypoxic/anoxic conditions overnight when the algae/macrophytes consume oxygen through respiration. This can lead to high stress and potentially the death of obligate aquatic fauna.

Low flows are likely to be reduced due to urbanisation and decreased groundwater accessions (Burns et al., 2012). The low flow recommendations are proposed based on the habitat characteristics of the river reaches, acknowledging that there will be variability in river flows throughout the year. In unregulated river reaches where reduced low flow and increased cease-to-flow events are expected to occur under climate change, achieving compliance with low flow recommendations can be challenging if the natural flow variability is not considered. Previously in FLOWS studies, EFTPs have recommended an 'or natural' clause to flow recommendations to address this compliance concern. However, including an 'or natural' clause presents implementation challenges as it does not alert environmental water managers to early indicators of potential ecological stress (through reduced compliance) due to the impacts of climate change (Szabo et al. 2024).

Rather than recommending a cease-to-flow or an 'or natural' clause, it is more important to manage the system through complementary measures. Increasing low flows, enhancing shade to protect water quality in pools, and maintaining pool depth are critical to the persistence of refuge pools during cease-to-flow periods. Complementary measures, such as managing water extraction and pumping rules and mitigating the impacts of urbanisation, are also essential for protecting the condition of the waterways.

Managing delivery of freshes in drier years

A multi-year approach may be taken in the delivery of freshes during drought and dry years, if the recommended freshes cannot be delivered with the recommended frequency. For example, if freshes cannot all be delivered in a given year to support the migratory requirements of a given species, freshes in the following year should be tailored for the species. i.e. if a fresh targeting downstream migration of short-finned eels cannot be provided in one year, an eel-specific fresh should be prioritised in the following year. Dispersal between pools should still be supported every year regardless of the species.

Managing take from unregulated waterways

Under future climate projections, Deep Creek will experience increased cease-to-flow periods and decreases in the lower flow range (Alluvium, 2025). The achievement of low flows and freshes recommendations is expected to decrease. In Emu Creek a general reduction in flow volumes throughout the year is predicted (Alluvium, 2025). A general reduction in flows will impact species that are dependent on the current flow regime and it will reduce the extent and condition of habitat, connectivity and productivity in the reach. Riddells Creek currently ceases to flow in summer / autumn periods and under high climate change it is predicted to experience an increase in dry spell incidence and duration in summer / autumn.

Extraction bans and cease-to-pump rules are currently applied at Deep Creek when the gauged flow is less than 0.5 ML/d. However, there are no cease-to-pump rules for Emu Creek and Riddells Creek. Given that cease-to-flow events do occur in these waterways, it is recommended undertaking a review of the pumping bans for these waterways to ensure waterway values and conditions are protected.

Groundwater management

Maintaining groundwater flow to stream refuges is important, however managing or protecting this flow has few management options to implement. One of the ways to protect stream refuges (fed by groundwater) is to ensure that any new groundwater licenses approval process adhere strictly to the Ministerial Guidelines for Protection of Groundwater Dependent Ecosystems (DEECA, 2015). This guideline was developed to protect high value groundwater dependent ecosystems by ensuring there is responsible take and use of groundwater for new groundwater licenses. For existing groundwater licenses, there are no formal agreement that could guarantee groundwater set aside for the environment (by pumping to stream refuge). With regards to the impact of urbanisation changing recharge rates and therefore groundwater flow to stream refuges, the management option available resides around the consideration of managed artificial recharge to aquifers (sourced from urban storm water) to increase groundwater levels and to maintain groundwater flow to those high value stream refuges.

Growling Grass Frog habitat management

Provision of terrestrial habitats and off-stream (artificial) waterbodies will support Growling Grass Frog populations in Emu Creek (Reach 3). For artificial waterbodies it is important to construct these habitats in line with the Melbourne Strategic Assessment Growling Grass Frog habitat design standards (Jacobs, 2021), where it considers the habitat and watering requirements of Growling Grass Frog for optimal outcome. It should be noted that watering of off-stream waterbodies will not be achieved through the delivery of the recommended flow regime.

Reducing the impacts of urbanisation (stormwater flow management)

Additional management objectives include the prevention of degradation of flows (impacts to magnitudes, rates of rise and fall, water quality) due to urbanisation. Excessive flow variability, exceedance of rates of rise and fall, and magnitudes that exceed scouring thresholds displace macroinvertebrates are all more likely with stormwater runoff, and expected to have a major negative impact on Platypus and Growling Grass Frog populations especially in Emu Creek and Deep Creek. Protecting the flow regime from stormwater risks is therefore necessary in protecting these values. One of the solutions to reduce stormwater impact is to install Water Sensitive Urban Design (WSUD) assets in the development catchments by mimicking the flow regime as closely as possible.

In river reaches where cease-to-flow events are expected to increase in frequency, extent and location, the impact on instream macroinvertebrate biota will intensify due to more frequent harmful events and a greater number of stressed refuges. Increased water temperatures, nutrient concentrations, and extreme fluctuations in dissolved oxygen will likely result in the loss of less tolerant species, indicative of healthy waterway conditions. This will lead to a depauperate suite of pollution/stress-tolerant fauna, including Chironomidae (midges) and Culicidae (mosquitoes).

To mitigate these effects, incorporating Water Sensitive Urban Design (WSUD) in new urban and industrial developments within the catchment is recommended (Newall and Walsh, 2005). WSUD will reduce stormwater runoff from impervious surfaces and enhance groundwater infiltration. Capturing and treating stormwater runoff at end-of-system wetlands before discharge to receiving river reaches, along with enforcing waterway protection during development, are essential to protect water quality in these river reaches.

Stormwater can also provide a valuable alternative water source for local communities. It is anticipated that the alternative supply will be used to fulfil some consumptive needs, freeing up river water for the environment. The use of these alternative supplies is critical to reducing demands on the system and limiting the duration of cease to flow periods in summer that are detrimental to a number of environmental values, in particular Platypus.

7 Review of recommendations - Reach 8 Maribyrnong River

As part of this study, the existing environmental flow recommendations were also examined to determine the extent to which they align with the flows recommended in the upper reaches. Although setting new recommendations for Reach 8 was not within the scope of this study, the existing environmental objectives and recommendations have been reviewed in consideration of their alignment with upstream recommendations.

The existing recommendations for Reach 8 are provided in Table 13. These recommendations were updated in 2015 to include functions to meet platypus objectives. The Reach 8 environmental objectives align with those revised and updated in this study. In addition, it is noted:

Objectives	The objectives from the 2016 study were updated to include platypus, but did not include the consideration of frogs (Alluvium, 2016). Based on the review of data, it is not expected that Growling Grass Frogs would be present in Reach 8.
Timing	The flow seasons for low (December to May) and high (June to November) align with the upper reaches
Summer / Autumn low flows	The existing Reach 8 Summer / Autumn low flow recommendation of 30 ML/day is unlikely to be achieved with a combination of low flow recommendation of 8 ML/day in Lower Jacksons Creek Reach 7, and 6 ML/d in Lower Deep Creek Reach 4.
Summer / Autumn fresh	The existing Reach 8 Summer / Autumn fresh recommendation of 100 ML/day (5 per season, 4 days duration) is likely to be achieved with a maximum Summer / Autumn fresh recommendation of 40 ML/day in Reach 7 delivered once per season, if timing coincides with the Summer / Autumn fresh (100 ML/d) in lower Deep Creek Reach 4. The 50 ML/d alternative flow recommendation is more likely to be achieved with delivery of a Summer / Autumn fresh to Reach 7 and also from Reach 4.
Winter / Spring low flow	The existing Reach 8 Winter / Spring low flow recommendation of 100 ML/day (continuous) may be unachievable with a maximum Winter / Spring low flow recommendation of 40 ML/day in lower Jacksons Creek each 7, and Winter / Spring low flow of 25 ML/d in lower Deep Creek Reach 4. The 40 ML/day maximum in Jacksons Creek is governed by maximum flow recommendations for Reach 7. The 50 ML/d alternative flow recommendation is more likely to be achieved.
Winter / Spring fresh	The existing Reach 8 Winter / Spring fresh recommendation of 800 ML/day (3 per season, 3 days duration) may be achieved if the revised Winter / Spring fresh recommendation of 400 ML/day in Reach 7 coincides with the timing of a Winter / Spring fresh event in lower Deep Creek (250 ML/d, 4 / season, 7 day duration).
High flows	The existing Reach 8 high flow recommendation of 1000 ML/day (1 event per year, 1 day duration) is exceeded by the revised Winter / Spring fresh recommendation of 2,000 ML/day in Reach 7, although the Reach 7 high flows are to occur in 3 in every 4 years, rather than every year. The high flow recommendation in lower Deep Creek Reach 4 (2,000ML/d, 1 per year, 1-2 day duration) will also exceed the Reach 8 high flow recommendation.

Table 13. Existing environmental flow recommendations for Reach 8, Maribyrnong River with revised environmental objectives

Flow Component	Magnitude	Timing	Frequency	Duration	Objectives (updated 2025)	Function
Summer / Autumn low Flow	30 ML/d	Dec – May	Continuous	Continuous	Maintain self-sustaining populations of macroinvertebrates (Habitat availability (pool / run), LWD inundation) Provide suitable conditions to maintain or restore instream vegetation abundance, diversity and structure (Instream vegetation inundation) Provide consistent baseflows to maintain resident platypus in the upper reaches.	Depth greater than 0.1m over run to provide habitat for macroinvertebrates and platypus
Summer / Autumn freshes	100 ML/d Or 50 ML/d	Dec – May	5 / period (or natural)	4 days (or natural)	Maintain self-sustaining populations of small bodied fish (maintaining fish passage – reach 8) Maintain water quality to ensure all environmental flow objectives are met (flushing of pools) Provide suitable conditions to maintain channel morphology and Maintain sediment accession onto the floodplain (Substrate scour to remove accumulations of fine sediment) Provide suitable conditions to maintain or restore instream vegetation abundance, diversity and structure (Instream vegetation disturbance)	Shallowest point over riffle > 0.12 m or 0.2 m to provide local movement of small-bodies native fish species and platypus during the summer / autumn period.
Winter / Spring flow	100 ML/d Or 50 ML/d (or natural)	Jun – Nov	Continuous	Continuous	Maintain self-sustaining populations of small bodied fish (Regional scale migration) Provide suitable conditions to maintain channel morphology, Maintain sediment accession onto the floodplain (disturbance, scour biofilms), prevent vegetation encroachment in channel and watering of canopy tree root zone	Depth over the shallowest point between pools > 0.12 m or 0.2 m providing fish passage throughout the entire Winter / Spring period (Jun – Nov).
Winter / Spring fresh	800 ML/d	Jun – Nov	3/ period (or natural)	3 days (or natural)	Maintain self-sustaining populations of macroinvertebrates (LWD inundation, entrain terrestrial carbon / woody debris on benches, disturb habitat) Maintain self-sustaining populations of small bodied fish and Maintain fish passage (spawning trigger) Provide suitable conditions to maintain or restore instream vegetation abundance, diversity and structure (Riparian habitat inundation, disturbance and watering of canopy tree root zone)	Inundation of benches and root zone to enhance the health of large canopy trees.
Bankfull flow	1000 ML/d	Any (exclude October –March period where possible)	1/ year (or natural)	2 days (or natural)	Provide suitable conditions to maintain channel morphology and maintain sediment accession onto the floodplain (disturbance and deposition of sediment) Provide suitable conditions to maintain or restore instream vegetation abundance, diversity and structure (Riparian habitat disturbance, Stimulate regeneration of seed) Prevent inundation of maternal platypus burrows and potential displacement/drowning of dependent nestlings during breeding season (Oct to Mar).	Inundation of the internal floodplain unit to maintain channel form and provide suitable regeneration conditions for endangered EVC – Floodplain Riparian Woodland.

8 Summary of flow recommendations

Below is a summary of all flow recommendations outlined in this report. Note: Some of these flow recommendations requires careful consideration as explained in Section 5 and 6.

Table 14. All updated environmental flow recommendations for the Maribyrnong Catchment

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
JACKSONS CREEK							
Low flows	6	Dec-May	4 ML/d	Continuous	Continuous	Refugia habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates, vegetation, and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, Fr7, **M3**, **P1**, V1, V4, V7, **WQ2,**
		Jun-Nov	20 ML/d	Continuous	Continuous	Refugia and maintain wetted areas for vegetation, fish and frogs. Plant growth and reproduction for submerged, floating-leaved vegetation and emergent vegetation. Reduce thermal stratification and maintaining gross channel size.	**Fi1**, Fr7, **P1**, V1, V4, V7, **WQ2**, G1
	7	Dec-May	8 ML/d	Continuous	Continuous	Refugia habitat, water quality for platypus, Growling Grass Frog (shallow stream margin and deep pools), small-bodied native fish and diadromous species and macroinvertebrates. Provide longitudinal connectivity for platypus. Plant growth and reproduction for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **Fr1**, **Fr4**, **Fr7**, M3, **P1**, **P3**, **V1**, **V4**, V7, WQ2
		Jun-Nov	40 ML/d	Continuous	Continuous	Refugia and provide longitudinal connectivity for Platypus, Growling Grass Frogs, vegetation and fish. Promote plant growth for submerged and emergent vegetation. Maintain gross channel size	Fi1, Fr1, Fr4, Fr7, P1, P3, **V1,** V4, V7, WQ2, G1
Freshes	6	Dec – May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Connectivity of habitat and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat condition for macroinvertebrates, vegetation diversity and vertical zonation (submerged, emergent, fringing). Water quality in pools and transport of silts, salts and nutrients	**Fi2**, **Fi3**, **M2,** V2, V3, V5, WQ1

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
		Jun – Nov	215 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools	Fi2, Fi3, **Fr6**, M1, M2, M4, **V2**, **V3**, **V5**, WQ1
		Jun – Nov	350 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat complexity for macroinvertebrates (which as resource for platypus, and also inundate vegetation), plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools and transport of silts, salts and nutrients	Fi2, Fi3, Fr6, **M1**, M2, M4, V2, V3, V5, WQ1, **P4, G2**
	7	Dec – May	40 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Migration of juvenile and adult diadromous species. Connectivity of habitat (Platypus, Growling Grass Frog and fish) and propagule dispersal. Habitat for macroinvertebrates (resource for platypus), vegetation diversity and vertical zonation (submerged, emergent, fringing) and to support tadpole and frog (thermoregulation and breeding opportunity). Water quality in pools and transport of silts, salts and nutrients	Fi2, **Fi3,** Fr3, **Fr5**, M2, P2, **V2, V3**, **V5**, WQ1
	7	Jun – Nov	400 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Longitudinal connectivity, breeding and recruitment, brumation cues (Growling Grass Frog). Maintaining geomorphic conditions (habitat complexity for macroinvertebrates), habitat for macroinvertebrates (resource for platypus), plant growth and propagule dispersal, vertical zonation	Fi2, Fi3, Fr3, Fr5, Fr6, Fr8, **M1**, M2, M4, **P2,** V2, V3, V5, WQ1, **G2**
High flows	6	Anytime	1,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent and fringing woody vegetation	**M5, V6, G3**
High flows	7	Anytime	2,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (frogs)	Fr2, **M5, V6, G3**

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
DEEP CREEK							
Low flows	1	Dec-May	2 ML/d	Continuous	Continuous	Refugia habitat and water quality for Yarra Pygmy Perch, small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **M3,** V1, V4, V7, **WQ2**
	2		3 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **M3**, V1, V7, **WQ2**
	4		6 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation, platypus and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain groundwater (for floodplain vegetation)	**Fi1**, Fr7, **M3**, P1, V1, V7, V8, **WQ2**
	1	Jun-Nov	20 ML/d	Continuous	Continuous	Refugia habitat for Yarra Pygmy Perch and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	Fi1, **V1**, V4, **V7**, WQ2, G1
	2		17 ML/d	Continuous	Continuous	Refugia habitat for fish and water quality. Maintain wetted areas for vegetation (plant growth for submerged). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	**Fi1**, **V1**, **V7**, **WQ2**, G1
	4		25 ML/d	Continuous	Continuous	Refugia habitat for fish and platypus and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent) and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance) and groundwater (floodplain vegetation)	Fi1, Fr7, P1, **V1**, **V7**, V8, WQ2, G1
Freshes	1	Dec- May	50 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal (adult and juvenile diadromous species), refugia habitat and water quality for small-bodied fish (Yarra Pygmy Perch) and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, Fi3, Fi4, M2, **V2**, **V3**, **V5**, WQ1

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
	2	Jun - Nov	17 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, **Fi3**, M2, **V2, V3, V5**, WQ1
	4		100 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 3 days AVE: 3 days WET: 5 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.	Fi2, **Fi3**, M2, **V2, V3, V5**, WQ1
	1		150 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for Yarra Pygmy Perch and other small-bodied native fish, connectivity and migratory cues (fish), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size	Fi2, **Fi3**, Fi4, M1, M2, **M4, V2, V3, V5**, WQ1, G2
	2		175 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size	Fi2, Fi3, Fr6, **M1**, M2, M4, V2, V3, V5, WQ1, **G2**
	4		250 ML/d	DRY: 3 AVE: 4 WET: 4	DRY: 6 days AVE: 6 days WET: 7 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates and its resource for platypus), vegetation diversity and vertical zonation for vegetation, flush propagules. Maintain gross channel size	Fi2, Fi3, Fr6, **M1**, M2, M4, **P4**, V2, V3, V5, WQ1, **G2**
High flows	1	Anytime	1,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**
	2		500 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**
	4		2,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
EMU CREEK							
Low flows	3	Dec-May	6 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates and vegetation	**Fi1**, **Fr4**, **M3**, **V4**, V8, **WQ2**
Low flows	3	Jun-Nov	14 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity and prevention of chytrid fungus for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates, vegetation (emergent and floodplain). Maintain gross channel size (physical disturbance) and groundwater for floodplain vegetation	**Fi1**, **Fr1**, **Fr4**, **Fr7**, M3, **V4**, V7, V8, WQ2, G1
Freshes	3	Dec-May	14 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 1 day AVE: 3 days WET: 3 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish), Growling Grass Frog breeding, thermoregulation and protection. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal.	Fi2, Fi3, Fr3, **Fr5**, M2, **V3**, **V5**, WQ1
Freshes	3	Jun – Nov	100 ML/d	DRY: 2 AVE: 3 WET: 4	DRY: 4 days AVE: 4 days WET: 4 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish). Breeding, thermoregulation, protection, connectivity and brumation opportunities for Growling Grass Frog. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal. Maintain gross channel size (physical disturbance)	Fi2, Fi3, Fr3, **Fr5**, Fr6, Fr8, M1, M2, M4, **V3**, **V5**, WQ1, G2
High flows	3	Anytime	1,000 ML/d	2 per 3 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (Growling Grass Frogs)	Fr2, **M5**, V5, **V6**, **G3**
RIDDELLS CREEK							
Low flows	5	Dec-May	2 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat	**Fi1**, **Fr7**, M3, V1, V4, V7, WQ2
Low flows	5	Jun-Nov	10 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)	Fi1, Fr7, **V1**, **V4**, **V7**, WQ2, G1

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported	Hydraulic criteria
Freshes		Dec - May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 2 days WET: 4 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal	Fi2, **Fi3**, M2, **V3**, **V5**, WQ1
		Jun - Nov	50 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 4 days AVE: 4 days WET: 5 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal. Maintain gross channel size (physical disturbance). Connectivity for frogs	Fi2, **Fi3**, **Fr6**, M1, M2, **M4**, **V3**, **V5**, WQ1, G2
High flows		Anytime	400 ML/d	1 per 2 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation	**M5, V6, G3**

9 References

ACHRIS 2024. Aboriginal Cultural Heritage Register and Information System. Available at: https://achris.vic.gov.au/#/dashboard

Allmanová, Z., Vlčková, M., Jankovský, M., Allman, M., & Merganič, J. (2021). How can stream bank erosion be predicted on small water courses? Verification of BANCS model on the Kubrica watershed. *International Journal of Sediment Research*, *36*(3), 419-429.

Alluvium (2016) Maribyrnong River Updated Flow Recommendations, Alluvium Consulting.

Alluvium (2025). Risk and Vulnerability Assessment. Memo prepared by Alluvium Consulting Australia for Melbourne Water as part of the Maribyrnong FLOWS study.

Alluvium (2025b). Maribyrnong FLOWS study site and issues paper, report prepared by Alluvium Consulting Australia for the Melbourne Water, Victoria

Bond, N., Crook, D., Hughes, J., Stewardson, M. (2008). Hydrologic variability, refugia, and population viability. eWater Cooperative Research Centre.

Brauer, C. J., Unmack, P. J., Hammer, M. P., Adams, M. and Beheregaray, L. B. (2013). Catchment-scale conservation units identified for the threatened Yarra Pygmy Perch (Nannoperca obscura) in highly modified river systems. 3. *PloS one* 8: e8295.

Brock, M.A. & Casanova, M.T. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. In *Frontiers in Ecology: Building the Links*. Edited by Klomp N & Lunt I. 181−192.

Brunner, Gary. W. (2016). HEC-RAS, River Analysis System Hydraulic Reference Manual.

Bureau of Meteorology (2025). Groundwater Dependent Ecosystem Atlas. Accessed 20th February 2025: http://www.bom.gov.au/water/groundwater/gde/

Cartwright and Gilfedder (2015). Mapping and quantifying groundwater inflows to Deep Creek (Maribyrnong catchment, SE Australia) using 222Rn, implications for protecting groundwater-dependant ecosystems. Applied Geochemistry, 52,118-129

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

Chee *et al*. (2023). Re-running Habitat Suitability Models with Updated Climate-impacted Projections and Other Scenarios of Interest. Version 1.2.

DEECA (2015). Release of Ministerial Guidelines for Protection of Groundwater Dependent Ecosystems. Accessed 4th March 2025: https://www.waterregister.vic.gov.au/about/news/185-release-of-ministerial-guidelines-for-protection-of-groundwater-dependent-ecosystems

DEECA (2023). Lancefield GMA Groundwater Report, accessed 1st May 2025: https://accounts.water.vic.gov.au/2023/local-water-reports/groundwater-by-area/lancefield-gma/#entitlements-and-use

DEECA (2023b). Bioregions and EVC benchmarks. State Government of Victoria. https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks

DELWP (2017). Growling Grass Frog Masterplan for Melbourne's Growth Corridors. Melbourne Strategic Assessment. The State of Victoria Department of Environment, Land, Water and Planning.

DELWP (2020). Long-Term Water Resource Assessment for Southern Victoria. Basin-by-Basin Results. The State of Victoria Department of Environment, Land, Water and Planning.

DELWP (2022a). Central and Gippsland Region Sustainable Water Strategy. Final Strategy. The State of Victoria Department of Environment, Land, Water and Planning.

DELWP (2022b). Water is Life – Traditional Owner Access to Water Roadmap. Department of Environment, Land Water and Planning. State Government of Victoria. Parts A and B are available at: https://www.water.vic.gov.au/our-programs/aboriginal-water-program/water-is-life-roadmap

DEPI (2013). FLOWS – a method for determining environmental water requirements in Victoria Edition 2. Report prepared by Sinclair Knight Merz, Peter Cottingham and Associates, DoDo Environmental and Griffith University for the Department of Environment and Primary Industries, Melbourne.

GHD (2012). Report for recharge and GDE Risk mapping. Final report for Melbourne Water, June 2012. Victoria.

eMelbourne (2008). Maribyrnong River. Accessed 27th February 2025: https://www.emelbourne.net.au/biogs/EM00900b.htm

Greet, J., McKendrick, S. A., Russell, K., Gower, T., Vietz, G., & Webb, J. A. (2024). Environmental flows drive sediment and seed supply in regulated rivers. *Earth Surface Processes and Landforms*, *49*(15), 4945-4955.

Griffiths J., Maino J. & Weeks A. (2019) Identifying key flow variables and quantifying their impact on platypus populations (Report to Melbourne Water). Cesar, Parkville, VIC.

Griffiths J., Tingley R. & Weeks A. (2024) Quantifying key habitat variables for platypuses to prioritise management actions in the lower Yarra River Catchment (Report for Melbourne Water). EnviroDNA, Brunswick, VIC.

Hammer, M. (2002). The South East fish inventory: distribution and conservation of freshwater fishes of south east South Australia. Native Fish Australia (SA) Inc., Adelaide.

HARC (2022). Development of the Maribyrnong Source Model: Maribyrnong Source Model Development Report. Report prepared for Department of Environment, Land, Water and Planning.

Heard, G. W., Scroggie, M. P., Ramsey, D. S., Clemann, N., Hodgson, J. A., & Thomas, C. D. (2018). Can habitat management mitigate disease impacts on threatened amphibians?. *Conservation Letters*, *11*(2), e12375.Jacobs (2013). Optimising environmental water delivery to Jacksons Creek - water quality assessment**.** Report prepared for Melbourne Water.

Jacobs (2021). Melbourne Water Growling Grass Frog Masterplan Program – water regime requirements and operational guidance for Growling Grass Frog Masterplan Program Habitat Wetlands. Final V4. Report prepared for Melbourne Water.

Jones, M. (2008). Threats, distribution and abundance of Yarra Pygmy Perch in Victoria during a drought period. Technical Report Series No. 184. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria

Jowett, L.G.; Elliot, M.A. (2009). Erosion Parameters for Cohesive Sediment in Auckland Streams. Prepared by NIWA Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2009/038.

Khorsandi, H., Faghiri, G., & Asadzadeh, A. (2004). The rate of bank erosion of meandering rivers. In *2nd International Conference on Scour and Erosion, Nanyang Technological University, Singapore* (Vol. 2, pp. 131-137).

Lloyd *et al*., 2012. Flow/ecology relationships and scenarios for the Lower Barwon Wetlands environmental entitlement: Final Report for Corangamite CMA

Main, A.C., Greet, J., Vivian, L.M., and Jones, C.S. (2022). Warmer water temperatures exacerbate the negative impacts of inundation on herbaceous riparian plants. *Freshwater Biology* 67: 11622-1173.

Marsh, N. A. Stewardson M. J. Kennard, M. J. (2003) River Analysis Package, Cooperative Research Centre for Catchment Hydrology, Monash University Melbourne. Available at: https://toolkit.ewater.org.au/Tools/RAP

Marsh, N. A. Grice, T, and . Arene, S (2009) eFlow Tool V1.0.0B. Available at https://toolkit.ewater.org.au/Tools/eFlow-Predictoroolkit.

Melbourne Water (2013). Healthy Waterways Strategy. Victoria.

Melbourne Water (2018a). Healthy Waterways Strategy 2018 Victoria State Government. https://www.melbournewater.com.au/about/what-we-do/publications/healthy-waterways-strategy

Melbourne Water (2021a). Jacksons Creek Environmental Water Action Plan. Melbourne Water.

Melbourne Water (2022). Maribyrnong River. Accessed 28th February 2025: https://www.melbournewater.com.au/water-and-environment/water-management/rivers-and-creeks/maribyrnong-river

Melbourne Water (2024). Science Inquiry: A Report to inform the mid-term review of the Healthy Waterways Strategy. Melbourne Water, Docklands, Victoria, Australia.

MWRA (2024). Maribyrnong River and Waterways Association's position statement on environmental flows in the Maribyrnong catchment. November 2024.

Newall, P. and Walsh, C. (2005). Response of epilithic diatom assemblages to urbanization influences. *Hydrobiologia.* 532, 53–67

Papanicolaou, A. N., Elhakeem, M., & Hilldale, R. (2007). Secondary current effects on cohesive river bank erosion. *Water Resources Research*, *43*(12).

Rankin and Bate (2000). Environmental Health of Streams in the Maribyrnong River Catchment. Publication 681, Environment Protection Authority, Victoria.

Roznik, E. A., Sapsford, S. J., Pike, D. A., Schwarzkopf, L., & Alford, R. A. (2015). Natural disturbance reduces disease risk in endangered rainforest frog populations. *Scientific Reports*, *5*(1), 13472.

Saddlier, S., Hammer, M. (2010). 'National Recovery Plan for the Yarra Pygmy Perch Nannoperca obscura. Department of Sustainability and Environment, Melbourne.

Szabo, K., Austin, K., Woods, K., Launchlan Arrorsmith, C. (2024). Impact of the 'or natural' clause on environmental flow compliance when modelling future climate change scenarios. *Proceedings of the 11th Australian Stream Management Conference*, 11-14 Aug,2024. Victor Harbor, SA.

Southern Rural Water (2023). Lancefield Groundwater Management Area Local Management Plan Version 1. April 2023, Victoria.

Southern Rural Water (2025). Rosslynne Reservoir, https://www.srw.com.au/water-and-storage/water-storages/rosslynne-reservoir

Streamology (2024). Jacksons Creek Maximum Environmental Flow Recommendations (Reach 7). Final Report for Melbourne Water.

TactEcol Consulting (2023). Growling Grass Frog surveys in the North-western Melbourne Growth Corridor. Surveys conducted by TactEcol Consulting (Jake Urlus and Joseph Leman) for the Department of Energy, Environment and Climate Action.

VEWH (2025). Maribyrnong. Available at: https://www.vewh.vic.gov.au/healthy-waterways/central-region/maribyrnong-river

WWCHAC (2021). Towards cultural and environmental renewal of Jacksons Creek (biik wurrdha Regional Parklands Cultural Values Study). Overview document. Wunrundjeri Woi-wurring Cultural Heritage Aboriginal Corporation.

Attachment 1: Bulk Entitlements, storages and licences

Table 15. Bulk Entitlement Conversion Orders in the Maribyrnong catchment

ID	Bulk Entitlement	Parameters	2021-2022 take (ML)[1]
WSE000114	Gisborne – Barringo Creek – Greater Western Water to take water from the waterway to supply water to the Gisborne Water Supply System	Up to 585 ML in any one year and up to 1600 ML in any consecutive 5-year period during months of June – Oct. A share of flow clause applies, and do environmental obligations, including the management of impacts on bed and banks, practices to remove silt from works, and practices to manage water quality in works on the waterway.	585
WSE000115	Lancefield – Greater Western Water to take water from Monument Creek, at the weir, and from Garden Hut Creek, at the storage, to supply water to Lancefield	Up to 315 ML of water from the system in any year at a rate not exceeding 1.1 ML/d at the storage and 0.85 ML/d at the weir. Subject to the above, the Authority may in any one year take up to 299 ML/yr from the storage, and 195 ML of water from the weir, with a minimum passing flow of 0.6 ML/d when flow > 0.6 ML/d, and passing flow of F when F < 0.6 ML/d	315
WSE000116	Macedon and Mount Macedon – to take water from waterways to supply Macedon and Mount Macedon – Greater Western Water	Up to 873 ML in any one year, and up to 3225 ML in any consecutive 5-year period from waterways. Uptake rates apply at several reservoirs and weirs. Minimum passing flow at Frank Mann Reservoir when of 0.2 ML/d when flow exceeds 0.2 ML/d. Passing flow of F, when F < 0.2 ML/d. Minimum passing flow of 0.7 ML/d when F > 0.7 ML/d at Anzac Road Gauging Station, or minimum passing flow of F, when F < 0.7 ML/d.	873
WSE000119	Maribyrnong (Jacksons Creek and Maribyrnong between Reservoir and Shepherd Bridge) – Greater Western Water	Up to annual average total of 6100 ML over any 5-year period at a rate not exceeding 69 ML/d. No passing flows. The obligation to meet passing flows is on WSE000118 Southern Rural Water (SRW operates the reservoir – amended 2006)	6100
WSE000117	Maribyrnong (Jacksons Creek and Maribyrnong between Reservoir and Shepherd Bridge) – Melbourne Water	Up to an annual average total of 1096 ML over any period of 5 consecutive years, and up to an annual total of 300 ML to supply entitlements under licenses. The obligation to meet passing flows is on WSE000118 Southern Rural Water (SRW operates the reservoir – amended 2006)	1396
WSE000118	Maribyrnong (Jacksons Creek and Maribyrnong between Reservoir and Shepherd Bridge, including pool formed by and immediately upstream of Rosslynne Reservoir) – Southern Rural Water	A share of 4.5% of the estimated storage capacity of the Reservoir, being 24 670 megalitres at a full supply level of 450.90 metres Australian Height Datum. The Bulk Entitlement was amended in 2006 to allow for passing flows, which depend on whether there is more than 2200 ML in GWW's capacity share. If >2200 ML, passing flows include the lesser of 3ML/d and natural flows at Gisborne gauging station, the lesser of 10ML/d and modified natural	682

ID	Bulk Entitlement	Parameters	2021-2022 take (ML)[1]
		flow at the Sunbury gauging station, and the lesser of 5 ML/d and the modified natural flow at the Keilor gauging location. An instantaneous minimum flow of 1 ML/d at the Gisborne and Sunbury Gauging Stations. A minimum flow at instantaneous rate of 20 ML/d at Gisborne gauging station during any period determined under subclause 12.2 (including, when the reservoir has not overflowed on or before Oct 1 in any year, and the cumulative inflow to the reservoir over the 24 months immediately preceding 1 October in that year is at least 10500 ML or less than 10500 ML and on Oct 1 the reservoir has in storage at least 13695 ML (55% capacity). When there is equal to or less than 2200 ML in GWW's capacity share, SRW must provide flows at Gisborne and Sunbury gauging stations agreed by Melbourne Water, GWW and SRW.	
WSE000120	Riddells Creek – Greater Western Water to take water from the waterway to supply water to the Riddells Creek Water Supply System	Up to 300 ML in any year from April to January inclusive, to supply water to the Riddell's Creek Water Supply System. Passing flows have been specified. From April – January, if 0 < F < 0.5 ML/d, passing flows = 0 ML/d. If 0.5 < F < 1.0, passing flows are F-0.5 ML/d. When F>1.0 ML/d, passing flows = 1 ML/d. In February – March, passing flows = 0 ML/d.	300
WSE000121	Romsey – Greater Western Water to take water from waterway to supply the Romsey Water Supply System	Up to 460 ML of water from the waterway in any year, and once the amount has been taken, any amount of water in the drought reserve (up to 280 ML). A share of flow clause applies, and do environmental obligations, including the management of impacts on bed and banks, practices to remove silt from works, and practices to manage water quality in works on the waterway.	460

[1] Volumes taken in 2021-2022 obtained from Victorian Water Accounts webpage (DEECA, 2024).

Table 16. Storage structures in the Maribyrnong catchment

Study Reach	Waterway	Structures	Flow passed?
Reach 1 – Deep Creek	Deep Creek	Garden Hut Reservoir 45 ML storage capacity Harvest limit 299 ML/yr	N
	Deep Creek	Monument Creek Diversion Weir Harvest limit set to 0.85 ML/d, and 195 ML/yr Note GWW has not used this weir in recent years	Y
Reach 3 - Emu Creek	Bolinda Creek	Weir diverting water to Kerrie Reservoir (off-stream storage) Harvest limit of 32 ML/day, and 460 ML/yr	Y
	Main Creek	Weir diverting water to Forster and Wright reservoirs (off-stream storages)	Y

Study Reach	Waterway	Structures	Flow passed?
		Harvest limit up to 1 ML/day, and 300 ML/yr	
Reach 5 - Riddles Creek	Turritable Creek	McDonalds Reservoir storage 88 ML Anderson Reservoir storage capacity 4.02 ML Total harvesting limit 1.7 ML/day	N
	Willimigongon Creek	Orde Hill Reservoir storage capacity of 250 ML Willimigongon Reservoir storage capacity 15 ML Total harvesting limit 2 ML/day	Y
	Middle Gully / Railway Creek	Frank Mann Reservoir storage capacity of 31 ML Kitty English Reservoir storage capacity 85 ML Total harvesting limit 2 ML/day	Y
	Barringo Creek	Pierce Reservoir storage capacity of 61 ML. Weir harvesting water for off-stream storage (Note this BE is currently underutilised – used to provide water for fire fighting, not consumption)	Y
Reach 6 – Jacksons Creek	Jacksons Creek	Rosslynne Reservoir storage capacity of 24 670 ML (at full supply level). Total harvesting limit of up to annual average of 382 ML over any five year period (Item 1), and up to annual total of 300 ML per year (Item 2).	Y

Table 17. Licences in the Maribyrnong catchment

Licence	Location	Allocation	2022-2023 Take[1]
Take and use licences	Unregulated surface water	1903 ML	111 ML
Licensed small catchment dams	On-waterway	130 ML	804 ML taken from licensed small catchment dams
Licensed small catchment dams	Off-waterway	1651 ML	

Attachment 2: Approach to the determination of flow recommendations

Application of hydraulic criteria

The hydraulic criteria have been determined by Environmental Flow Technical Panel members based on relevant literature and expert knowledge. These criteria have been updated from the previous FLOWS study to reflect the updated objectives and the best available science.

Hydraulic modelling

The magnitudes of the flow required to achieve the flow functions were estimated using 2-dimensional hydraulic models. The HEC-RAS modelling software, developed by the US Army Corp of Engineers, has been used as the hydraulic modelling platform for this part of the investigation.

Five new models were developed as part of this study based on the new site survey data for Deep Creek (Reach 1, 2 and 4), Emu Creek (reach 3) and Riddells Creek (Reach 5). Two existing models for Jacksons Creek were modified in 2D HEC-RAS models to be consistent with the five new models. Detailed of the hydraulic models are provided in Attachment 4.

For a given flow rate (magnitude), the hydraulic models provide the resultant hydraulic conditions in the presentative site, this includes stream velocity, shear stress, inundation depths and inundation extents. Many flow rates are run through the model and the Environmental Flows Technical Panel and project team are then able to assess which flow rate produces the hydraulic conditions that best meet the target criteria at various locations throughout the representative site (e.g. the minimum velocity through a pool or the inundation over a specific bench).

Each recommendation is comprised of a flow component, discharge (magnitude), timing (period), frequency (generally number of times per period) and duration (generally in days), as well as the inclusion of climate condition. In this section, the recommendations are described for each reach and for each flow component. Flows components for river reaches are summer / autumn low flow, summer / autumn fresh, winter / spring low flow, winter / spring fresh, high flows.

Hydrologic modelling and analysis

The hydrologic modelling and analysis was undertaken using modelled natural and current hydrologic data at key gauging locations extracted from Maribyrnong Source model (HARC 2022).

Rates of rise and fall

Rates of rise and fall relate refer to the rate at which flow magnitudes change from day to day, where the rate of rise denotes the rate at which flows increase, and rates of fall denote the rates at which flows decrease within a given reach. Rapid changes in flow rates can have significant ecological impacts and cause ecological harm. For example, excessive rates of rise and fall can lead to fish stranding, bank instability, and negative impacts on growling grass frogs.

Recommended maximum rates of rise and fall are provided to managers to minimise risks of ecological harm through the delivery of 'managed' flows. They are reported in Table 18 as the maximum rate of permissible rise / fall from one day to the next, and are based on the natural rates or rise and fall experienced in each reach. The maximum rates of rise and fall for each reach were calculated from modelled daily 'natural' hydrological data, for the period 1/6/1900 – 31/5/2021, inclusive. The maximum rate of rise was defined as 90th percentile rate of rise. The maximum rate of fall was defined as the 10th percentile rate of fall.

Table 18. Maximum permissible rates of rise and fall, in each season, in Maribyrnong reaches.

Reach	Season	Rise	Fall
1	Dec - May	3.7	0.7
	Jun - Nov	3.3	0.7

2	Dec - May	2.8	0.7
	Jun - Nov	2.8	0.7
3	Dec - May	5.1	0.6
	Jun - Nov	4.1	0.7
4	Dec - May	2.6	0.8
	Jun - Nov	2.5	0.8
5	Dec - May	2.4	0.8
	Jun - Nov	2.4	0.7
6	Dec - May	3.1	0.5
	Jun - Nov	6.3	0.5
7	Dec - May	2.6	0.7
	Jun - Nov	3.0	0.6

For a rate of rise or fall to be included in the analyses, the flow rate must exceed the seasonal low flow magnitude for the corresponding reach. For example, summer autumn daily rates of rise and fall in reach 6 are included in the analyses when the daily flow magnitude exceeds the summer / autumn low flow magnitude of 4 ML/day. Similarly, winter / spring daily rates of rise and fall in reach 6 are included in the analysis when the daily flow magnitude exceeds with winter/ spring low flow magnitude of 20 ML/day. In summer, if the flow rate is 5 ML/day and the maximum recommended rate of rise in summer is 3.1, the flow on the following day should not exceed 15 ML/day (5 x 3.1). Similarly, if the flow rate is 5 ML/day and the maximum recommended rate of fall is 0.5, the flows on the following day should not be less than 2.5 ML/day.

Timing

The timing of freshes and high flows was determined by the Environmental Flows Technical Panel based on relevant literature on flow – ecology relationships, and expert knowledge.

Derivation of annual climate condition (dry, average, wet)

Interpolated daily rainfall data for the period 1/06/1900 – 31/5/2021 was obtained from SILO (https://www.longpaddock.qld.gov.au/silo/) for each reach at the locations shown in Table 19.

Table 19. SILO rainfall locations used for each reach of the Maribyrnong catchment

Reach	SILO location
Reach 1	Lancefield gauge 87029
Reaches 2 and 4	Latitude -37.45, Longitude 144.90
Reach 3	Latitude: -37.50, Longitude: 144.75
Reach 5	Latitude: -37.45, Longitude: 144.65
Reaches 6 and 7	Gisborne gauge 87026

Annual rainfall was calculated for each year beginning June 1. Annual rainfall percentiles (0 – 100 %) were then determined. Dry years were defined as those whose annual rainfall was within the lowest tertile (0 – 33 %) of annual rainfalls in the analysed period. Average years were defined as those whose annual rainfall was within the middle tertile (34 – 67 %) of annual rainfall in the analysed period. Wet years were defined as those whose annual rainfall was within the highest tertile (68 – 100 %) of annual rainfalls in the analysed period.

Spell analysis

Reaches 1-5, and Reach 7

The frequencies and durations of freshes and high flows were determined using the 'high spell' project option in the 'time series analysis' function of the River Analysis Package (RAP, v3.0.8, Marsh et al. 2003). Source modelled daily current hydrological data from 1/6/1900 to 31/5/2021 served as input data, applying the magnitude threshold (as determined by the environmental flows technical panel based) and spell independence of 7 days.

Spell frequency in average climate years was defined as the median number of events per year of the analysed data period. Spell duration in average climate years was defined as the median of the average duration of spells per year in which a spell occurred.

The frequencies and durations of spells in dry, average and wet years were determined by aligning the spells analysis outputs (annual outputs for the period 1/6/1900 – 31/5/2021), with the above derivation of annual climate condition (for the period 1/6/1900 – 31/5/2021). The frequency and duration of peak events in dry, average and wet years were subsequently adjusted based on these results, environmental objectives, expert judgement and EFTP review.

Reach 6

Current hydrological data was unsuitable for use in spells analysis, due to the impacts of Rosslynne Reservoir. As it was not the EFTPs intention to return flows to a natural regime, the frequency and duration of freshes in reach 6 were instead based on the frequency and duration of spells determined for Reach 7 (which receives inflows from Reach 6 and Reach 5), to ensure consistency across Reaches 6 and 7.

Performance analyses

The performance of the recommended flow regime for average rainfall years for each reach, was determined using eFlow Predictor v3.0.134 (Marsh et al 2009). Results are presented in Attachment 6. Seven day spell independence was applied to freshes and high flows components.

Interpretation of performance scores

eFlow Predictor determines the extent to which a flow component is delivered in each year (beginning June 1) of the modelled hydrological dataset (modelled current flows, modelled high 2045 climate flows, and modelled high 2065 climate flows, for the period 1900 – 1921).

- A performance score of 100% indicates full delivery of the flow component in a given year
- A performance score of 0% indicates that the flow component was not delivered at all in a given year
- A performance score between 0% and 100% indicates the extent of partial delivery of the flow component in a given year.

Two types of flow components were assessed, which differ in the way performance is reported.

1. Low flows – The performance score represents the proportion of days is in the relevant season in which the flow magnitude is met. For example, In Reach 1, low flows of 2 ML/day are required during December – May (182 day period). If this threshold is achieved on 50 days of a given December – May period, the performance score for the corresponding year would be 50/182*100 = 27%
2. Event-based peak flows (freshes and high flows) – The performance score represents the proportion of required events that were delivered in a given season. To be successfully achieved, the flow must both equal or exceed the required magnitude, *and* equal or exceed the required duration. If the required magnitude is met but the duration is not met, the event is scored as unsuccessful.
   For example, in reach 1, the delivery of a high flow of 1000 ML/day for 2 days in duration any time of year (Jun -May) in a given year would receive a performance score of 100%, as only one event per season is required. In reach 1, the delivery of three of the required four 150 ML/day Winter / Spring freshes, each lasting for at least 5 days in duration during June – November would result in a performance score of 75%. Note: should a winter/spring peak event exceed 150 ML/day but only last for 4 days, it would be scored in the performance analysis as an unsuccessful event.

Average annual/seasonal performance is presented, as is the performance in each year/season of the modelled data.

Attachment 3: Environmental objectives and hydraulic criteria

Additional information on developing geomorphic criteria

Table 20 below describes the flow criteria identified by technical panel to achieve the geomorphic goals. Note that flow criteria are expressed in terms of shear stress targets as they are more relevant for erosion than simple discharge criteria. Shear stresses can be predicted with 2D hydraulic models deployed for this study.

Table 20: Rationale for geomorphic flow criteria (based on values in Section 1).

Geomorphic Goal	Flows required
Increase / maintain extent of suitable ecological habitat Maintain gross channel size by preventing vegetation encroachment across the main channel	Keeping standing water in the channel (especially the pools) for over six (6) weeks limits the encroachment/colonisation of terrestrial vegetation into the channel bed. Once vegetation has filled the bed it will trap more sediment and be difficult to remove. In addition to 'drowning-out' encroaching vegetation, flows that scour phragmites beds also contribute to keeping channels open in deeper areas. According to the literature these shear stress values are between 10 and 15 Pa (note that Pa and N/m^2 are the same units) for around 12 hours. Note that these are similar shear stresses to scour cohesive sediments and gravels, so they represent useful thresholds (Jowett and Elliot, 2009).
Increase / maintain extent of suitable ecological habitat Periodic disturbance of the whole channel is important for biological processes	Goal is to disturb bed, limit encroachment of macrophytes across the channel, and maintain pool depth. These processes occur when the flows just cover the benches and point bars in the channel (these flows are usually sufficient to turn-over the bed). Shear stress to move the bed material and scour reeds is 10 - 15 Pa (equivalent to velocities of 1 -2 m/s in clay, 2-3m/s for dense stands) (Jowett and Elliot, 2009).
Increase / maintain extent of suitable ecological habitat Limit colmation (clogging of gravels) that would affect macroinvertebrate, fish and platypus	Winter-Spring freshes. The shear stress required to turn over the bed of the Maribyrnong streams will vary – but not by much. Most of the channels have similar modest bed loads of sand, find gravels, or cohesive bed sediments. Again, flows that cover the bars with shear stresses in the range of 10 – 15 Pa will be sufficient to turn the bed over.
Erode river banks to undermine trees that fall into the channel to become woody habitat	Bankfull flows required to erode the toe of river banks (i.e. erode the bank) tend to be higher than flows required to turn over the bed material, and typically range from15 to 25 Pa, and can be higher in the cohesive sediments of the Maribyrnong Streams. The ratio of point shear stress to average shear stress has been used by some researchers, for the evaluation of erosion forces. The variation of this ratio is in the 2 to 2.5 ranges, as reported by most of the references (Khorsandi, H., et.al. (2004); Allmanová, et.al. (2021); Papanicolaou, et.al. (2007)).

Environmental objectives and hydraulic criteria

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
Fish	Maintain diversity and extent of Small-bodied native fish populations and diadromous species	All reaches	Protect refuge / low flows and maintain water quality	Low flows	All year	Fi1	Depth of pools ≥ 0.5 m Velocity in pools ≥ 0.1 m/s
			Cue downstream migration of adult diadromous species (short-finned eel: Summer – Autumn; tupong: May – Aug; Common galaxias: Mar – May)	Summer / Autum and Winter / Spring freshes	December – May (short-finned eel); May – August (Tupong); March – May (Common galaxias)	Fi2	Depth over riffles ≥ 0.1 m
			Cue dispersal between refuge pools for all species	Summer / Autum and Winter / Spring freshes	September – January	Fi3	Depth over riffles ≥ 0.1 m Increase depth 0.2 – 0.3 m above corresponding low flows
			Cue immigration of juvenile diadromous species into system from estuarine reach (all species Spring-Summer)	Summer / Autum and Winter / Spring freshes	September – January	Fi2	Depth over riffles ≥ 0.1 m
	Maintain population abundance and extent of Yarra Pygmy Perch	Deep Creek upper (reach 1)	Protect refuge / low flows and maintain water quality	Low flows	All year	Fi1	Depth of pools ≥ 0.5 m Velocity in pool ≥ 0.1 m/s
				Summer / Autumn fresh	December – March	Fi4	Velocity in pools ≥ 0.3 m/s
			Cue dispersal between refuge pools for all species	Summer / Autum and Winter / Spring freshes	September – January	Fi2	Depth over riffles ≥ 0.1 m
Frogs	Improve size and number of GGF populations	Reaches 3 and 7	Provide pool habitat (with permanent deep zones) and shallow margins.	Low flows	September - March	Fr1	Depth of pools ≥ 0.5 m (R7) and > 1.0m (R3)
			Ensure connectivity to adjoining wetlands.	High flows	August	Fr2	Increase depth 0.2 – 0.3 m above corresponding low flows
	Support and enhance GGF breeding and recruitment	Reaches 3 and 7	Manage aquatic vegetation. Allow growth and reproduction of macroinvertebrates communities.	Summer / Autum and Winter / Spring freshes	September - March	Fr3	Depth of pools ≥ 0.5 m Velocity in pool ≥ 0.3 m/s
			Prevent increase in flow including from stormwater run-off during breeding season	N/A	September - March		N/A

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
Frogs			Provide pools/ no or slow flow permanent water, or as close to permanent as practicable, between September and April	Low flows	September - April	Fr4	Depth of pools ≥ 0.5 m
			Provide shallow margins with aquatic vegetation to support tadpole, and juvenile frog thermoregulation, protection from predators and foraging.	Summer / Autum and Winter / Spring freshes	September - March	Fr5	Depth of pools ≥ 0.5 m Variability in depth 0.2 - 0.3 m with freshes
	Improve condition and extent of frog populations	All reaches	Provide longitudinal connectivity between reaches (wetted edge and good vegetation cover). Help maintain and increase the number of connected / adjoining off-stream wetland sites.	Winter / Spring fresh	All year	Fr6	0.1 m depth over thalweg winter/ spring (low flows) Increase depth 0.2 – 0.3 m above corresponding low flows
				High flows			
	Increase the resilience of frogs to disease and fluctuations in hydrological conditions	All reaches	Ensure shallow stream margins that can warm and help to supress chytrid fungus. Provide pool habitat (with permanent deep zones).	Low flows	September - March	Fr7	Depth of pools ≥ 0.5 m (R7) and ≥ 1.0m (R3) Velocity in pool ≥ 0.1 m/s (low flows) Velocity in pool ≥ 0.3 m/s (freshes)
	Support survival of GGF over winter	Reaches 3 and 7	Raise flows to encourage frogs to seek suitable (above FWL) sites for brumation/sheltering over winter.	Winter / Spring fresh	Late March / April	Fr8	Velocity in pool ≥ 0.3 m/s Increase depth above corresponding low flows 0.2 – 0.3 m
	Maintain suitable water quality	Reaches 3 and 7	Prevent the incursion of untreated stormwater. Stormwater must be treated, and treatment must remove gross pollutants and filter out suspended solids, excess nutrients, heavy metals and chemical pollutants.	N/A	All year		N/A
	Prevent increase in flow variability from stormwater run-off during breeding season			N/A	September to March		N/A
Macroinvertebrates	Maintain existing aquatic habitat and restore degraded habitat for invertebrates	All reaches	Scour pools and create habitat complexity and coarser armouring on riffles	Winter / Spring fresh	June – November	M1	Velocity in pools ≥ 0.3 m/s Shear stress 10 – 15 Pa

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
	Maintain habitat condition (bed scouring) water quality (dissolved oxygen) to support macroinvertebrates	All reaches	Sustain macroinvertebrate communities in riffles, runs and pools during spring and summer	Summer / Autum and Winter / Spring freshes	September – February	M2	Depth over riffles ≥ 0.1 m Velocity in pools ≥ 0.3 m/s
				Summer / Autumn low flows	December – February	M3	Velocity in pools ≥ 0.1 m/s
	Provide natural breeding cues and recruitment of macroinvertebrates as important components in the ecosystem, including as carbon processors and food sources	All reaches	Inundate benches and aquatic vegetation beds to enhance diversity and extent of aquatic habitats for macroinvertebrates	Winter / Spring fresh	August – November	M4	Increase depth 0.2 – 0.3 m above corresponding low flows
	Provide woody habitat from river bank to river channel	All reaches	Provides habitat and substrate for macroinvertebrate populations	High flows	Anytime	M5	Shear stress 15 – 25 Pa
Platypus	Maintain conditions to support current platypus populations	Reaches 7 and 8	Maintain habitat, minimise predation risk and provide longitudinal connectivity between reaches for local movement	Low flows	All year, but particularly an issue in December – May	P1	Depth of pools ≥ 0.5 m Velocity in pools ≥ 0.1 m/s
			Flow freshes to keep fine sediment from infilling gravel beds and allow large macroinvertebrate populations for food	Summer / Autum and Winter / Spring freshes	All year	P2	Velocity in pools ≥ 0.3 m/s (all year) Shear stress 10 – 15 Pa (winter / spring)
			Provide pool habitat (>1 m depth) for refuge/ permanent habitat	Low flows	All year	P3	Depth of pools ≥ 0.5 m
	Prevent increase in flow variability from stormwater run-off – Limit flow variability and peaks above scouring threshold that will displace macroinvertebrates			N/A	All year		N/A
	Protect recruitment by avoiding bankfull or overbank flows during breeding season			Bankfull	October – January (inclusive)		N/A

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
	Improve conditions to allow for expansion of existing population into surrounding reaches	Reaches 4 and 6	Reduce/eliminate cease to flow events to provide habitat for platypus and food resources	Summer / Autumn low flows	December - May		N/A
			Provide pool habitat for refuge/ permanent habitat	Low flows	All year	P1	Depth of pools ≥ 0.5 m Velocity in pools ≥ 0.1 m/s
			Flow freshes to keep fine sediment from infilling gravel beds and allow large macroinvertebrate populations for food	Winter / Spring fresh	All year	P4	Shear stress 10 – 15 Pa
Vegetation	Maintain condition, extent and diversity of submerged and floating-leaved vegetation within the stream	Reaches 1,2, 4, 5, 6 and 7	Maintain adequate depth and quality of permanent water in channel or in deep pools to permit plant growth and reproduction (sexual and asexual), which can be achieved either by consistent low flows or in ephemeral waterways by periodic freshes to recharge the pools (depending on hydrological and hydraulic characteristics of each reach)	Low flows	All year	V1	Depth of pools ≥ 0.5 m Velocity in pools ≥ 0.1 m/s Winter / spring low flows 0.1 m over thalweg
				Summer / Autum and Winter / Spring freshes	December – May June – November	V2	Depth of pools ≥ 0.5 m Increase depth 0.2 – 0.3 m above corresponding low flows
			Facilitate downstream movement of propagules (seeds and plant fragments)	Summer / Autum and Winter / Spring freshes	September – November	V3	Increase depth 0.2 – 0.3 m above corresponding low flows Winter / spring low flows 0.1 m over thalweg
	Improve condition, extent and diversity of emergent (fringing non-woody) vegetation alongside the stream	Reaches 1, 3, 5, 6 and 7	Maintain adequate depth and quality of permanent water in channel or in deep pools to permit plant growth and reproduction	Low flows	All year	V4	Depth of pools ≥ 0.5 m Velocity in pools ≥ 0.1 m/s
				Summer / Autum and Winter / Spring freshes	December - May June – November	V3	Increase depth 0.2 – 0.3 m above corresponding low flows Winter / spring low flows 0.1 m over thalweg
			Maintain soil water to permit plant growth and reproduction	Summer / Autum and Winter / Spring freshes	All year December - May June – November	V5	Increase depth 0.2 – 0.3 m above corresponding low flows
			Promote vertical zonation of different plant taxa				
			Promote plant reproduction (sexual and asexual)				

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
			Facilitate downstream movement of propagules (seeds and plant fragments)				
			Periodic physical and ecological disturbance	High flows	Anytime	V6	Shear stress 15 – 15 – 25 Pa
Vegetation	Maintain condition, extent and diversity of fringing woody vegetation in the riparian zone	Reaches 1,2,4, 5 and 6	Maintain soil water to permit plant growth and reproduction	Low flows	All year	V1	Depth of pools ≥ 0.5 m Winter / spring low flows 0.1 m over thalweg
				Summer / Autum and Winter / Spring freshes	December - May June – November	V5	Increase depth 0.2 – 0.3 m above corresponding low flows
			Promote plant reproduction (sexual and asexual)	Summer / Autum and Winter / Spring freshes	September – November and December – February	V5	Increase depth 0.2 – 0.3 m above corresponding low flows
			Facilitate downstream movement of propagules (seeds and plant fragments)	Summer / Autum and Winter / Spring freshes	September – November and December – February	V5	Increase depth 0.2 – 0.3 m above corresponding low flows
			Periodic physical and ecological disturbance	High flows	Anytime	V6	Shear stress 15 – 25 Pa
	Maintain condition and extent of floodplain vegetation	Reaches 3 and 4	Maintain groundwater to support water-dependent plants on the floodplain	Low flows	All year	V8	Maintain appropriate depth to water table across floodplain.
			Engage flood-runners to inundate floodplain	High flows	September – November	V5	Increase depth 0.2 – 0.3 m above corresponding low flows
	Prevent terrestrialisation of the stream channel	All reaches	Maintain adequate depth and permanence (i.e. duration) of water in stream channel to prevent encroachment of terrestrial or riparian plants into aquatic habitats	Low flows	All year	V7	0.1 m over thalweg
				Summer / Autum and Winter / Spring freshes	December - May June – November	V3	Increase depth 0.2 – 0.3 m above corresponding low flows Winter / spring low flows ≥ 0.1 m over thalweg
Water quality	Maintenance of sufficient dissolved oxygen at depth in pools	All reaches	Maintain sufficient flows to enhance water mixing and reduce thermal stratification in pools	Summer / Autum and Winter / Spring freshes	September – November and December – February	WQ1	Velocity in pools ≥ 0.3 m/s
				Low flows	December – February	WQ2	Velocity in pools ≥ 0.1 m/s

Value	Objectives	Reaches	Flow function	Flow component	Timing	ID	Hydraulic Criteria
	Improve transport of silts, salts and nutrients through reaches and delivery to the estuary section of the Maribyrnong	All reaches	Provide sufficient, regular flows that can transport silt, salt and nutrients downstream	Summer / Autum and Winter / Spring freshes	Anytime	WQ1	Velocity in pools ≥ 0.3 m/s
				Low flows	All times	WQ2	Velocity in pools ≥ 0.1 m/s
Geomorphology	Increase / maintain extent of suitable ecological habitat	All reaches	Maintain gross channel size by preventing vegetation encroachment across the main channel	Winter / Spring low flows	June - November	G1	Maintain appropriate minimum flows. Ensure permanently wet margins through winter / spring.
			Also, periodic disturbance of the whole channel is important for biological processes	Winter / Spring fresh	Anytime	G2	Shear stress 10 – 15 Pa
				High flows	Anytime	G3	Shear stress 15 – 25 Pa
			Limit colmation (clogging of gravels) that would affect macroinvertebrate, fish and platypus	Winter / Spring fresh	Anytime	G2	Shear stress 10 – 15 Pa
				High flows	Anytime	G3	Shear stress 15 – 25 Pa
	Maintain large woody habitat	All Reaches	Erode river banks to undermine trees that fall into the channel to become woody habitat	High flows	Anytime	G3	Shear stress 15 – 25 Pa

Attachment 4: Maribyrnong FLOWS 2D Hydraulic Modelling

Introduction

This memorandum documents the assumptions and parameters used in the development of 2D HEC-RAS hydraulic models for seven reaches (including three reaches of Deep Creek, one reach of Emu Creek, one reach of Riddells Creek, and two reaches of Jacksons Creek) for the Maribyrnong FLOWS project in 2024.

HEC-RAS model inputs and setup

The following subsections document the datasets used, the parameters, the model assumptions and the limitations of the models, and the QA process.

Model terrain

The terrain in the study areas were digitised by creating Digital Elevation Models (DEMs) for each reach using three data sources, in order of priority:

1. 2024 bathymetric survey cross sections, surveyed for the project (for reaches 1 to 5)
2. 1m LiDAR captured in 2017 (for reaches 1 to 5)
3. 1m LiDAR captured in 2010 (for reaches 6 and 7).

For reaches 1 to 5, DEMs combining the points collected in each of the survey cross sections were first created using a 12d model, with breaklines used to refine the DEMs by enforcing links between key points within each section (e.g. the level between points along the bottom of the bank was enforced).

The survey DEM and the LiDAR DEM were then mosaicked to generate a model DEM/terrain for each study reach.

A model domain boundary was drawn to cover the study reach in question. The model terrains and domain boundaries for each reach are shown in Figure 15 to Figure 21.

Land cover and roughness coefficients

The surface roughness in HEC-RAS is specified using Manning's number n, values for which are commonly estimated based on land cover. Aerial imagery was inspected and the dominant land cover types in the study area were discretised as one of:

- Open grassland
- Stream
- Dense trees
- Light trees.

Polygons classifying each of these land cover categories were drawn based on aerial imagery (Figure 15 to Figure 21). The Manning's n numbers for each land cover were selected based on the HEC-RAS modelling guideline (Brunner, 2016). The landcover definitions and corresponding Manning's values are presented in Table 21.

Table 21. Manning's values by land cover definition

Land Cover Definition	Manning's n
Dense trees	0.1
Light trees	0.06
Open grassland	0.035
Stream	0.045

Computational mesh

The models comprised 2D computational mesh areas with a base grid cell size of 2 m x 2 m. The model domain areas were refined during model development based on trial and error, ensuring the model domain covered the entire floodplain for each modelled flow event.

Breaklines were added along the crest of the weirs in reach 4 and reach 5 to ensure the computational cell boundaries captured the weir crests.

Weirs

The weirs in reach 4 (Figure 18) and reach 5 (Figure 19) were modelled as SA/2D Connections. The connection was set as a 'weir/embankment' structure to represent the weir crest, the dimensions of which were measured from the survey data collected for the project. The reach 4 weir was set to have a crest elevation of 83.60 mAHD and width of 20 m, and the reach 5 weir was set to have a crest elevation of 357.74 m and width of 3.5 m.

Boundary conditions

Each model used two boundary conditions, one at the upstream end and one at the downstream end where flows extended out the model domain.

The upstream boundary conditions were set as inflow hydrographs for a range of flow events shown in Table 22. These reflected both target flows, as well as a range of high flows to help the team understand the patterns of inundation.

Table 22. Boundary condition parameters

Reach	Modelled inflows (ML/day)	Upstream bed slope (m/m)	Downstream bed slope (m/m)
1	2, 5, 10, 15, 20, 50, 100, 120, 200, 370, 400, 450, 500, 1000, 2000, 2500, 3000	0.002	0.008
2	3, 5, 10, 17, 25, 50, 70, 100, 175, 250, 350, 500, 1000, 2000, 3800, 6000	0.014	0.018
3	6, 10, 14, 30, 50, 100, 500, 1000, 2000, 3000	0.004	0.030
4	6, 10, 25, 40, 50, 75, 100, 250, 500, 1000, 2000, 3000, 4000, 4500	0.027	0.041
5	2, 5, 10, 20, 30, 50, 70, 80, 100, 150, 200, 400, 1000, 2000	0.009	0.004
6	4, 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 350, 500, 1000, 2000, 4000	0.003	0.001
7	6, 10, 15, 20, 40, 70, 100, 120, 200, 400, 700, 1000, 2000, 3000, 3800	0.003	0.0004

The downstream boundary conditions were set at normal depth, with slopes derived from the terrain data.

Model configuration figures

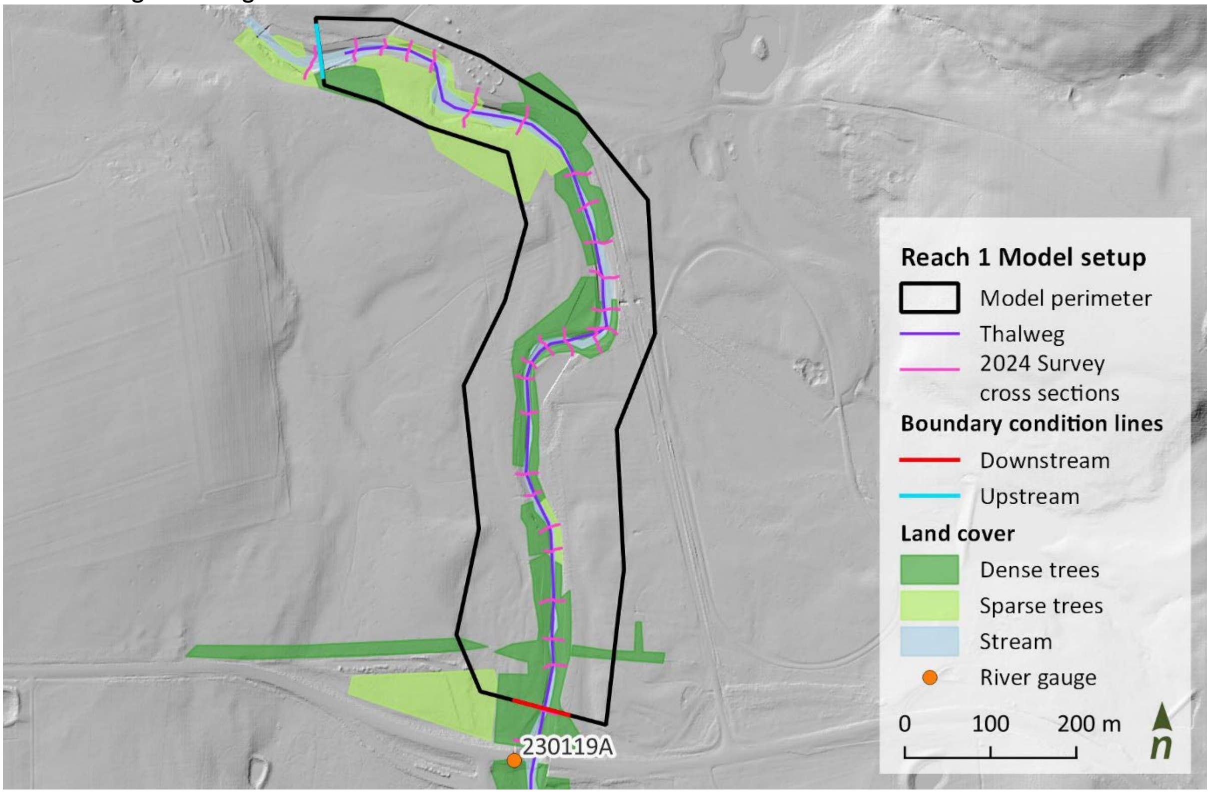


Figure 15. *Reach 1 HEC-RAS model setup*

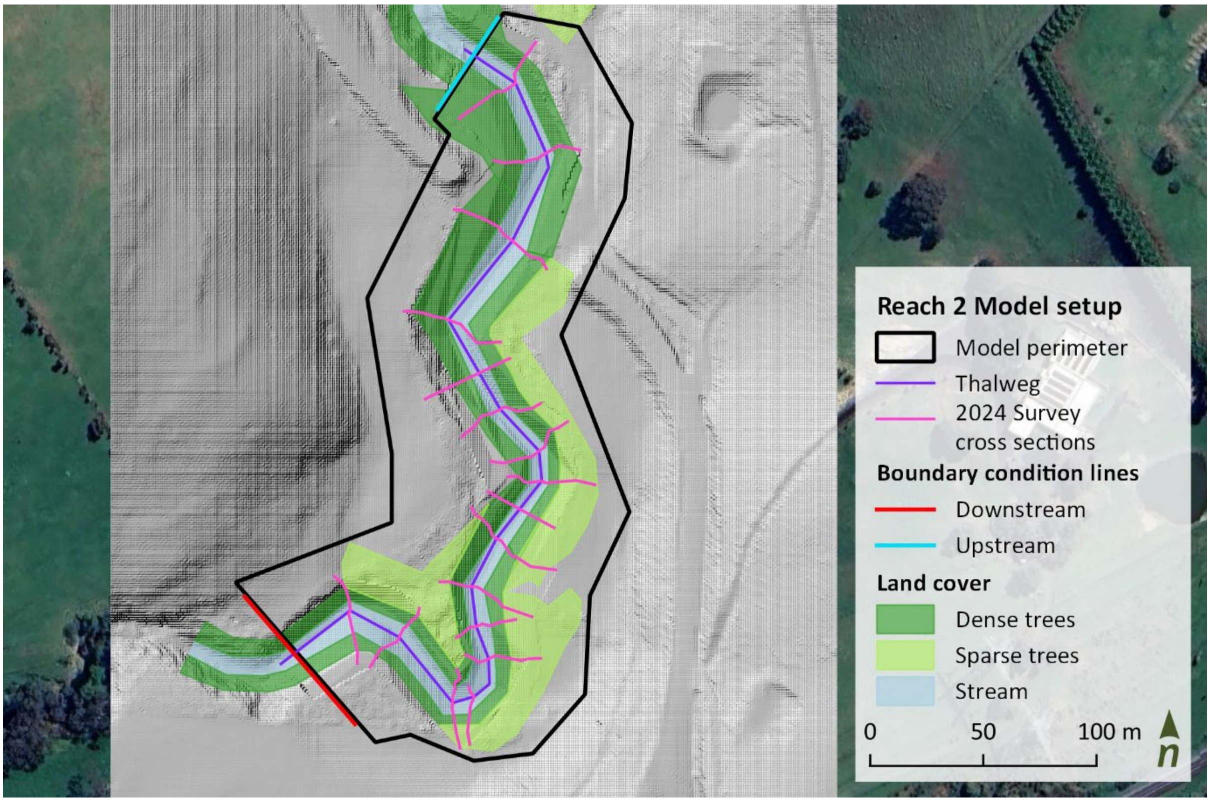


Figure 16. *Reach 2 HEC-RAS model setup*

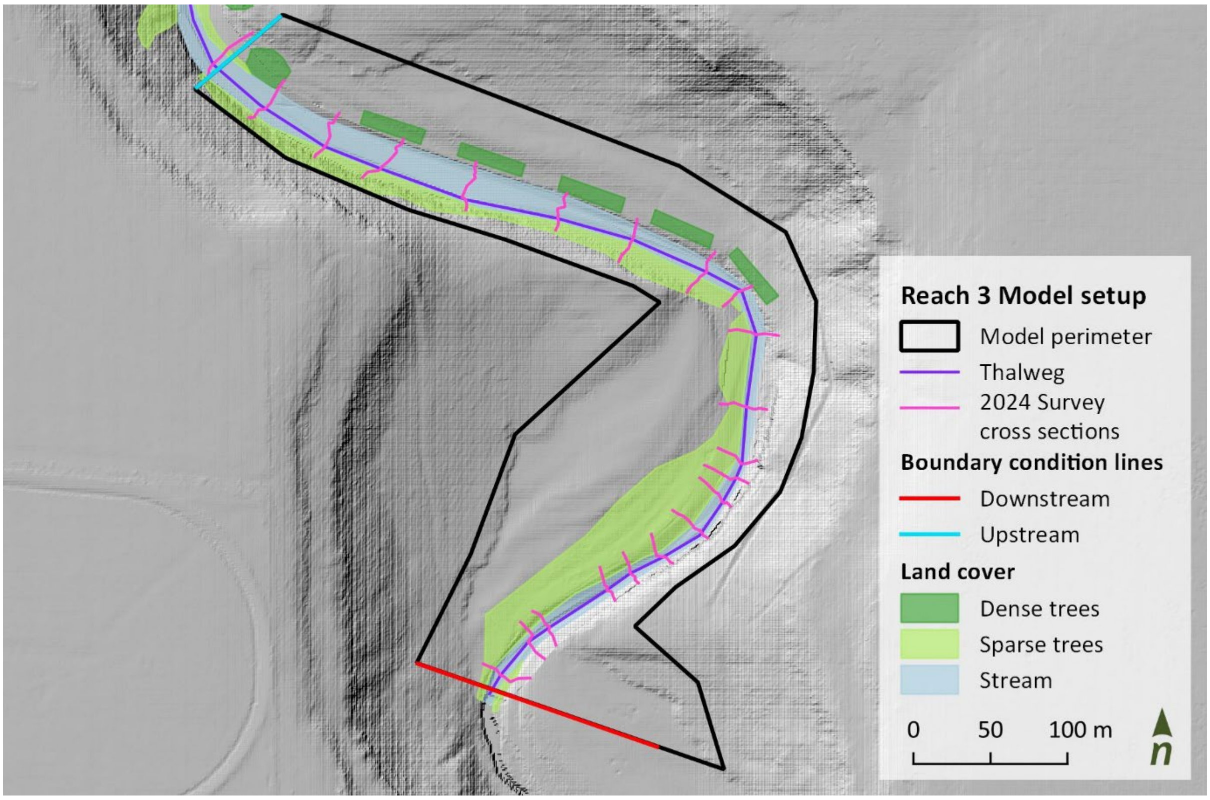


Figure 17. *Reach 3 HEC-RAS model setup*

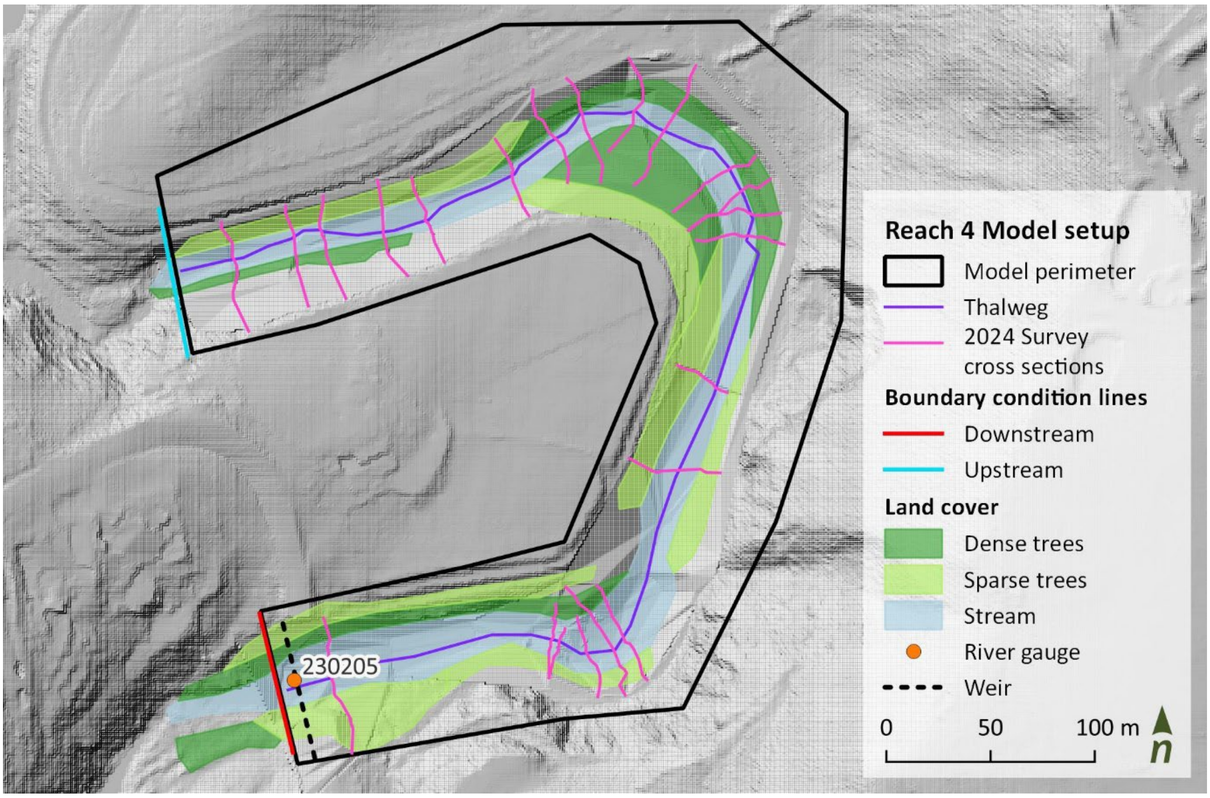


Figure 18. *Reach 4 HEC-RAS model setup*

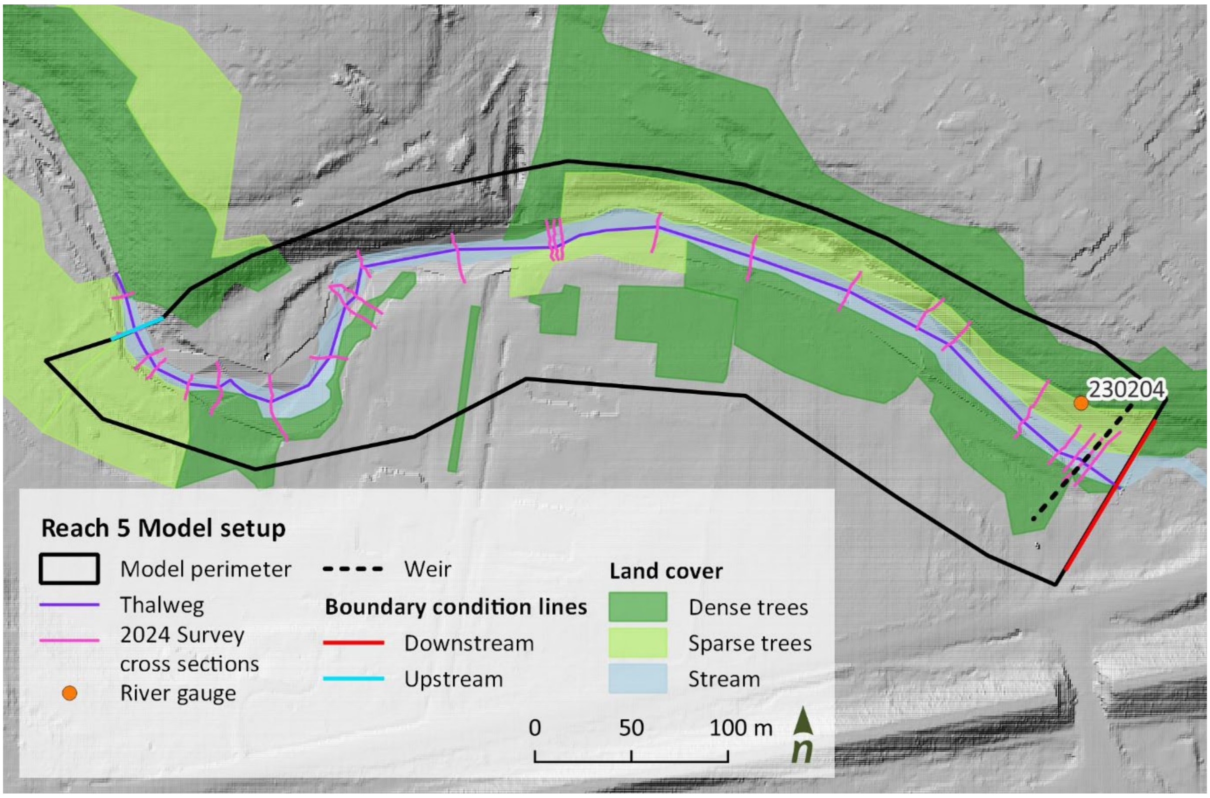


Figure 19. *Reach 5 HEC-RAS model setup*

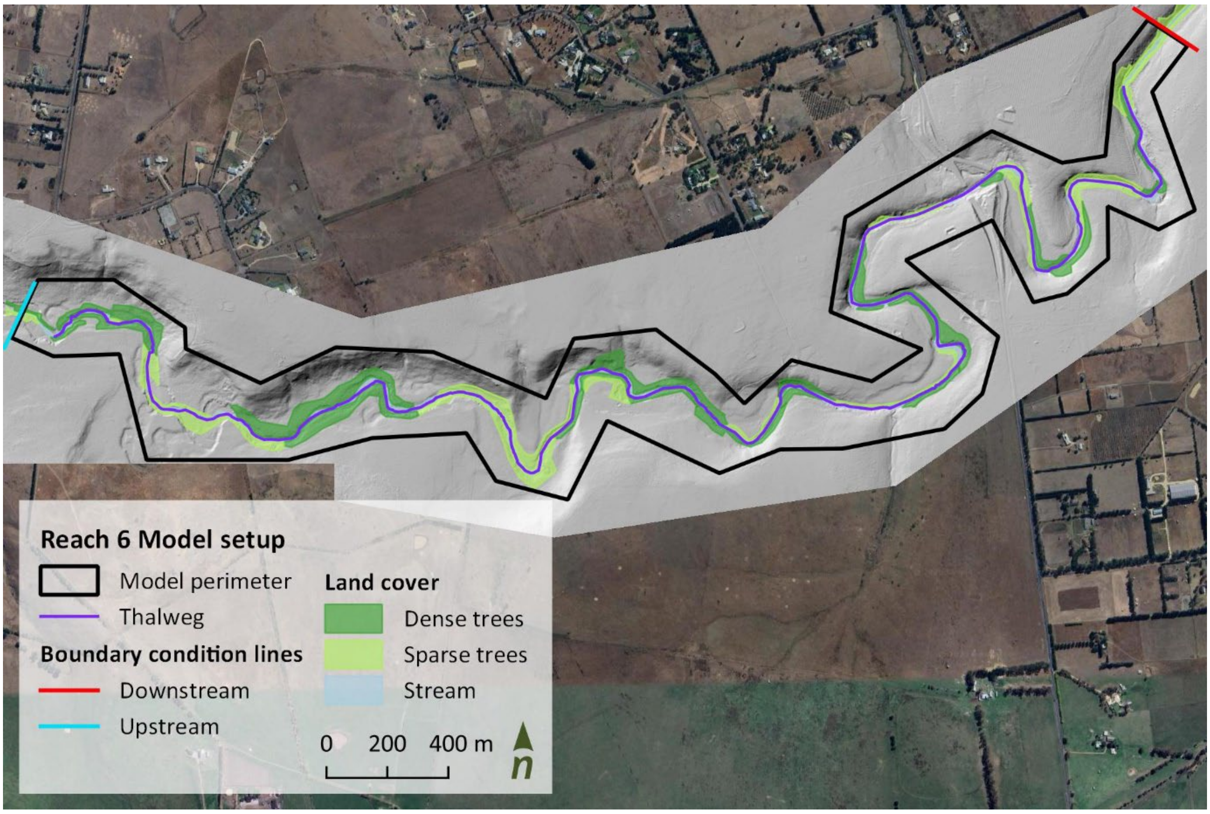


Figure 20. *Reach 6 HEC-RAS model setup*

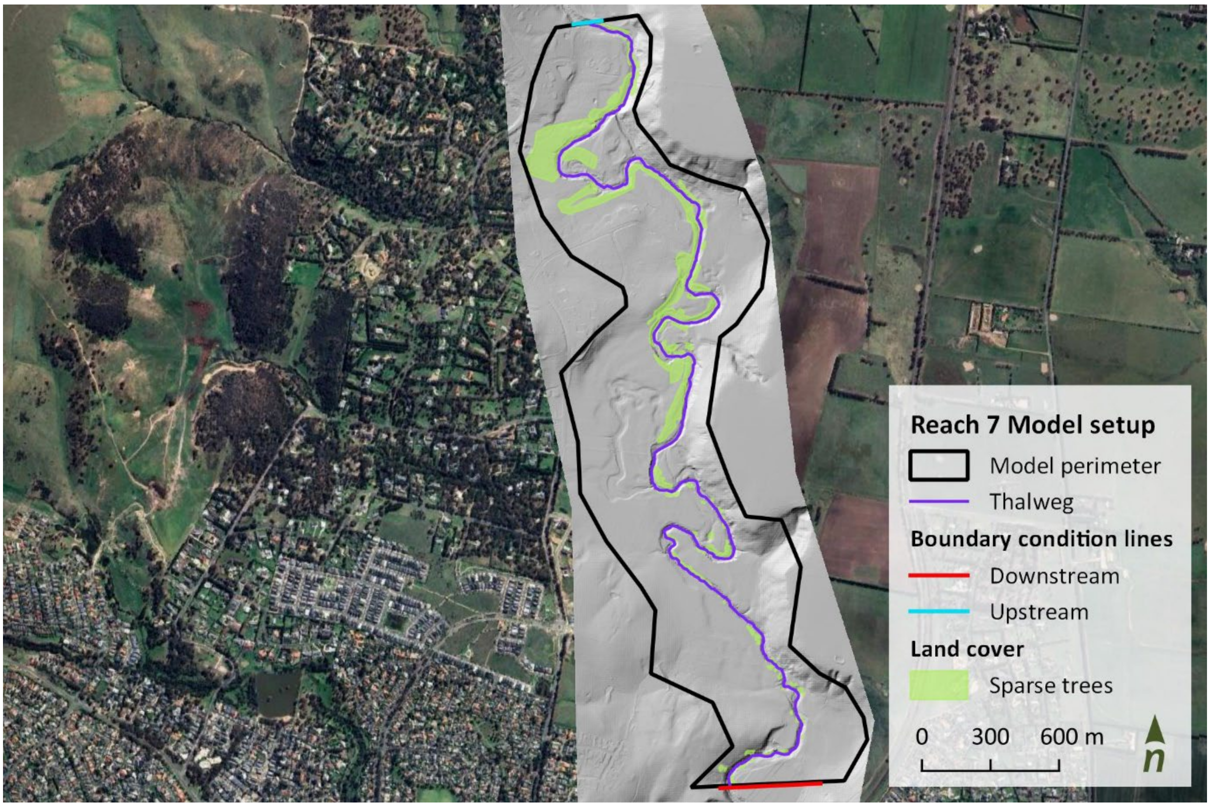


Figure 21. *Reach 7 HEC-RAS model setup*

Unsteady Flow Analysis
The model was set to use the Diffusion Wave equation solver method. Simulation lengths for the range of modelled events in Table 22 are shown in Table 23. These simulation lengths covered the duration after which the event peak flows had passed each reach. The models ran adopted a computational timestep suitable for each flow based so to satisfy minimum and maximum Courant conditions.

Table 23. Unsteady Flow simulation parameters

Reach	Simulation length (hours)	Timestep (seconds)
1	2 to 34	1 to 5
2	4 to 48	1 to 5
3	2 to 3	0.5 to 4
4	120 to 624	1 to 2
5	2 to 9	0.5 to 5
6	4 to 120	1 to 2
7	13 to 168	3

Model calibration

Stream level gauges are located within reaches 1, 4 and 5. In these reaches, the models were modified to produce similar results against the gauged values. The model boundary condition was the parameter having the most impact on water levels given that the gauges were all near model downstream boundaries. As such, the model boundary slopes were modified to gain good agreement with the rating curves.

Model review

During the initial phase of model development an internal model checklist was developed to ensure all processing tasks are undertaken systematically. Each model was self-checked, peer-checked against the checklist and then reviewed by a senior engineer.

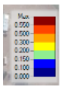
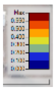
Model limitations

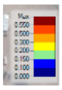
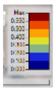
These models were developed to investigate the flows at which waterway assets are expected to be inundated. The models were developed using the available data and have an associated level of uncertainty. Some models were subject to a calibration exercise, however, this was only able to achieve water level agreement at one location in the model and should not be considered a comprehensive calibration. Other models were not calibrated. This uncertainty should be considered in the use of model results for decision-making.

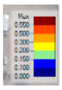
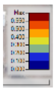
The models should not be used for any other purpose, particularly flood planning or infrastructure.

Attachment 5: Hydraulic model outputs

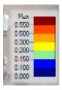
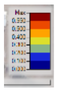
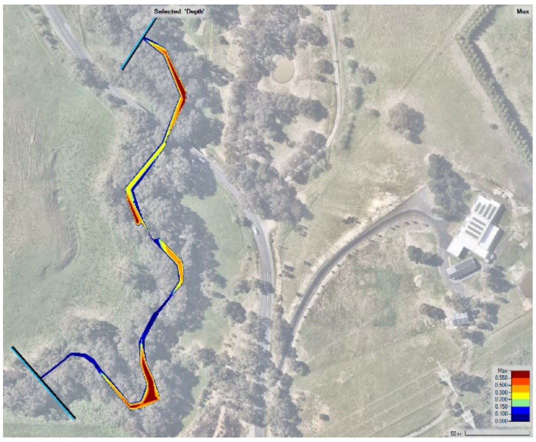
Reach 1 – Upper Deep Creek

Flow	Depth 	Velocity 
2 ML/day		
20 ML/day		
50 ML/day		

Flow	Depth 	Velocity 
		
150 ML/day		
1000 ML/day		

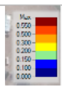
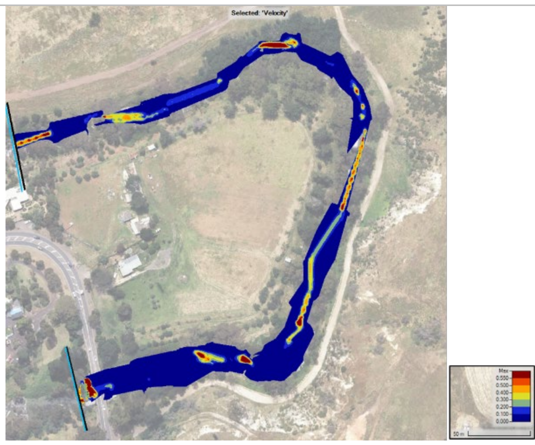
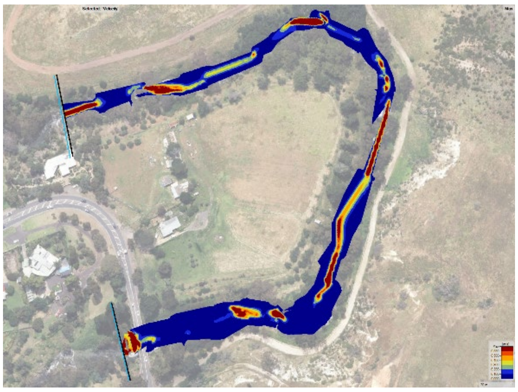
Flow	Depth 	Velocity 
		

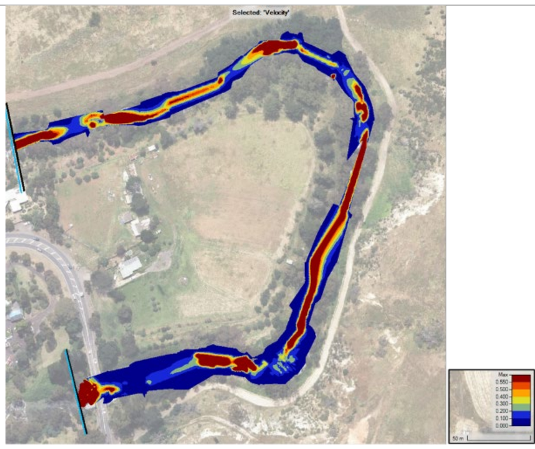
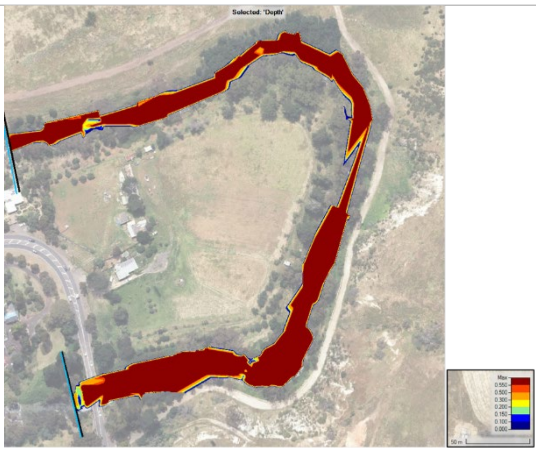
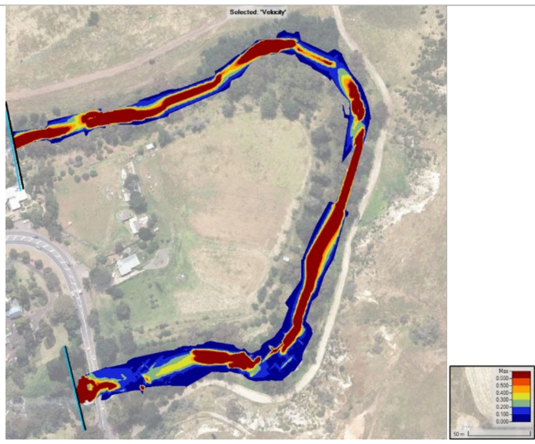
Reach 2 – Deep Creek - mid

Flow	Depth 	Velocity 
3 ML/day Summer / Autumn low flows		
17 ML/day Summer / Autumn fresh and Winter / Spring low flows		
175 ML/day Winter / Spring fresh	 Note: Shear stress (Pascal)	
500 ML/day High flow		

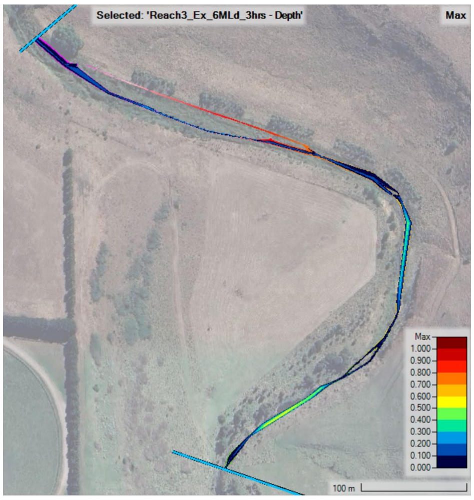
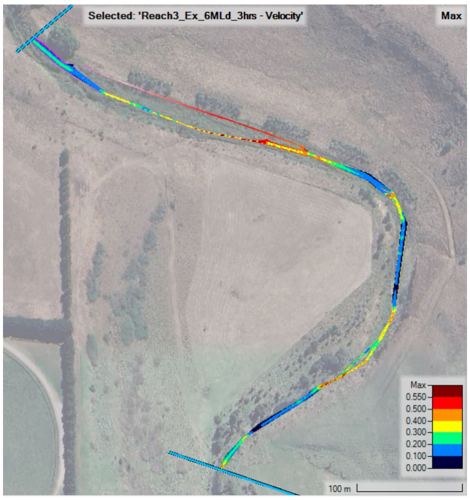
		

Reach 4 – Deep Creek Lower

Flow	Depth 	Velocity 
6 ML/day Summer / Autumn low flows		
25 ML/day Winter / Spring low flows		

100 ML/day Summer / Autumn fresh		
250 ML/day Winter / Spring fresh		
2000 ML/day High flow		

Reach 3 – Emu Creek

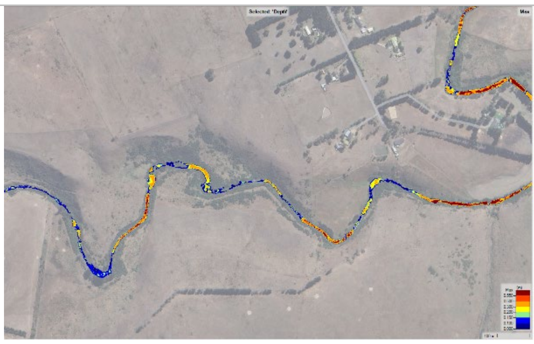
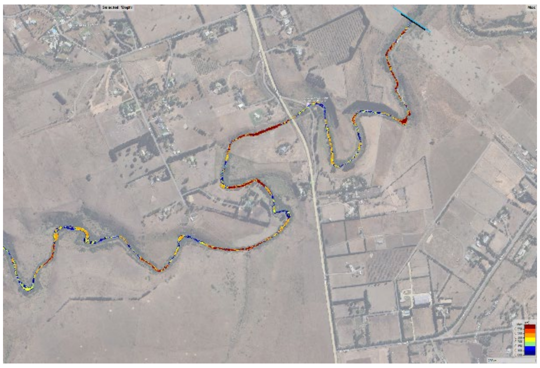
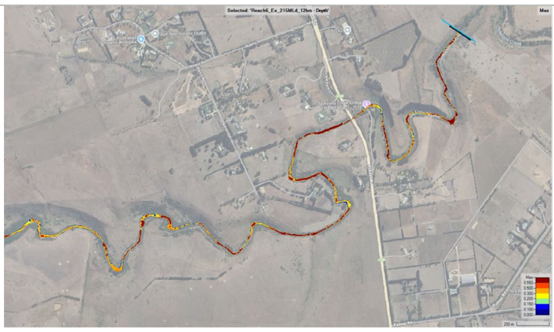
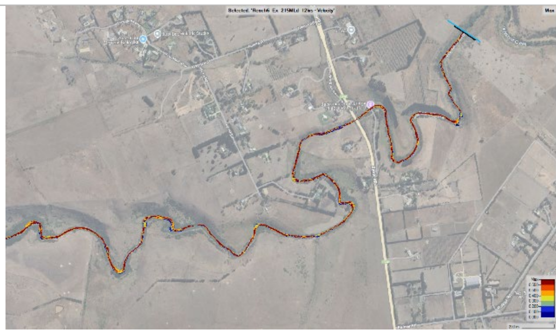
<table>
<tr><th>Flow</th><th>Depth</th><th>Velocity</th></tr>
<tr><td>6 ML/day
Summer / Autumn low flows</td><td>
</td><td>
</td></tr>
<tr><td>14 ML/day
Summer / Autumn Fresh and Winter / Spring low flows</td><td></td><td></td></tr>
<tr><td>100 ML/day
Winter / spring fresh</td><td></td><td></td></tr>
</table>

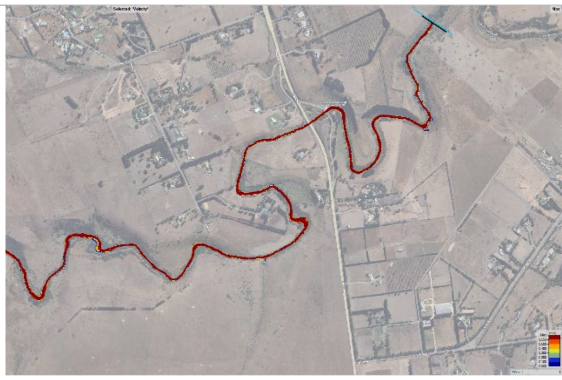
1000 ML/day High flow	**Shear stress**  	

Reach 5 – Riddells Creek

Flow	Depth	Velocity
2 ML/day Summer / Autumn low flows		
10 ML/day Winter / Spring low flows		
20 ML/day Summer / Autumn fresh		
50 ML/day Winter / Spring fresh		
400 ML/day High flows	**Shear stress** 	

Reach 6 – Jacksons Creek Upper

Flow	Depth	Velocity
4 ML/day Summer / Autumn low flows		
20 ML/day Summer / Autumn fresh and Winter / Spring low flows		
215 ML/day Winter / Spring fresh		
350 ML/day Winter / Spring fresh		

1000 ML/day High flows		

Reach 7 – Jacksons Creek Lower

Flow	Depth	Velocity
8 ML/day Summer / Autumn low flows		
40 ML/day Summer / Autumn fresh and Winter / Spring low flows		

400 ML/day Winter / Spring fresh		
2000 ML/day High flows		

Attachment 6: Performance analysis results

Performance analysis approach

The performance of the recommended flow regime for average rainfall years for each reach, was determined using eFlow Predictor v3.0.134 (Marsh et al 2009). Seven-day spell independence was applied to freshes and high flows flow components.

Interpretation of performance scores [annual EFC met (%)]
eFlow Predictor determines the extent to which a flow component is delivered in each year (beginning June 1) of the modelled hydrological dataset (modelled current flows, modelled high 2045 climate flows, and modelled high 2065 climate flows, for the period 1900 – 2021).

- A performance score of 100% indicates full delivery of the flow component in a given year
- A performance score of 0% indicates that the flow component was not delivered at all in a given year
- A performance score between 0% and 100% indicates the extent of partial delivery of the flow component in a given year.

Two types of flow components were assessed, which differ in the way that partial performance is reported.

3. **Low flows** – The performance score represents the proportion of days is in the relevant season in which the flow magnitude is met. For example, In Reach 1, low flows of 2 ML/day are required during December – May (182 day period). If this threshold is achieved on 50 days of a given December – May period, the performance score for the corresponding year would be 50/182*100 = 27%
4. **Event-based peak flows** (freshes and high flows) – The performance score represents the proportion of required events that were delivered in a given season. To be successfully achieved, the flow must both equal or exceed the required magnitude, *and* equal or exceed the required duration. If the required magnitude is met but the duration is not met, the event is scored as unsuccessful.
   For example, in reach 1, the delivery of a high flow of 1000 ML/day for 2 days in duration any time of year (Jun -May) in a given year would receive a performance score of 100%, as only one event per season is required. In reach 1, the delivery of three of the required four 150 ML/day Winter / Spring freshes, each lasting for at least 5 days in duration during June – November would result in a performance score of 75%. Note: should a winter/spring peak event exceed 150 ML/day but only last for 4 days, it would be scored in the performance analysis as an unsuccessful event.

A performance summary (average flow recommendations using modelled current hydrologic data) is provided for each reach, as is the performance in each year/season of the modelled data.

Note: due to the variable nature of flows and the setting of freshes according to median annual frequency and durations, high performance is not expected.

The performance results for climate change scenarios are captured in the climate change and vulnerability memo (Alluvium, 2025).

Cease to flow

Cease to flow analysis was performed on Source-modelled data for natural, current and future climate (High 2045, and high 2065) hydrologic data for each reach. Flows were defined as having ceased if the daily flow magnitude was below 0.1 ML/day. Cease to flow data is presented as:

(1) the average percentage of summer / autumn (Dec – May) days on which the reach ceases to flow.
(2) the number of summer / autumn seasons where the reach ceases to flow on 100% of days (i.e. completely dry seasons).
(3) the average percentage of winter / spring (Jun – Nov) days on which the reach ceases to flow.
(4) the number of winter / spring seasons where the reach ceases to flow on 100% of days (i.e. completely dry seasons).

Performance analysis – Reach 1 (Deep Creek Upper)

Mean annual summer / autumn low flow performance in reach 1 is poor (17%). On average, reach 1 ceases to flow on 62% of days under current flow conditions, which is a logical explanation for poor summer / autumn low flow performance. Winter / Spring low flow performance ranges from 0 – 100%, with an average annual performance of 48% (i.e. on average, flows exceed 20 ML/day on 48% of days in the December – May period). Full achievement of the recommended freshes and high flow is low to moderate. At least 1 Winter / Spring fresh is delivered in most (92/121) years, and full achievement of Winter / Spring low flows occurred in 31/121 years (26%).

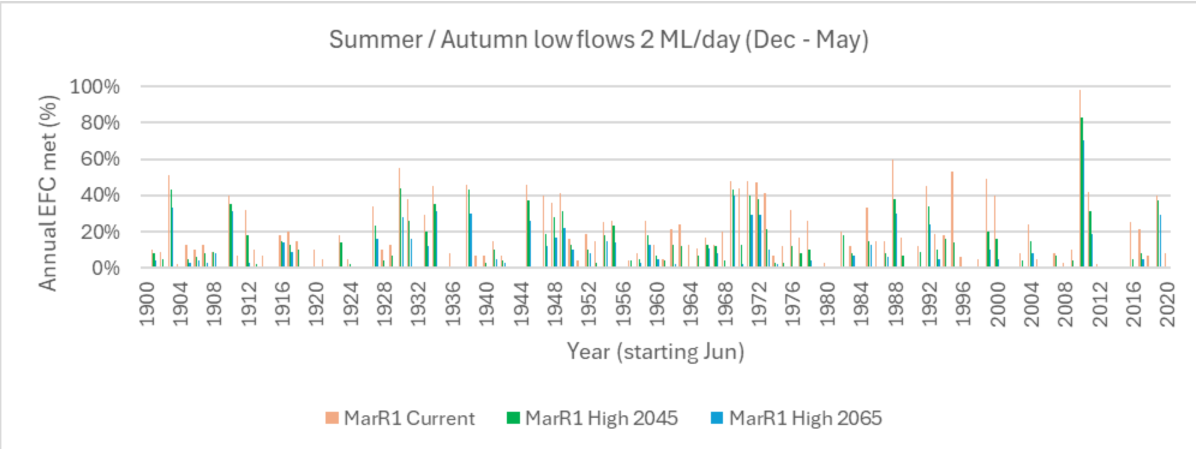
Performance decreased under future climate conditions for each flow component.

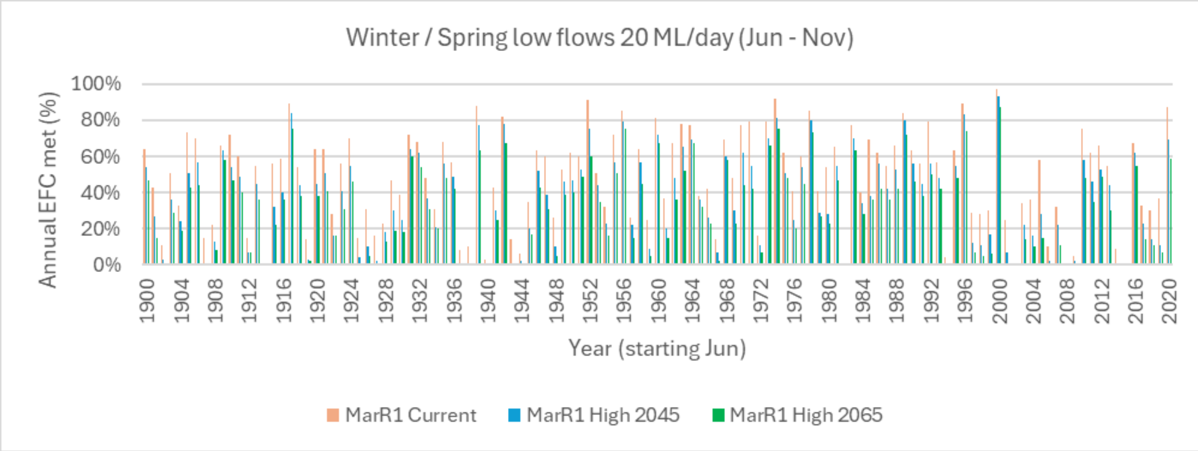
Performance summary – current climate.

Flow component	Summer / Autumn low flows 2 ML/day (Dec - May)	Winter / Spring low flows 20 ML/day (Jun - Nov)	Summer / Autumn fresh 50 ML/day (Dec - May)	Winter / Spring fresh 150 ML/day (Jun - Nov)	High flow 1000 ML/d (Jun - May)
Mean annual performance	17%	48%	27%	52%	43%
Min annual performance	0%	0%	0%	0%	0%
Max annual performance	98%	97%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	48	92	52
Number of years with full achievement of recommendation*	0	0	17	31	52

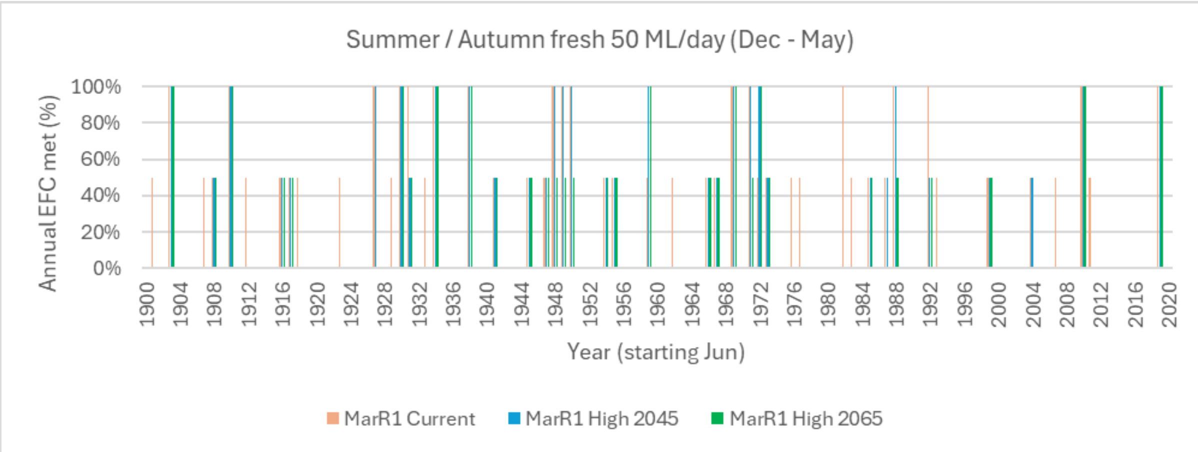
*out of the maximum possible 121 years

Annual performance in current climate, high 2045 climate, high 2065 climate.

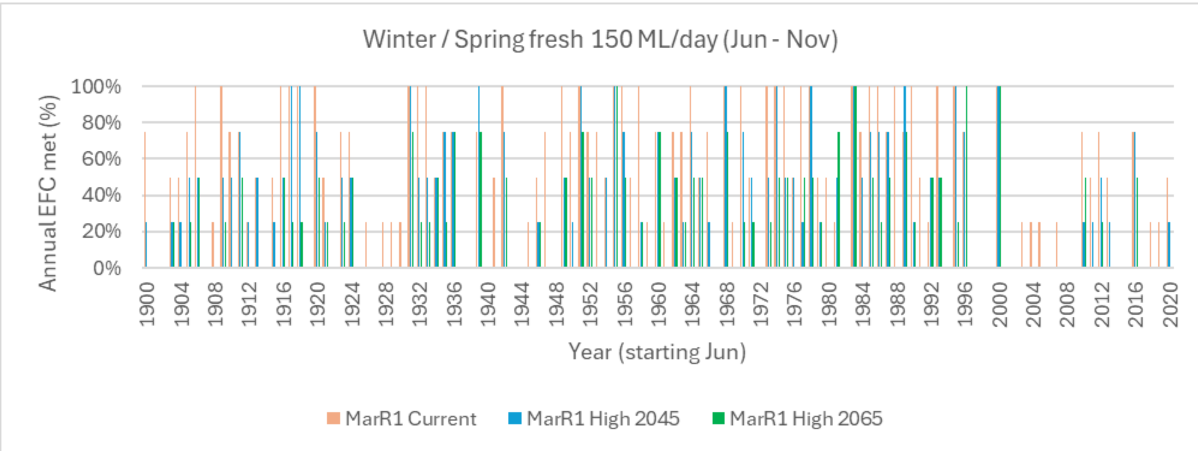




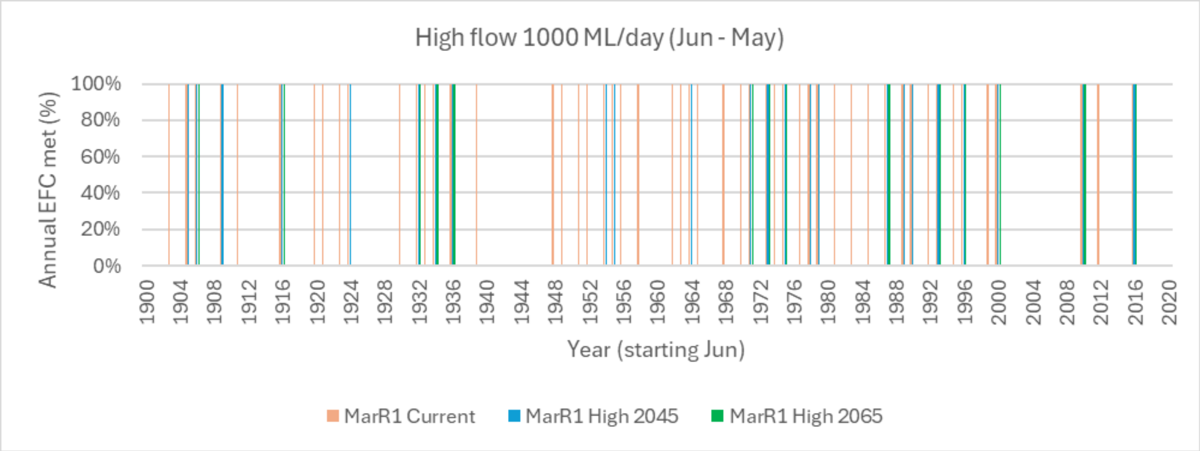
Winter / Spring low flows 20 ML/day (Jun - Nov)
Annual EFC met (%)
Year (starting Jun)
MarR1 Current
MarR1 High 2045
MarR1 High 2065



Summer / Autumn fresh 50 ML/day (Dec - May)
Annual EFC met (%)
Year (starting Jun)
MarR1 Current
MarR1 High 2045
MarR1 High 2065



Winter / Spring fresh 150 ML/day (Jun - Nov)
Annual EFC met (%)
Year (starting Jun)
MarR1 Current
MarR1 High 2045
MarR1 High 2065



Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	53%	62%	68%	89%
# Completely dry Dec - May	2	6	9	50
Av % CTF Jun - Nov	4%	9%	12%	40%
# Completely dry Jun - Nov	0	0	0	2

Performance analysis - Reach 2 (Deep Creek Mid)

Low flows performance (in Summer / Autumn and Winter / Spring) in reach 2 is improved compared to that of reach 1. Cease to flow days less prevalent (25% of days) in reach 2 compared to those of reach 1, and no longer explain poor low performance. Winter / Spring performance averaged 58% per June – November season. Summer / Autumn fresh and Winter / Spring fresh averaged 43% and 59%, respectively, with at least one fresh event occurring in the more than half of years. Good performance was observed in the delivery of high flows (mean annual performance 78%).

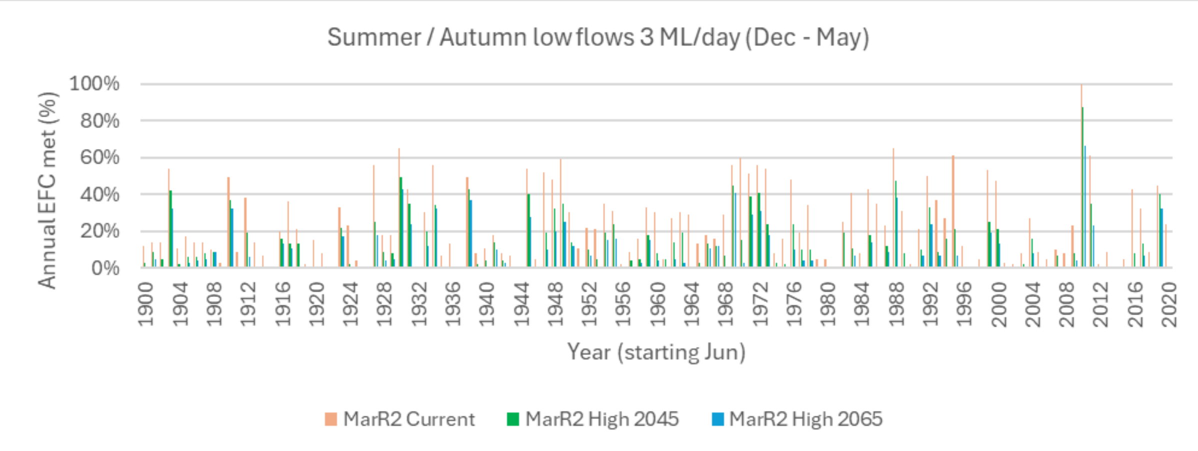
Performance decreased under future climate conditions for each flow component.

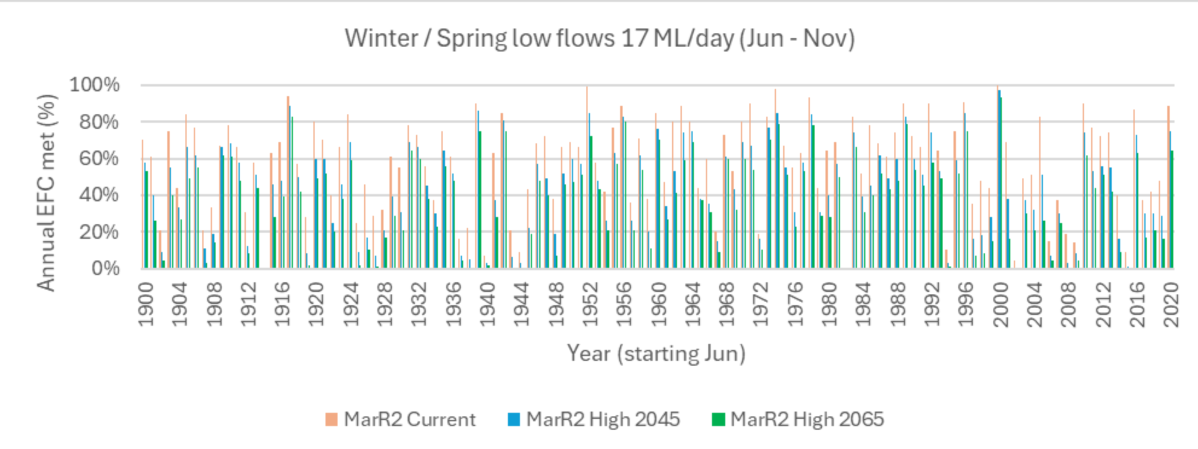
Performance summary – Current climate

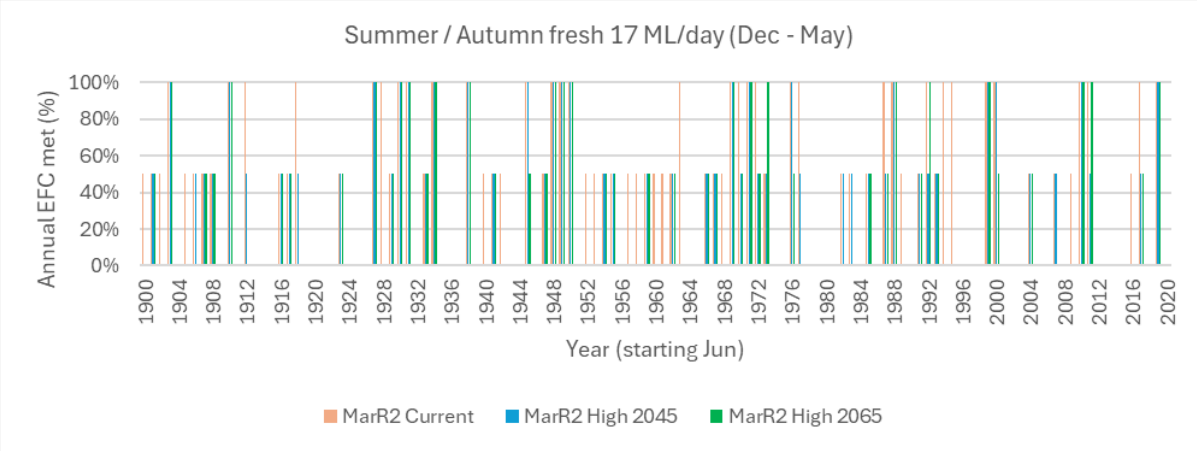
Flow component	Summer / Autumn low flows 3 ML/day (Dec - May)	Winter / Spring low flows 17 ML/day (Jun - Nov)	Summer / Autumn 17 ML/day (Dec - May)	Winter / Spring 175 ML/day (Jun - Nov)	High flow 500 (Jun - May)
Mean annual performance	24%	58%	43%	59%	78%
Min annual performance	0%	0%	0%	0%	0%
Max annual performance	100%	100%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	72	96	94
Number of years with full achievement of recommendation*	0	0	32	42	94

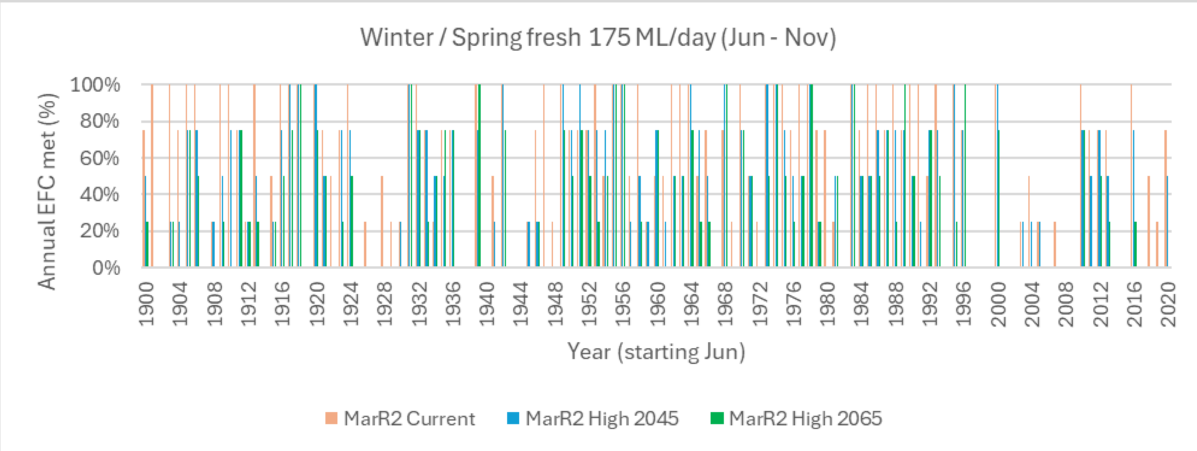
*out of the maximum possible 121 years

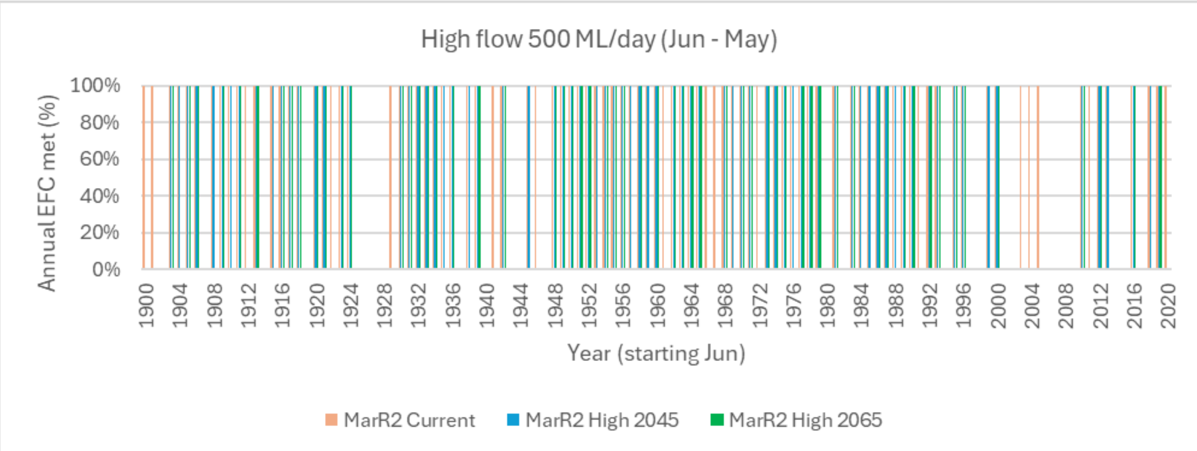
Annual performance in current climate, high 2045 climate and high 2065 climate











Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	17%	25%	43%	87%
# Completely dry Dec - May	0	0	0	48
Av % CTF Jun - Nov	0%	1%	3%	29%
# Completely dry Jun - Nov	0	0	0	0

Performance analysis - Reach 3 (Emu Creek)

Reach 3 shows particularly poor performance in the achievement of low flows (mean 11% performance, Dec – May). Poor performance is not explained by cease to flow events, which average only 12% of days in December – May. Low to modest performance in Winter / Spring low flows and Summer / Autumn freshes was observed (35% and 31%, respectively). Winter / Spring fresh and high flow performance both averaged 49% performance, with flows of the recommended magnitudes occurring at least once in 74/121 and 78/121 of years, respectively.

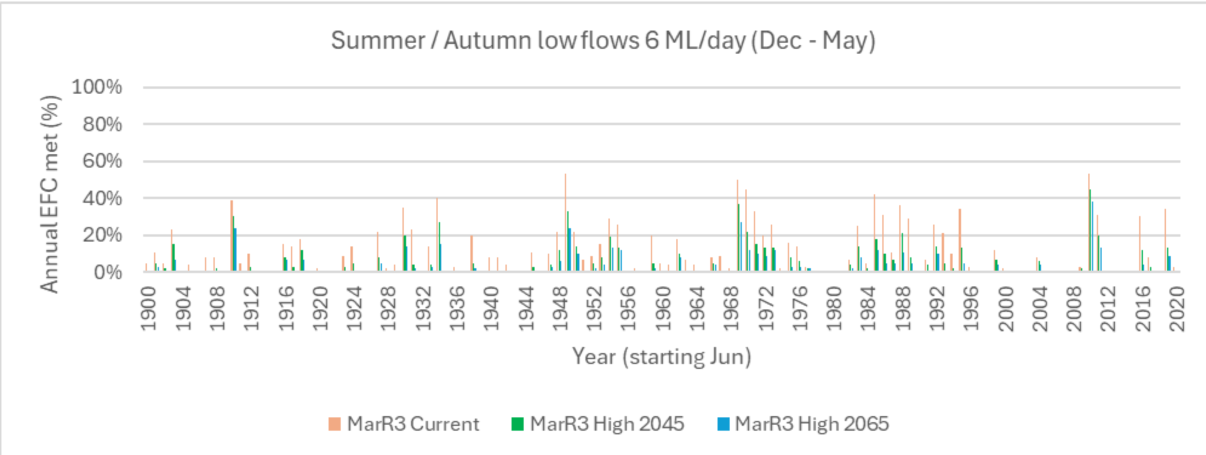
Performance decreased under future climate conditions for each flow component.

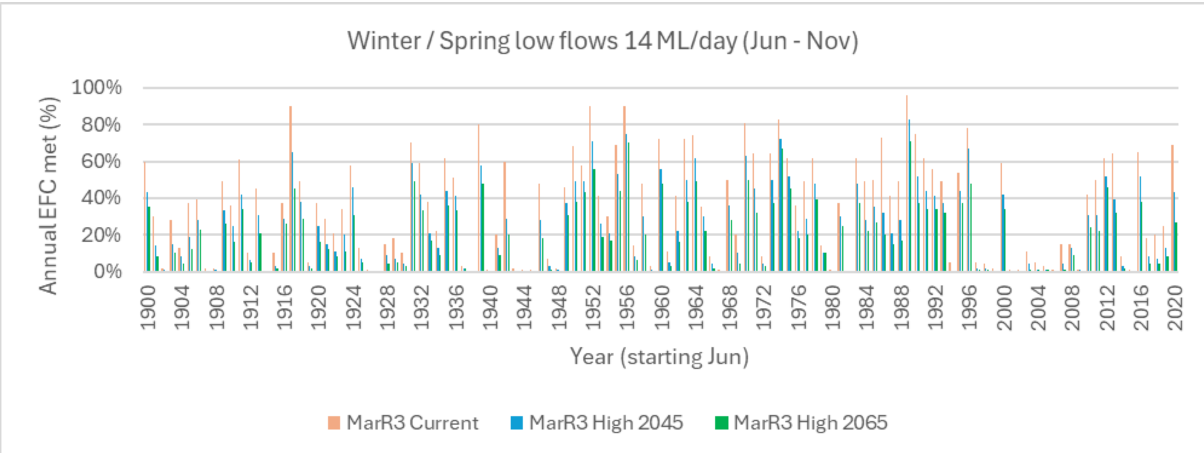
Performance summary – current climate

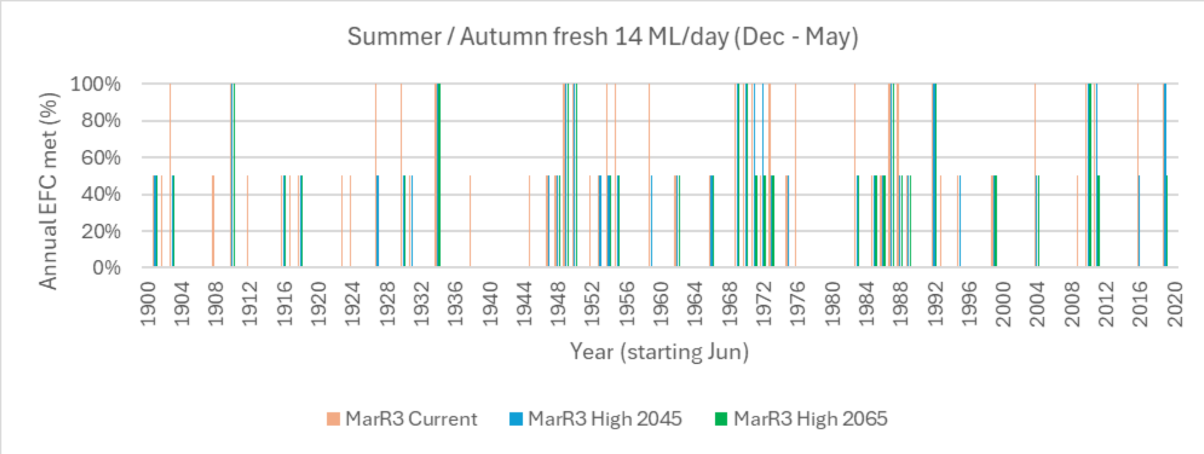
Flow component	Summer / Autumn low flows 6 ML/day (Dec - May)	Winter / Spring low flows 14 ML/day (Jun - Nov)	Summer / Autumn fresh 14 ML/day (Dec - May)	Winter / Spring fresh 100 ML/day (Jun - Nov)	High flow 1000 (Jun - May)
Mean annual performance	11%	35%	31%	49%	49%
Min annual performance	0%	0%	0%	0%	0%
Max annual performance	53%	96%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	51	74	78
Number of years with full achievement of recommendation*	0	0	24	41	40

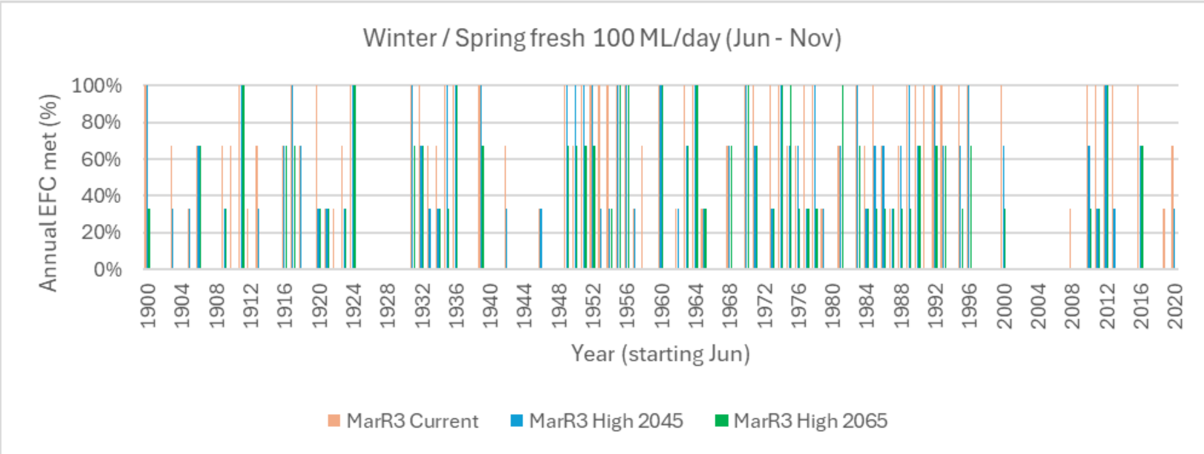
*out of the maximum possible 121 years

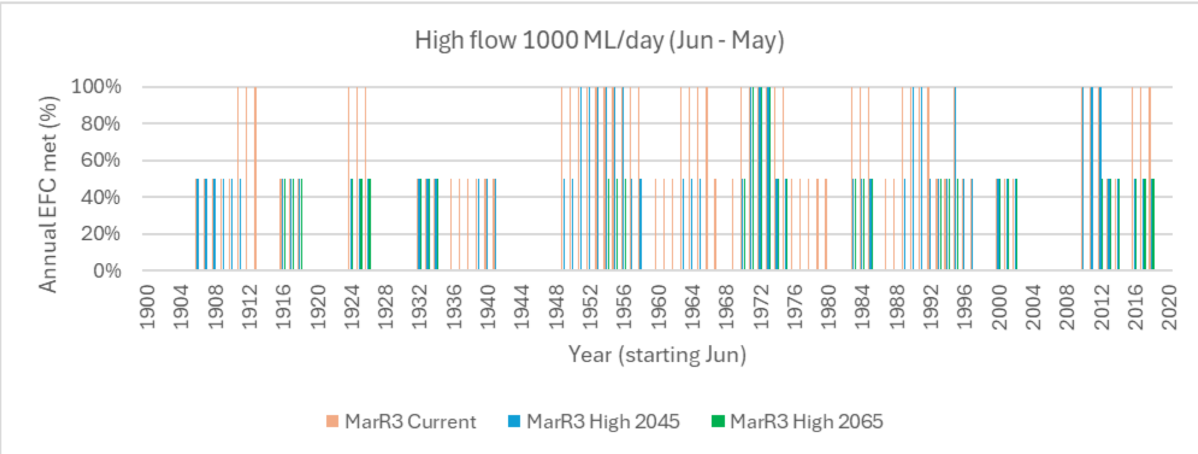
Annual performance in current climate, high 2045 climate and high 2065 climate.











Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	2%	12%	22%	27%
# Completely dry Dec - May	0	0	0	0
Av % CTF Jun - Nov	0%	1%	2%	3%
# Completely dry Jun - Nov	0	0	0	0

Performance analysis - Reach 4 (Deep Creek Lower)

In reach 4, performance scores ranged from 0% - 100% for each flow component. Mean annual performance of Summer / Autumn low flows in Reach 4 was poor (24%) and could not be explained by cease-to-flow events (average cease to flow of 15% in December – May, under current modelled flows). Winter / Spring low flows performance was generally good (mean annual performance 58%). Moderate performance was observed for the delivery of freshes and high flows. At least one Winter / Spring fresh event was achieved in 91/121 years, however full achievement of recommended Winter / Spring freshes only occurring in 23/121 years.

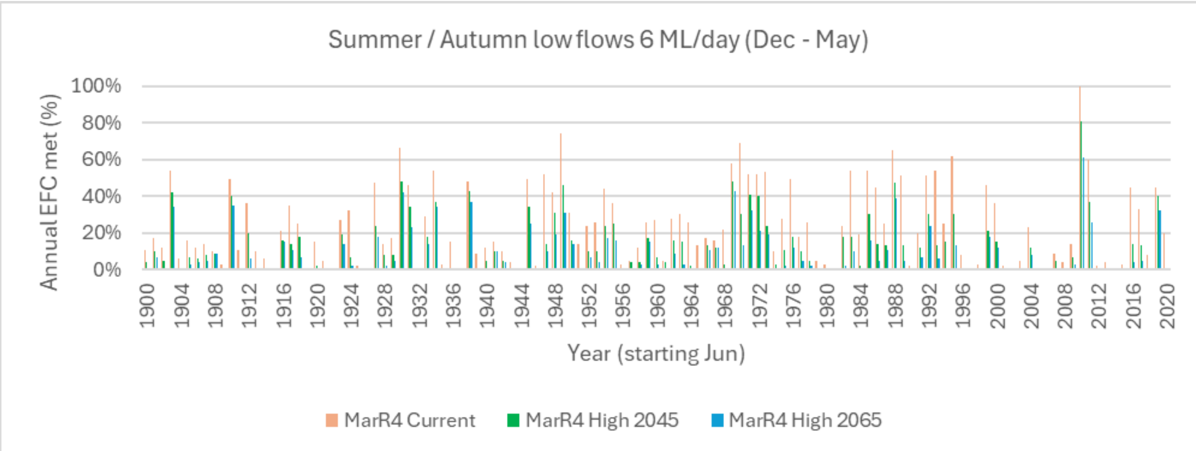
Performance decreased under future climate conditions for each flow component.

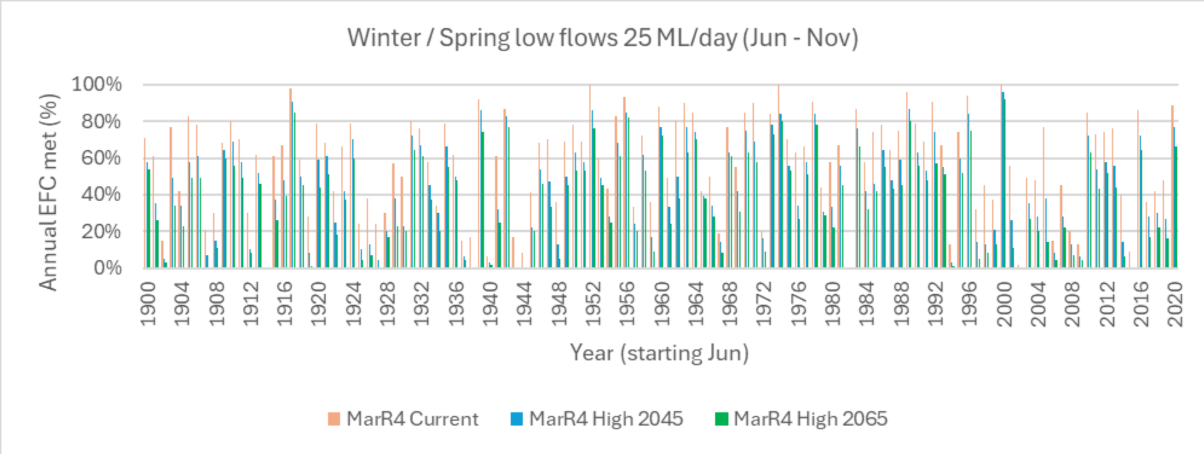
Performance summary – current climate

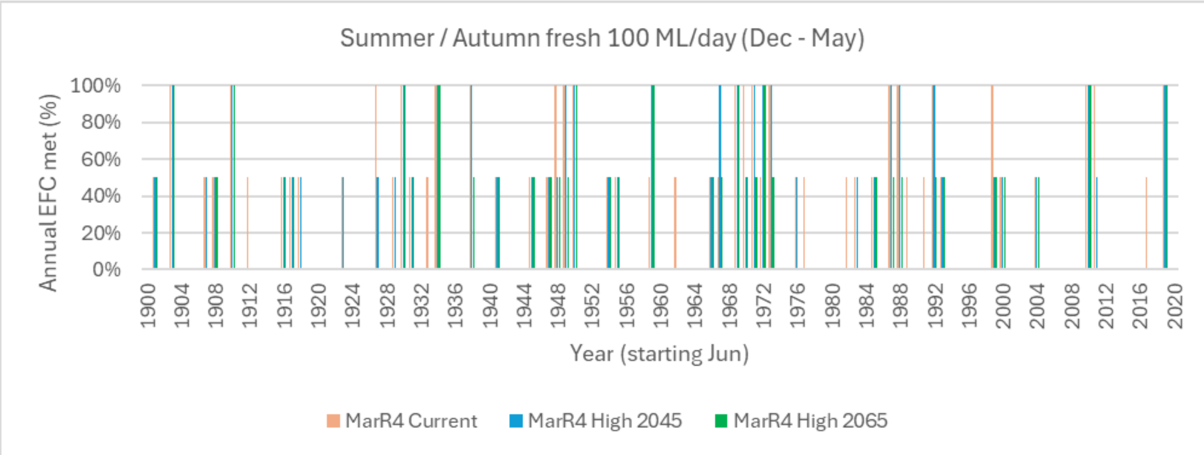
Flow component	Summer / Autumn low flow 6 ML/day (Dec - May)	Winter / Spring low flows 25 ML/day (Jun - Nov)	Summer / Autumn fresh 100 ML/day (Dec - May)	Winter / Spring fresh 250 ML/day (Jun - Nov)	High flows 1000 (Jun - May)
Mean annual performance	24%	58%	30%	49%	47%
Min annual performance	0%	0%	0%	0%	0%
Max annual performance	100%	100%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	52	91	57
Number of years with full achievement of recommendation*	0	0	20	23	57

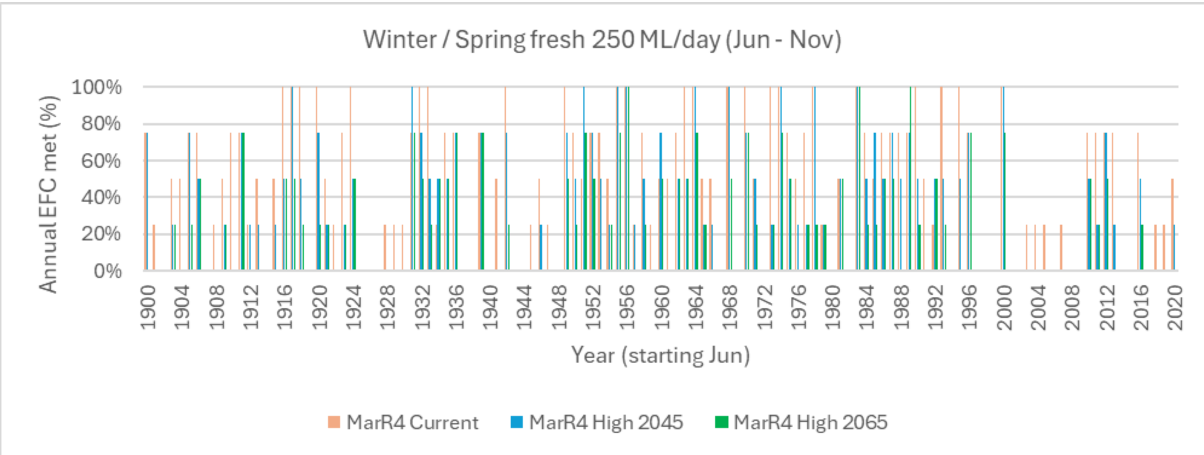
*out of the maximum possible 121 years

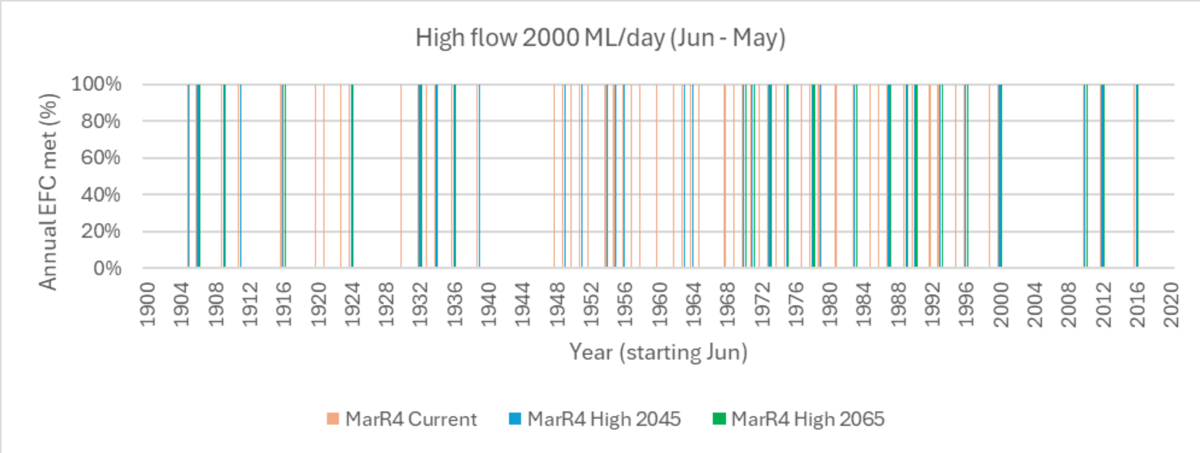
Annual performance in current climate, high 2045 climate and high 2065 climate




Winter / Spring low flows 25 ML/day (Jun - Nov)
Annual EFC met (%)
Year (starting Jun)
MarR4 Current
MarR4 High 2045
MarR4 High 2065


Summer / Autumn fresh 100 ML/day (Dec - May)
Annual EFC met (%)
Year (starting Jun)
MarR4 Current
MarR4 High 2045
MarR4 High 2065


Winter / Spring fresh 250 ML/day (Jun - Nov)
Annual EFC met (%)
Year (starting Jun)
MarR4 Current
MarR4 High 2045
MarR4 High 2065



Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	1%	15%	26%	32%
# Completely dry Dec - May	0	0	0	0
Av % CTF Jun - Nov	0%	3%	7%	11%
# Completely dry Jun - Nov	0	0	0	0

Performance analysis - Reach 5 (Riddells Creek)

In reach 5, low to moderate achievement of the recommended flows was observed, with average annual performance scores ranging from 34% - 54%. Two-thirds of years (82/121) experienced at least one Winter / Spring fresh event. Approximately one-fifth of analysed years saw full delivery of the recommended freshes. Full achievement of recommended high flows occurred in over half of years (65/121 = 54%).

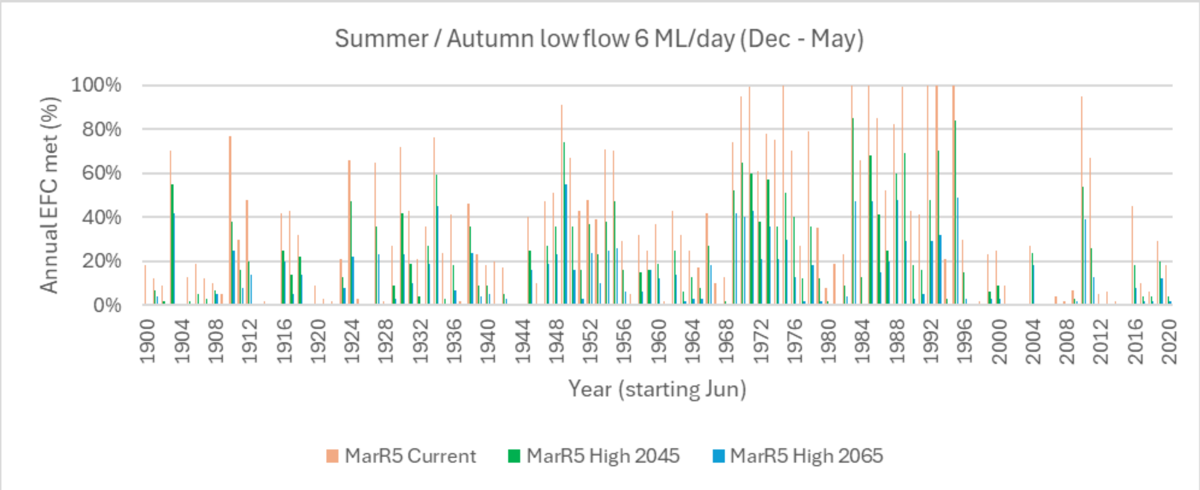
Performance decreased under future climate conditions for each flow component.

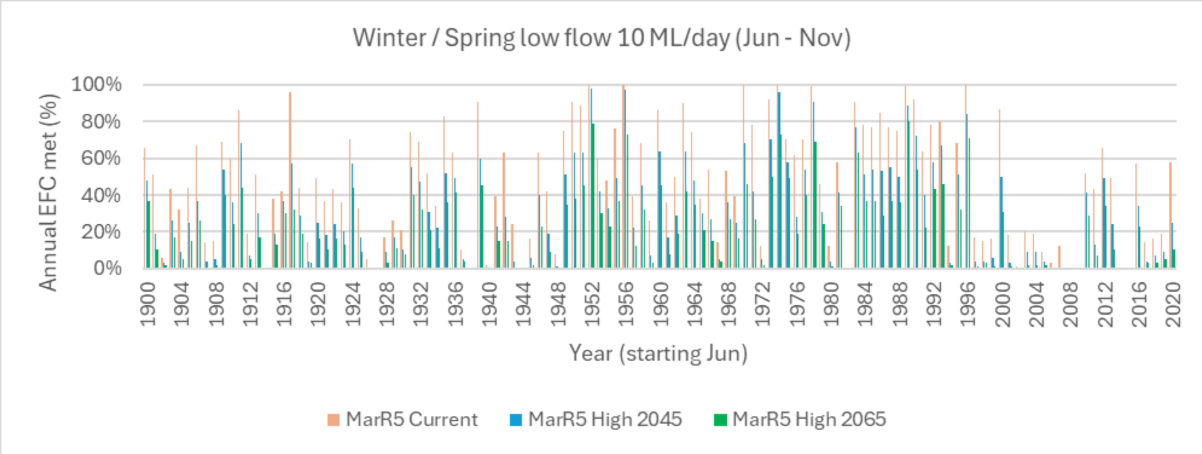
Performance summary – current climate.

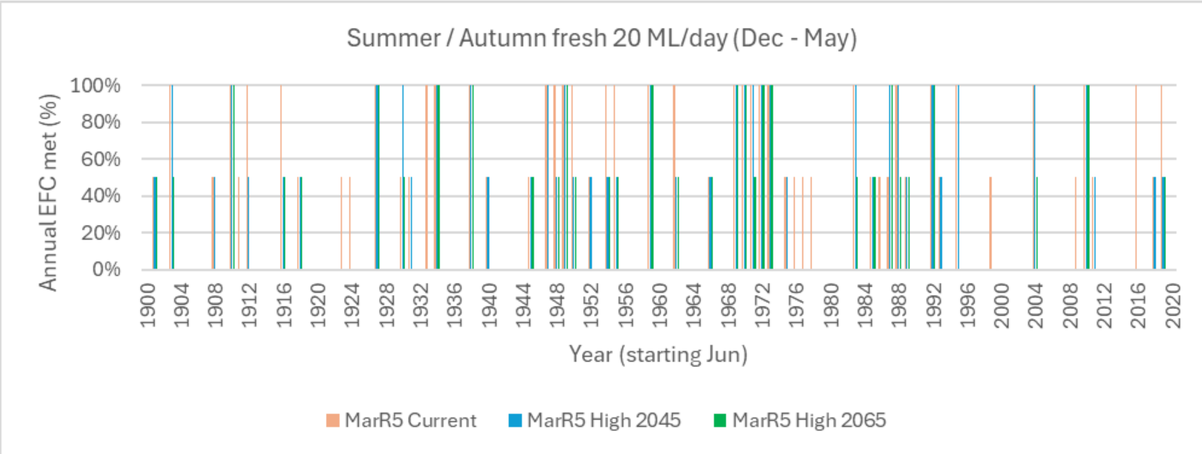
Flow component	Summer / Autumn low flows 6 ML/day (Dec - May)	Winter / Spring low flows 10 ML/day (Jun - Nov)	Summer / Autumn fresh 20 ML/day (Dec - May)	Winter / Spring fresh 50 ML/day (Jun - Nov)	High flow 400 (Jun - May)
Mean annual performance	35%	47%	34%	44%	54%
Min annual performance	0%	0%	0%	0%	0%
Max annual performance	100%	100%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	54	82	65
Number of years with full achievement of recommendation*	0	0	29	24	65

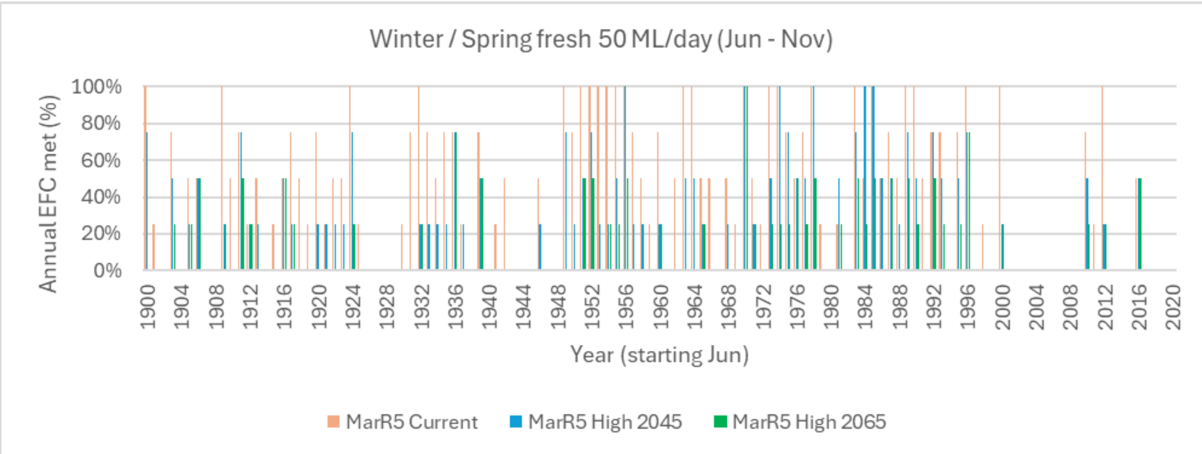
*out of the maximum possible 121 years

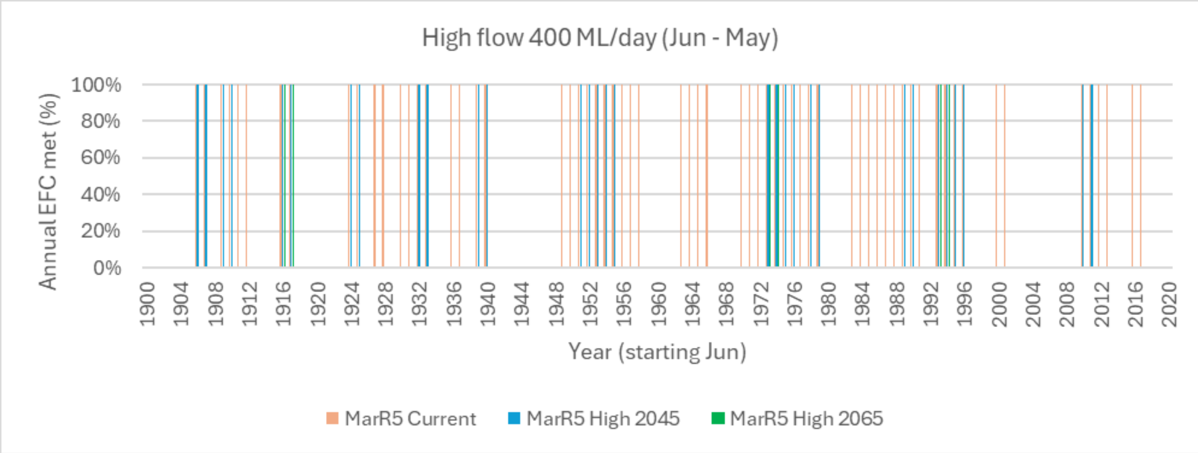
Annual performance in current climate, high 2045 climate and high 2065 climate




Winter / Spring low flow 10 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR5 Current
MarR5 High 2045
MarR5 High 2065


Summer / Autumn fresh 20 ML/day (Dec - May)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR5 Current
MarR5 High 2045
MarR5 High 2065


Winter / Spring fresh 50 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR5 Current
MarR5 High 2045
MarR5 High 2065



Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	22%	39%	55%	65%
# Completely dry Dec - May	0	1	8	16
Av % CTF Jun - Nov	3%	7%	18%	26%
# Completely dry Jun - Nov	0	0	0	1

Performance analysis – Reach 6 (Jacksons Creek Upper)

In Reach 6, excellent performance (84%) was observed for the delivery of low flows. This is presumed due to the consistent flows released from Rosslynne Reservoir.

The current capacity of the outlet at Rosslynne Reservoir is 20 ML/day, and under operational conditions this limit is closer to 15 ML/day. The limited capacity of the outlet and the lack of environmental entitlements therefore likely explain the very poor performance in the delivery of Winter / Spring low flows, freshes and high flows under modelled current conditions. Winter / Spring low flows and Summer / Autumn freshes both require operation of the outlet at maximum capacity (which is generally infeasible). Winter / Spring freshes and high flows can only be achieved through natural rainfall events (high local runoff) and overtopping of the reservoir spillway (rarely happens with the last two events having occurred in 1996 and October 2022; P. Mitchell, 2025)

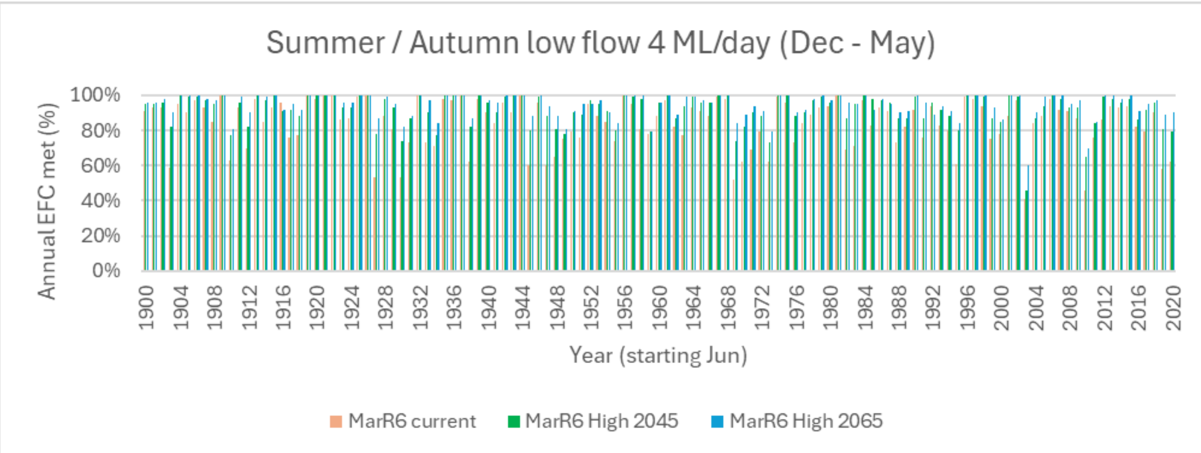
Performance decreased under future climate conditions for each flow component.

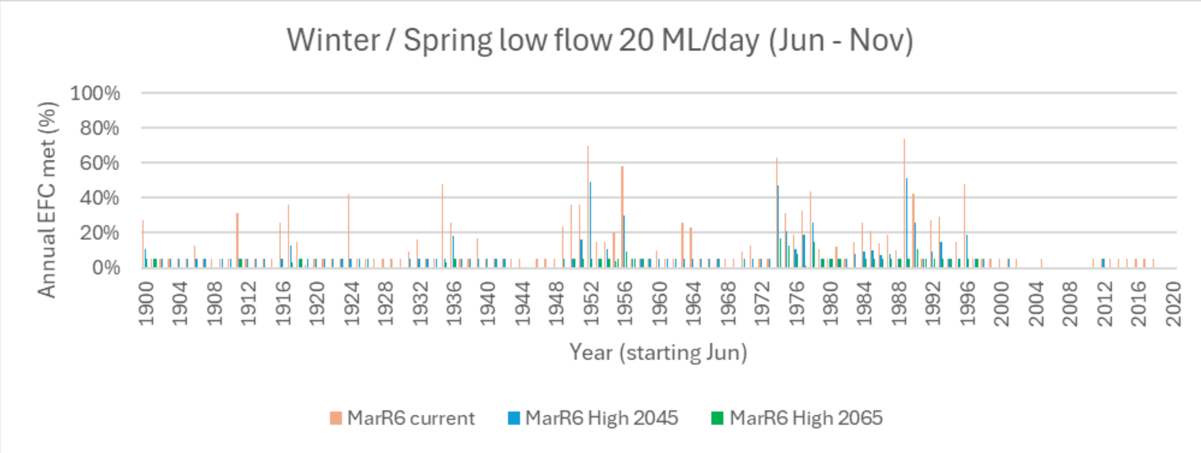
Performance summary – current climate

Flow component	Summer / Autumn low flows 4 ML/day (Dec - May)	Winter / Spring low flows 20 ML/day (Jun - Nov)	Summer / Autumn fresh 20 ML/day (Dec - May)	Winter / Spring fresh 1 215 ML/day (Jun - Nov)	Winter / Spring fresh 2 350 ML/day (Jun – Nov)	High flow 1000 (Jun - May)
Mean annual performance	84%	13%	5%	22%	11%	22%
Min annual performance	41%	0%	0%	0%	0%	0%
Max annual performance	100%	74%	100%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	11	33	22	50
Number of years with full achievement of recommendation*	0	0	2	20	5	7

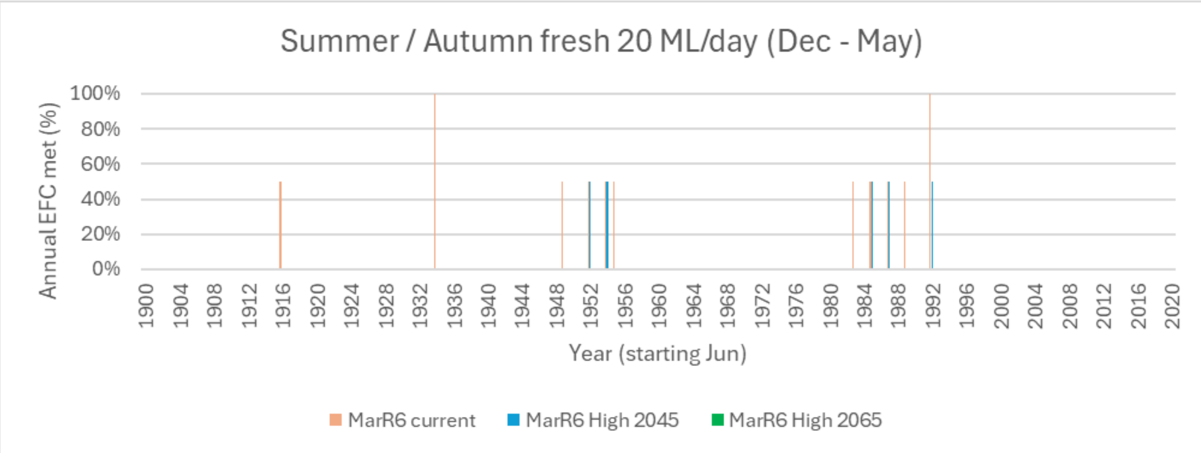
*out of the maximum possible 121 years

Annual performance in current climate, high 2045 climate and high 2065 climate

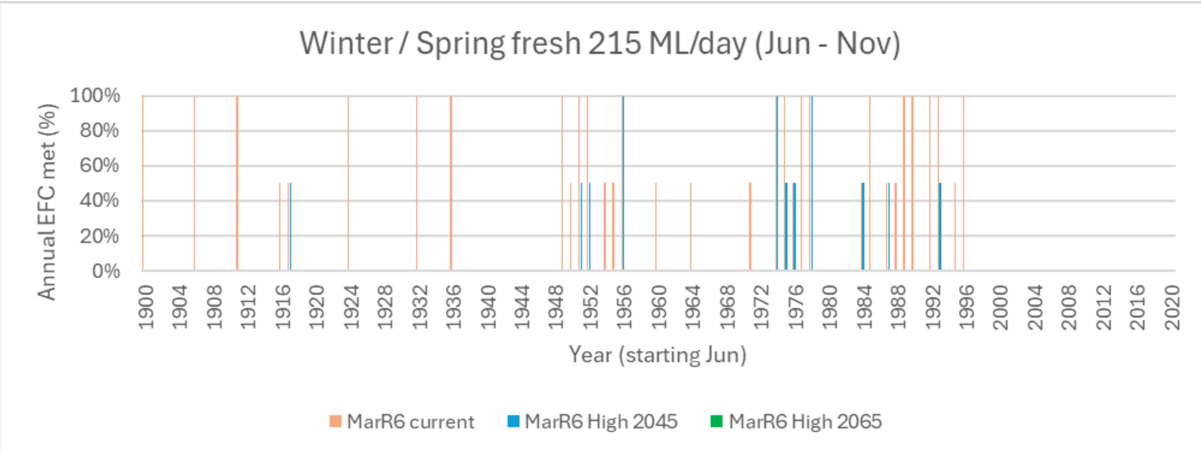




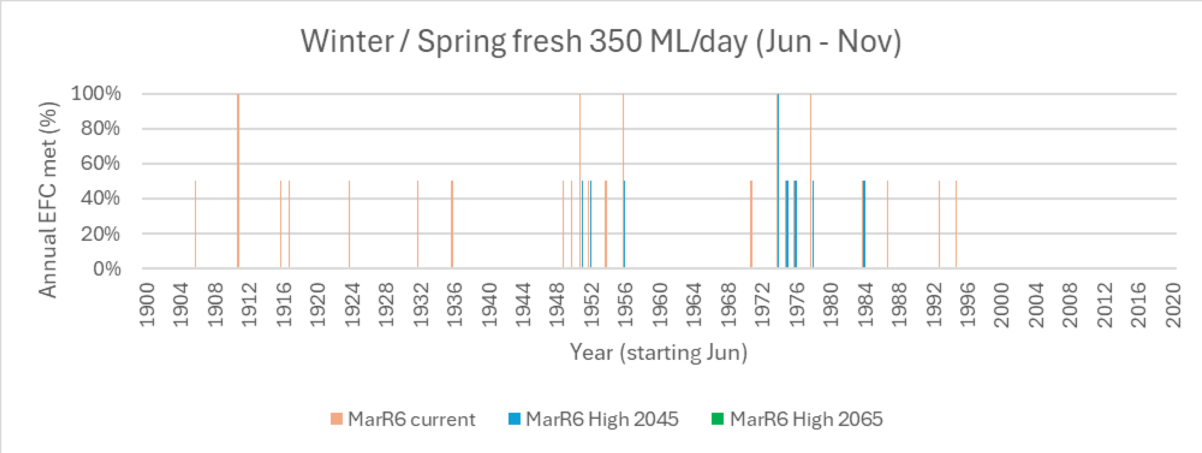
Winter / Spring low flow 20 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR6 current
MarR6 High 2045
MarR6 High 2065

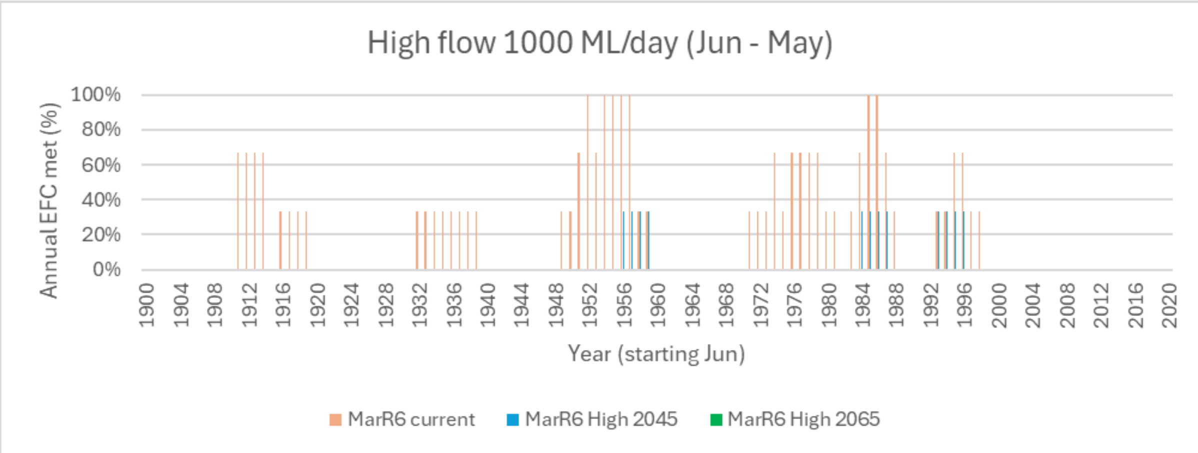


Summer / Autumn fresh 20 ML/day (Dec - May)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR6 current
MarR6 High 2045
MarR6 High 2065



Winter / Spring fresh 215 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR6 current
MarR6 High 2045
MarR6 High 2065





Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	21%	0%	0%	0%
# Completely dry Dec - May	0	0	0	0
Av % CTF Jun - Nov	5%	0%	0%	0%
# Completely dry Jun - Nov	0	0	0	0

Performance analysis – Reach 7 (Jacksons Creek Lower)

Good performance was observed in the delivery of Summer / Autumn low flows in Reach 7 (mean performance 65%). Poor to moderate average performance (33% – 44%) was observed for Winter / Spring low flows, freshes and high flows. Performance scores were generally higher in reach 7 than those of Reach 6, (particularly in the performance of higher magnitude flows) and this is thought due to unregulated inflows from Riddells Creek.

Cease to flow events do not occur in Reach 7 under modelled current conditions.

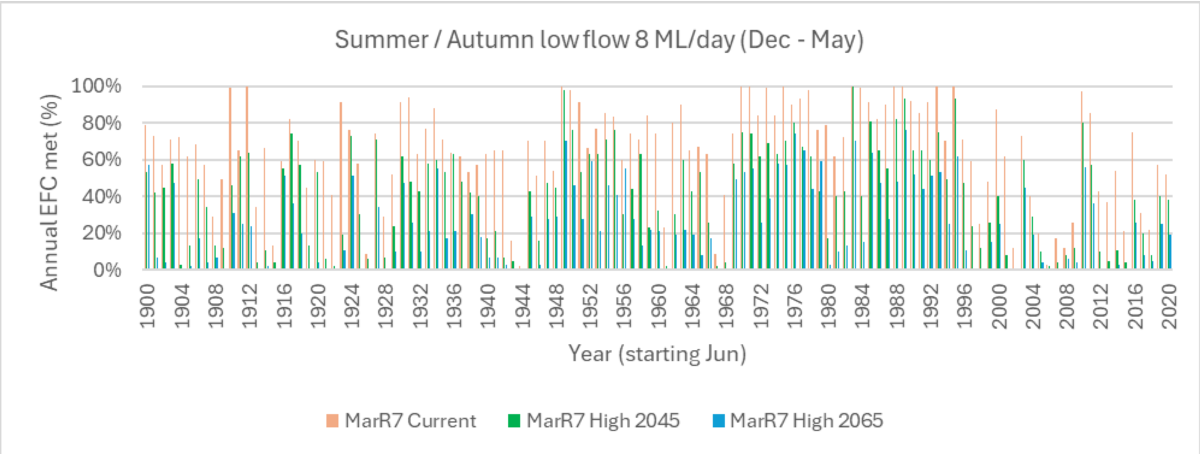
Performance decreased under future climate conditions for each flow component.

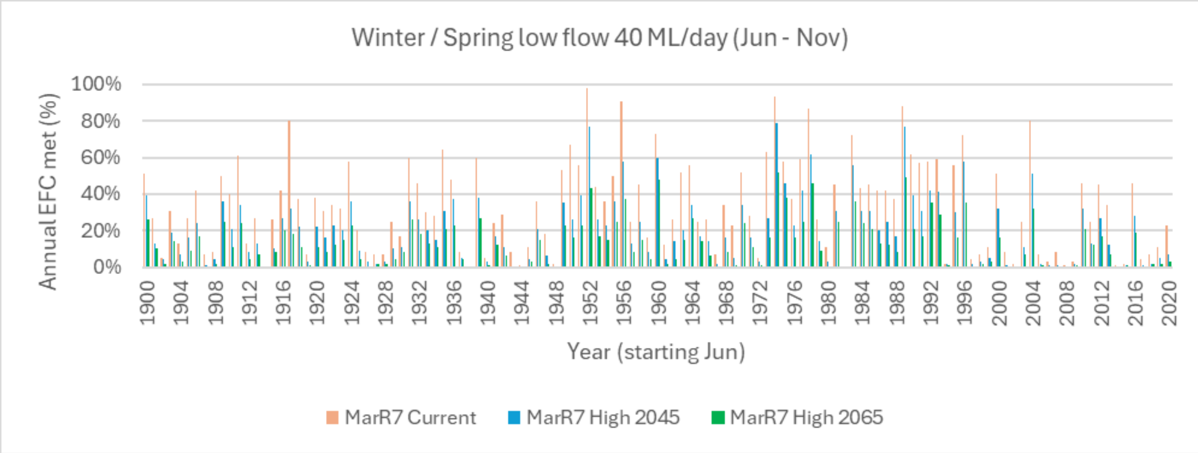
Performance summary – current climate

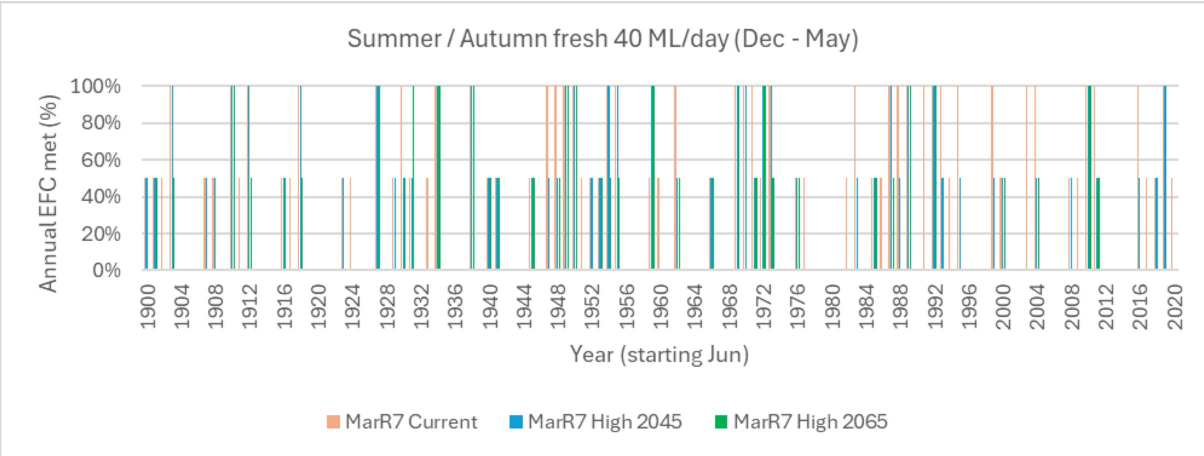
Flow component	Summer / Autumn low flows 8 ML/day (Dec - May)	Winter / Spring low flows 40 ML/day (Jun - Nov)	Summer / Autumn fresh 40 ML/day (Dec - May)	Winter / Spring fresh 400 ML/day (Jun - Nov)	High flow 2000 (Jun - May)
Mean annual performance	65%	33%	43%	38%	44%
Min annual performance	2%	0%	0%	0%	0%
Max annual performance	100%	98%	100%	100%	100%
Number of years with at least 1 event*	N/A	N/A	69	57	90
Number of years with full achievement of recommendation*	0	0	34	36	23

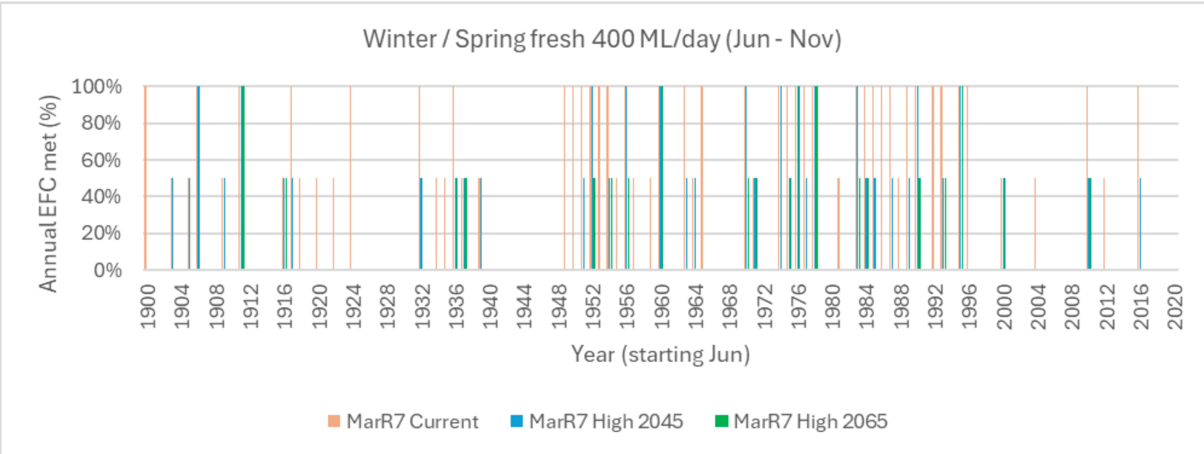
*out of the maximum possible 121 years

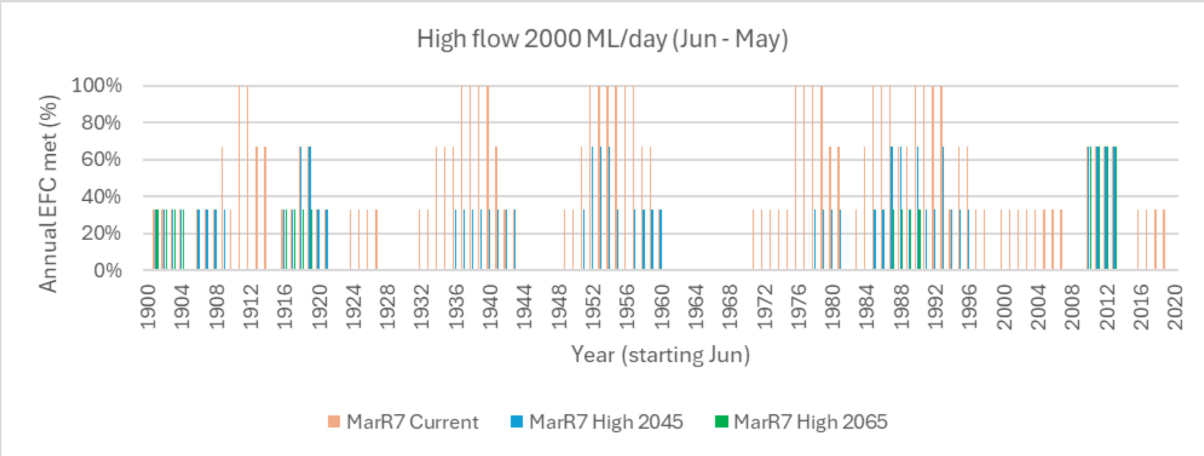
Annual performance in current climate, high 2045 climate and high 2065 climate




Winter / Spring low flow 40 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR7 Current
MarR7 High 2045
MarR7 High 2065


Summer / Autumn fresh 40 ML/day (Dec - May)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR7 Current
MarR7 High 2045
MarR7 High 2065


Winter / Spring fresh 400 ML/day (Jun - Nov)
Annual EFC met (%)
100%
80%
60%
40%
20%
0%
1900 1904 1908 1912 1916 1920 1924 1928 1932 1936 1940 1944 1948 1952 1956 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 2008 2012 2016 2020
Year (starting Jun)
MarR7 Current
MarR7 High 2045
MarR7 High 2065



Cease to flow statistics

Modelled scenario	Natural	Current	High 2045	High 2065
Av % CTF Dec - May	6%	0%	0%	0%
# Completely dry Dec - May	0	0	0	0
Av % CTF Jun - Nov	0%	0%	0%	0%
# Completely dry Jun - Nov	0	0	0	0