Macalister River Environmental Water Management Plan

West Gippsland Catchment Management Authority

May 2023

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Document history and status

Revision and distribution

Version no.	Description	Issued to	Issue date
1	First draft	Eleisha Keogh (WGCMA)	Various
2	Second draft	Jamie Bell (DELWP), Macalister PAG, Martin Fuller (WGCMA), David Stork (WGCMA), Eleisha Keogh (WGCMA)	17.11.2015
3	Third draft	Internal WGCMA review and update	Various
4	Final draft	DELWP	23.12.2022

Management

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Name of document:	Macalister River Environmental Water Management Plan

Acknowledgements

Acknowledgment of Country

We acknowledge and pay our respects to the Traditional Owners of the region, the Gunaikurnai, their rich culture and spiritual connection to Country. We also acknowledge their responsibility to care for Country and pay our respects to Elders, past, present, and emerging.

Traditional Owner input and guidance on objectives and values was received from the Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) via the Gunaikurnai Cultural Water Team.

Contributions to the Macalister River EWMP

The WGCMA would like to gratefully acknowledge the contribution of the following people in preparing the EWMP:

- Amanda Wealands, Amanda Shipp and Hamid Ghajarnia, Alluvium Consulting
- Wayne Koster, Paul Boon, Dom Blackham, Nick Marsh, Jon Fawcett, Josh Griffiths, Tim Doeg and Ian Smales – Expert Panel for Macalister Environmental Flows Study
- Gavin Prior and Terry Clapham, Southern Rural Water
- Mark Toomey, Victorian Environmental Water Holders
- Susan Watson, Department of Environment, Land, Water and Planning
- Macalister Project Advisory Group (PAG/EWAG) including Rob Caune (VRFish), Tim Curmi (Native Fish Australia), Phil Taylor (Environment Victoria), Duncan Fraser (Maffra and districts landcare network), Steve Dwyer (MID landholder), Alex McArthur (MID landholder), Fiona Pfeil and Jolyon Taylor (Gippsland Water), Tim Rowe and Melissa Bastian (Wellington Shire Council) and Rod Johnston (WGCMA)
- Uncle Lloyd Hood and Timothy Paton, GLaWAC Water Officers
- Kate Austin, Brad Neale and Katherine Szabo, HARC

Glossary of terms and abbreviations

DEECA	Department of Energy, Environment and Climate Action The new Victorian government department established in early 2023 that is now responsible for the management of the state's water resources.
DELWP	Department of Environment, Land, Water and Planning The previous Victorian government department established in late 2014 that was responsible for the management of the state's water resources.
DEPI	Department of Environment and Primary Industries The earlier Victorian government department (2010-2014) that was responsible for the management of the state's water resources.
Ecological flow objectives	Measurable outcomes that are linked with the hydrologic management of environmental water. The achievement of ecological objectives should be able to be measured through monitoring programs. They may also be referred to as environmental objectives.
EFTP	Environmental Flows Technical Panel The technical panel is part of the broader project team and is comprised of scientists/engineers with expertise in the areas of vegetation, hydrology, fish biology and geomorphology. Their role is to undertake the technical assessments for the Macalister eflows project in order to determine the important flow requirements for the river.
EFRs	Environmental Flow Recommendations
Environmental flows	The flows required to maintain healthy aquatic ecosystems such as waterways, floodplains or wetlands. These flows reflect the needs of animals, plants, habitats and processes that are dependent on the specific hydraulic and physico-chemical conditions created with different flow events that help to maintain their ecological integrity.
Environmental water	Refer to *environmental flows*.
EWR	Environmental Water Reserve An amount of water set aside specifically to benefit the aquatic ecosystem for which it is to be delivered. This water includes statutory environmental water entitlements (i.e. environmental water held in storages), minimum passing flows that are delivered from consumptive water entitlements held by urban and rural water corporations and unregulated flows and spills from storages.
EWMP Scientific Panel	Environmental Water Management Plan Scientific Panel A state government mandated panel whose role is to review all the EWMPs developed around the state. They will be reviewing the Macalister River EWMP and the scientific integrity of the underlying data.
EWMP	Environmental Water Management Plan A long term scientifically-based management plan that will set the ecological objectives and the watering regime required to meet these objectives. The EWMP will inform the Seasonal Watering Proposals that set the annual priorities for watering in that year.
Flow regime	The hydrologic pattern of flows that occurs in a waterway, floodplain or wetland influencing the hydraulics, ecology and geomorphology of that ecosystem. Flow regimes are typically described using flow events (e.g. fresh, bankfull flow), as well as the duration, timing, frequency and magnitude parameters. Natural flow regimes are those where there is no human intervention to the natural flow patterns for the system. Developed or regulated flow regimes are those where human intervention has altered the natural flow pattern. Intervention may include the presence of water storages or flow control points, the extraction of water, or the input of water.
Flow regulation	The alteration of the natural flow pattern in an aquatic ecosystem through the installation of water storages that control the hydrology of a range of incoming flows. The Macalister River is considered a regulated river system due to the presence of Glenmaggie Weir and Maffra Weir.
FLOWS method:	A systematic, repeatable and scientific method provided by DEPI to determine the environmental water requirements for aquatic ecosystems in Victoria. The method was updated in 2013 following its original release in 2002.

Flow recommendations	One of the outputs of the FLOWS method. The recommendations describe the full suite of flow components that would be present under a natural flow regime for a system. Flow recommendations will be determined with the Macalister eflows project.
Flow targets	Flow targets link the hydrologic objectives to a target site or reach. For example, an annual 4 day spring 800 ML/day fresh in Reach 2 of the Macalister River.
GLaWAC	Gunaikurnai Land and Waters Aboriginal Corporation
Macalister eflows project:	The scientific study underlying the Macalister River EWMP. It implements many steps from the FLOWS method as well as stakeholder consultation to define and prioritise the flow requirements for the Macalister River and improve water management. The Macalister eflows (environmental flows) project is the short form for the official project name; the Macalister River Environmental Flows and Management Review Project.
Management goals	A long term health goal or vision statement reflective of the water dependent values of the Macalister River.
MID2030	Macalister Irrigation District 2030 A project led by Southern Rural Water to modernise the water supply to the Macalister Irrigation District (MID). This is via a combination of pipelining and channel automation to achieve water savings, improve supply service and enable increased productivity in the MID.
PAG	Project Advisory Group A representation of stakeholders in the community linked to environmental water, and more broadly, water management within the Macalister River.
SC	Steering Committee This is a committee established specifically for this project. The members of this committee represent stakeholders that are directly involved in the management of environmental water. These stakeholders are DELWP, VEWH, SRW and WGCMA. The Steering Committee's role is to oversee the implementation of the project.
SRW	Southern Rural Water The company responsible for rural water supply for the Macalister catchment. They are the storage managers for Glenmaggie and Maffra Weirs.
ToR	Terms of Reference Statement of the purpose, structure and role of a project/group. For this project, two ToRs have been established to guide the PAG and the SC.
VEWH	Victorian Environmental Water Holder An independent statutory organisation that works with Catchment Management Authorities (CMAs) and Melbourne Water to ensure that Victoria's environmental water entitlements are effectively managed to achieve environmental outcomes.
Water dependent values	Components of the ecosystem that are dependent on water provided from the river for critical life history stages or maintenance of its ecological integrity. Values may be a species, a community, a place of natural value, a process or habitat.
WGCMA	West Gippsland Catchment Management Authority The waterway manager for all waterways within the West Gippsland region, including the Macalister River. The WGCMA is also the project manager for this project and a key stakeholder. As such, the WGCMA will be represented in the PAG and the SC.

Contents

Macalister River Environmental Water Management Plan i
Disclaimer ii
Copyright ii
Document history and status ii
Acknowledgements iii
Contributions to the Macalister River EWMP iv
Glossary of terms and abbreviations v
Executive summary 1
1. Introduction 4
Purpose and Scope 4
EWMP development process 5
Consultation 6
Partnerships 7
Delivery partners 8
Traditional Owners 8
Community 9
2. Site Overview 10
Site location 10
Catchment Setting 11
Climate 11
Hydro-physical characteristics 14
Land status and management 19
Waterway management 21
Environmental water management 21
Environmental water sources and delivery 22
Related agreements, policies, plans and reports 25
3. Hydrology and water use 27
Surface water hydrology 27
Average daily flows 30
Streamflow monitoring 31
Water quality 31
Groundwater 32
Groundwater-surface water connectivity 33
Consumptive water use 33

Environmental watering..34
Environmental Flow Compliance 36
Environmental water shortfalls...37
4. Ecological values of the Macalister River...40
Overall condition of the system 40
Fish...40
Flow-ecology linkages 41
Macroinvertebrates 45
Flow-ecology linkages 45
Platypus and rakali...45
Flow-ecology linkages 46
Birds, turtles, and frogs 47
Flow-ecology linkages 47
Vegetation..48
Flow-ecology linkages 49
Water-related threats to ecological values...51
5. Traditional Owner Values of Wirn wirndook Yeerung (Macalister River) 52
Gunaikurnai Country 53
Wirn wirndook Yeerung (Macalister River)..54
Carran Carran (Thomson River) 54
Durt-Yowan (Latrobe River) & lower Latrobe Wetlands 54
Cultural objectives and environmental water linkages 55
6. Socio-economic values of the Macalister River...57
Recreational values 57
Economic values...57
Shared benefits...57
7. Management objectives..59
Macalister River vision statement...59
Management objectives 59
Water dependent ecological values 60
Ecological outcomes and ecological flow objectives 60
Flow recommendations 65
8. Implementing an environmental watering regime..76
Planning and prioritisation of watering events 76
The habitat assessment approach...76
Scenario Planning 80
Environmental water shortfalls 83

9. Managing risks to achieving objectives....84
10. Environmental water delivery constraints....86
11. Demonstrating outcomes: monitoring....88
Operational monitoring....88
Intervention monitoring....89
Condition monitoring....89
12. Recommendations....90
Addressing knowledge gaps....90
Complementary works....94
References....95
Appendix A: Fish survey records....100
Appendix B: List of water dependent fauna (excl. fish) in the Macalister River....101
Appendix C: List of water dependent flora in the Macalister River....103
Appendix D: Habitat preference curves....108
Reach 1....108
Reach 2....110

Executive summary

The Macalister River Environmental Water Management Plan (EWMP) is a guiding document that sets out long-term (5-10 years) ecological outcomes, objectives and water requirements for the Macalister River (*Wirn wirndook Yeerung*) downstream of Lake Glenmaggie.

The EWMP has been developed using the principles identified in the established vision statement for the Macalister system:

"In partnership with the community, we will preserve and enhance habitat to support native water dependent plants, animals and the ecological character of the Macalister River and floodplains for current and future generations."

This plan sets out a flow management template to maintain and rehabilitate the ecological health of the Macalister River reaches using a habitat provision approach. The plan clearly identifies where environmental water (and flow management) can make contributions to habitat using the flow requirements of various ecological values.

The EWMP draws on guidance from multiple data sources including the overarching West Gippsland Regional Waterway Strategy (WGCMA, 2014), DELWP EWMP guidelines (DELWP, 2022), technical studies and community input.

It is intended that this document will remain dynamic, with information updated to reflect the best available information regarding the Macalister River system, the environmental entitlement, ecological condition, and Traditional Owner knowledge and objectives.

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The Macalister River EWMP is comprised of the following sections.

Section 1 describes the purpose and scope of the EWMP, the major inputs and the consultation undertaken to develop this plan.

Section 2 describes the climate, hydro-physical characteristics, land and waterway management in the Macalister River. This section also lists the sources of environmental water available to the river, recognising multiple potential sources outside of the formal environmental entitlement. This section provides an illustrated overview of both reaches using aerial imagery and landscape photographs.

Section 3 outlines the key changes to the hydrology of the Macalister River using modelled flow scenarios. This section highlights that there are significant reductions in annual streamflow, flow augmentation during naturally low flow periods, and decreased high and medium flow peaks during the winter and spring season. This section also briefs on the groundwater-surface water relationships and water quality in the system.

Section 4 summarises the water dependent ecological values in the Macalister River, outlining the existing condition and flow-ecology linkages for fish, macro-invertebrates, birds/turtles/frogs, platypus/rakali and vegetation. This section also outlines the key water-related threats which include in-stream barriers, poor water quality, introduced species, degraded stream bank and floodplain condition and cold water/low oxygen releases from Lake Glenmaggie.

Section 5 outlines high level Gunaikurnai Traditional Owner culture, values and linkages, and how they are to be meaningfully incorporated in annual and long term environmental water planning.

Section 6 outlines the main socio-economic values of the Macalister River, reflecting its existing recreational values. The river is also recognised for its significant economic contributions to the local and statewide economy.

Section 7 summarises the management objectives and targets as they relate to the ecological flow recommendations. It also details the flow management template upon which environmental watering in this system will be based. It specifies the ecological outcomes, measurable ecological flow objectives, and corresponding flow recommendations for reaches 1 and 2. The flow recommendations are characterised by targets for magnitude, timing, duration, and frequency.

Section 8 discusses the proposed tools and approaches for planning, prioritisation and implementation of an environmental watering regime. This section also highlights the need to quantify the environmental water shortfall in the system and suggests different mechanisms to address shortfalls.

Section 9 presents results from a qualitative risk assessment focussing on the risks to water dependent ecological values and environmental water management.

Section 10 identifies the delivery constraints for environmental watering in the system.

Section 11 summarises the types of monitoring that have been undertaken in reaches 1 and 2 to inform environmental water management.

Section 12 presents the key knowledge gaps and identifies activities to address these gaps through monitoring, technical studies or other works. This section also identifies complementary on-ground works that may maximise the benefit of environmental watering in the Macalister.

The key recommendations emerging from this EWMP include:

1. Use the *flow recommendations* for future environmental water planning and delivery. The bulk of the flow events recommended reinstate the key elements of the "natural" flow regime that have now been modified due to flow regulation
2. Continue to explore options to reconcile the environmental water shortfall
3. Invest in *intervention monitoring* that *builds the empirical evidence* for conceptual flow-ecology linkages that underpin the flow recommendations
4. Shift from a sole hydrologic focus to a hydrologic and *habitat provision focus* to inform future environmental water planning and prioritisation activities
5. *Build on existing collaborative relationships* between government and non-government institutions, with a focus on the partnership between the waterway manager (WGCMA) and the storage manager (SRW)
6. *Build on existing collaborative relationships* between the WGCMA and GLaWAC to meaningfully incorporate Traditional Ecological Knowledge, objectives and values into environmental flow management decisions
7. Continue to *strengthen community engagement* through environmental water management and increase community advocacy for the welfare of the river

1. Introduction

Purpose and Scope

The Macalister River Environmental Water Management Plan (EWMP) has been prepared by the West Gippsland Catchment Management Authority (WGCMA) to establish the long-term management goals of the Macalister River system. The purpose of the EWMP is to:

- Identify the long-term ecological outcomes, objectives and water requirements for the Macalister River (*Wirn wirndook Yeerung*).
- Describe the most effective use of the *Macalister River Environmental Entitlement 2010* based on the best available evidence;
- Provide an avenue for community consultation;
- Inform the development of Seasonal Watering Proposals and Seasonal Watering Plans; and
- Guide short and long term decision making associated with water resource and waterway management in the Macalister River system.

The EWMP will serve as a guiding document for the WGCMA, Victorian Environmental Water Holder (VEWH) and the Department of Energy, Environment and Climate Action (DEECA)and a reference point for the community.

The aspects that are in scope and out of scope for the Macalister River EWMP are detailed in Table 1.

Table 1. Items within and outside of the scope for the Macalister River Environmental Water Management Plan

In scope	Out of scope
• Macalister River reaches from downstream Lake Glenmaggie to the Macalister-Thomson Rivers confluence • Description of the water dependent values and ecological condition of the system • Establishment of ecological objectives, and ecological flow objectives • Development of flow recommendations based ecological, hydrologic and hydraulic inputs • Identification of ancillary works to maximise the benefit of environmental watering • Identification of knowledge gaps, constraints, opportunities and monitoring requirements to enable continual improvement	• Macalister River upstream of Lake Glenmaggie and downstream of the Macalister-Thomson confluence • Detailed discussion and/or assessment of ancillary works to maximise the benefit of environmental watering • Detailed consideration of environmental benefits to the Gippsland Lakes and Wetlands • Comprehensive ecological condition assessments on water dependent flora, fauna and ecosystems

EWMP development process

The Macalister River EWMP was prepared using input from:

1. ***Technical FLOWS study****:* the Macalister River Environmental Flows and Management Review project updated the environmental flow recommendations for the Macalister River in 2015, based on current ecological, hydrologic and hydraulic modelling information. This study also consolidated these inputs to describe the ecological condition of the system, and make an assessment of water shortfalls, priorities, monitoring requirements and knowledge gaps.
2. ***Updated hydrologic modelling:*** In 2022, the Thomson-Macalister Source model was used to develop different flow scenarios and the calculation of shortfalls. This new information has now been incorporated into this revision. This has replaced the REALM modelling data from 2014-15 which consisted of monthly averages for current and un-impacted flow scenarios.
3. ***Project Advisory Group (PAG):*** the PAG was comprised of members from the broader community with links to the Macalister River. Members included representatives for landholders, Southern Rural Water (SRW), Native Fish Australia, Victorian Recreational Fish, Environment Victoria, Maffra Landcare network, Wellington Shire Council, Gippsland Water and the WGCMA. The PAG have contributed their local knowledge, values and concerns through a series of workshops so that the content in the EWMP are not at odds with community values and expectations.
4. ***Steering Committee:*** The Steering Committee was comprised of stakeholder groups directly involved with flow management in the Macalister River including a member from DEECA, WGCMA, SRW and the VEWH. The Steering Committee oversaw the Technical Eflows Study and the EWMP development to ensure both were achieving their desired purpose. The Steering Committee also provided feedback and guidance on effective engagement with the PAG.
5. ***Idea and knowledge exchanges with other CMAs:*** EWMP workshops attended by various CMAs provided opportunities to clarify content, exchange ideas and problem solve approaches to different elements of the EWMP. These workshops also encouraged the sharing of ecological information and draft EWMPs that have inspired improved ways of communicating complex content in a way that is engaging and clear.
6. ***Review and updating:*** Updated guidelines from DEECA were finalised in 2022. Changes to the initial Macalister EWMP draft have been incorporated to reflect these changes and improve the overall structure, details and function of this management plan. Also included are updates to models and technical information.
7. ***Traditional Owner engagement:*** As part of this review process, the WGCMA and GLaWAC have, and will continue to, discuss options and opportunities for increased participation and inclusion of Gunaikurnai Traditional Owner input and collaboration in the ongoing management of environmental water to support and improve the *Wirn wirndook Yeerung* (Macalister River).

Consultation

Consultation for the Macalister River Environmental Water Management Plan was undertaken through the following avenues:

- An established **Project Advisory Group (PAG)** that consists of representatives from a broad range of stakeholders groups associated with the Macalister River. The group was engaged through four workshops that informed and obtained their feedback on different elements of the plan development.
- A **Steering Committee** consisting of stakeholders directly involved in the development of the EWMP, to provide oversight for the overall project.
- Widespread **public consultation** through publication of the draft EWMP on the WGCMA website to invite feedback from the general public.
- GLaWAC – through Water Program Officers, Uncle Lloyd Hood and Timothy Paton. Information was shared between the WGCMA and GLaWAC through the EWMP review process and through the completion of the Thomson and Latrobe flows studies. Noting that this is an evolving space, and as capacity and resourcing allows GLaWAC would like to take the lead on preparing cultural objectives and values for waterways and the broader region.

The roles of the Macalister PAG and the Steering Committee in the technical environmental flows study (Alluvium, 2015) and the development of the Macalister EWMP is summarised in Table 2.

Table 2. Membership and role of the groups involved in EWMP development

Group	Membership	Role in EWMP development
Macalister Project Advisory Group (PAG)	• Southern Rural Water • Maffra and Districts Landcare Network • Native Fish Australia • Victorian Recreational Fishing • Environment Victoria • Gippsland Water • Lower Macalister landholders/irrigators (2) • Wellington Shire Council • Gunaikurnai Land and Water Aboriginal Corporation (late 2015)	**Provided input on:** • Water dependent values • Vision statement • Ecological objectives • Monitoring requirements and knowledge gaps • Opportunities for improvement **Provided feedback on:** • Ecological & flow objectives • Flow recommendations • Technical reports from eflows study • Draft EWMP
Macalister Steering Committee	• Victorian Environmental Water Holder • Department of Environment, Land, Water and Planning • WGCMA • Southern Rural Water	• Project oversight and direction • Project timeline management • **Provided feedback on:** • Engagement with PAG • Technical reports from eflows study • Draft EWMP
Water and Catchments – EWMP Guideline	• Department of Environment, Land, Water and Planning	• Updated EWMP guidelines in 2022

Group	Membership	Role in EWMP development
development working groups		
GLaWAC	• Traditional Owners – GLaWAC Water Officers • EWAGs	• Cultural input – objectives and values in flows studies for the Thomson and Latrobe • Review of annual planning process (Seasonal Watering Proposals) • Consultation around monitoring and other NRM opportunities in the Macalister region

Partnerships

Strong partnerships between agencies involved in flow management is critical to the long-term health and well-being of the Macalister River ecosystem. It is important that there is ongoing engagement between agencies for all water management activities and complementary works that occur on the Macalister River.

The Water for the Environment Community Engagement Plan sets out the direction for engagement around water for the environment (WftE) in West Gippsland from 2019 to 2024 (WGCMA, 2019). The WGCMA developed this plan with input from the VEWH and DELWP (now DEECA) with the aim of engaging with stakeholders in the West Gippsland region, specifically (but not limited to) those who interact with the Thomson, Latrobe, and Macalister river systems and the lower Latrobe wetlands. A community engagement goal of the plan is to have a water literate and environmentally aware community that is connected to their waterways and reaps the benefits of water for the environment.

The purpose of the engagement plan is to;

1. Increase community awareness and understanding of WftE in the region
2. Improve our understanding of, and provide opportunities for, providing and enhancing the shared benefits of WftE
3. Increase community capacity and provide meaningful opportunities to participate in management of WftE
4. Support Traditional Owners to build their capacity to contribute Aboriginal values and objectives to water management, whilst building our own capacity to work together with Traditional Owners

This should result in the following long-term outcomes;

1. Collaborative relationships that support flow regimes which are optimised for multiple needs
2. Community support and advocacy for waterways and water for the environment
3. Ensuring the “environment” is seen as a legitimate water user
4. Traditional Owners are empowered to participate in water management and progress their interests in water management

Delivery partners

Collaboration is particularly important between the waterway manager (WGCMA), water holder (VEWH) and the storage manager (SRW), and areas for collaborative work include:

- Working together to shape unregulated releases from Lake Glenmaggie during SRW's filling season, which requires SRW to contact WGCMA when forecasting such a release
- WGCMA consulting with SRW on inflows to the storage and consumptive demand to determine the current climate scenario
- WGCMA and SRW working out a suitable timing to deliver environmental watering actions during irrigation season, so that both consumptive and environmental water demands may be met
- SRW to endorse annual Seasonal Watering Proposals
- VEWH, WGCMA, and SRW to maintain and review the Macalister River Operating Arrangements (VEWH, 2014), which formalise the approaches, roles and responsibilities for management and delivery of the environmental water holdings in the Macalister system.

Traditional Owners

The Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) is the Registered Aboriginal Party (RAP) for the Gunaikurnai community, the Traditional Owners of Country encompassing the WGCMA, as determined by the Victorian Aboriginal Heritage Council under the Aboriginal Heritage Act, 2006 (GLaWAC - Who we are, 2022).

The WGCMA will continue to collaborate with the Gunaikurnai Community through the GLaWAC Cultural Water team. As outlined in the WGCMA WftE engagement plan, our aim is to support Traditional Owners to build their capacity to contribute Aboriginal values and objectives to water management, whilst building our own capacity to work together with Traditional Owners. Specific actions and activities will include:

- Building of cultural water knowledge through the GLaWAC cultural water program and WGCMA environmental water program teams working closely together – knowledge sharing, two-way capacity building and mentoring, and technical and field work support
- GLaWAC engagement and input into flows studies and EWMPs (through Project Advisory Groups)
- GLaWAC engagement and input into annual water planning (Seasonal Watering Proposals) (e.g., inclusion of Traditional Owner values in annual planning)
- GLaWAC represented on Environmental Water Advisory Groups (EWAGs)
- Supporting other activities that build capacity of Traditional Owners to build cultural water knowledge and build skills in natural resource management (e.g., cultural and ecological monitoring opportunities, etc)

Community

The Macalister Environmental Water Advisory Group (EWAG) acts in an advisory role and the WGCMA will consider all feedback and advice provided, however the EWAG does not have formal decision-making powers. EWAGs represent stakeholders including community members and relevant agencies on management of water for the environment. The EWAGs main purposes are to:

1. Provide a forum for stakeholder input into the WGCMA's plans for managing environmental water (annual Seasonal Watering Proposals),
2. Increase the knowledge and understanding of managing water for the environment within the community and stakeholder/interest groups, and
3. Provide a reference group of representatives to test ideas about management of water for the environment.

The Macalister EWAG is made up of representatives from the following groups and agencies:

- VEWH
- SRW
- Gippsland Water
- GLaWAC
- Victorian Fisheries Authority
- Communities of special interest
    - Recreational fishers
    - Native Fish Australia
    - Landcare and Friends of groups
    - Conservation groups
    - Local landholders/irrigators
    - Recreational users

2. Site Overview

Site location

The Macalister River (*Wirn wirndook Yeerung)* is in Central Gippsland and drains a catchment area of 2,330km^2, beginning in the northern slopes of the Great Dividing Range below Mt Howitt through to its confluence with the Thomson River. The river is regulated by two in-stream structures; Lake Glenmaggie and Maffra weir. The river's 177km course meanders in a south-easterly direction through predominantly forested confined valleys and narrow floodplains upstream of Lake Glenmaggie to extensively cleared floodplains. This 55km length of river between Lake Glenmaggie and the confluence with the Thomson River is the focus of this EWMP and comprises two reaches (Figure 1).

1. **Reach 1 –** a 33km stretch extending from downstream of Lake Glenmaggie to Maffra Weir; and
2. **Reach 2 –** a 22km stretch extending from downstream Maffra Weir to the Macalister-Thomson River confluence.

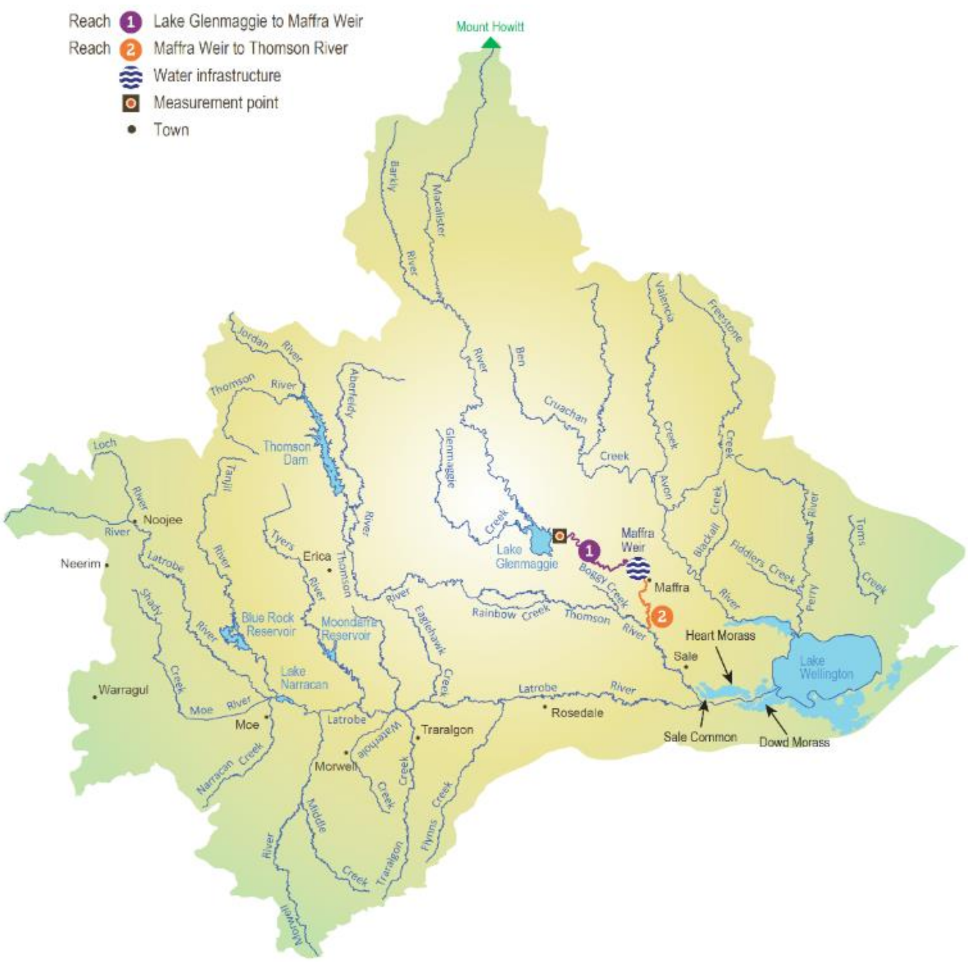

Figure 1 The Macalister River (*Wirn wirndook Yeerung*) within the broader West Gippsland catchment, including reaches 1 and 2 (highlighted) (VEWH, 2014).

Catchment Setting

The Macalister catchment comprises about 11% of the Gippsland Lakes catchment, providing around 16% of the total discharge to the Lakes. The catchment is made up of 70% forested public land, including Alpine National Park, all of which occurs in the upper catchment (SKM, 2009). The mid to lower catchment has undergone significant landscape and hydrologic changes since European settlement, with much of the floodplain downstream of Licola being cleared for cattle grazing (SKM, 2009). According to the Interim Biogeographic Regionalisation of Australia (IBRA) classification, the Macalister River catchment is comprised of three main IBRA bioregions. They include the Australian Alps and South Eastern Highlands in the upper and mid catchments, and the South East Coastal Plains bioregion in the lower catchment (downstream of Lake Glenmaggie) (Yates, et al., 2015). The latter is the largest within Gippsland but has undergone dramatic landscape changes. The native grassland and eucalypts that once covered the South East Coastal Plain bioregion have now been mostly cleared for agriculture. According to 2001 estimates, 21% of pre-1750 vegetation remains unmodified by human activity (Yates, et al., 2015). Remnant stands of lowland and foothill forests, temperate rainforest, heath and grassy woodlands along with coastal scrub and grassland still occur within this region (Yates, et al., 2015).

The Macalister has the widest Holocene floodplain in Gippsland. This floodplain is occupied by three major channel systems. From north to south they are the Newry creek system, the modern Macalister and the Boggy Creek system. Newry creek is an abandoned course of the Macalister River (Erskine, Rutherford, & Tilleard, 1990). The modern Macalister avulsed out of the old Newry Creek channel about 3km below Lake Glenmaggie. It re-joins the old channel at Bellbird Corner (Erskine, Rutherford, & Tilleard, 1990).

The cleared alluvial floodplains surrounding the lower Macalister River are part of the Macalister Irrigation District (MID), covering approximately 53,000 hectares around the Macalister and Thomson rivers. This is the largest irrigation district south of the Great Dividing Range, extending from downstream of Lake Glenmaggie to Sale. Over half of this is irrigated land, with approximately 90% dedicated to pasture (SRW, 2021). The Macalister River is the main source of irrigation water for the MID and was formerly also used to supply potable water to the nearby towns of Coongulla, Maffra, Stratford, Heyfield and Glenmaggie. To provide greater water security to residents of Coongulla and Glenmaggie, Gippsland Water have constructed a pipeline that connects the townships to Heyfield’s more reliable water supply, which is sourced from the Thomson River, with construction completed in 2022 (Gippsland Water, 2022).

Climate

Climate in the greater Gippsland Basin is considered temperate as per the Koppen-Geiger climate classification (Yates, et al., 2015). The West Gippsland has mild to warm summers with average maximum temperatures around 23 - 25°C across inland areas, and slightly lower around coastal and elevated areas at 21 - 23°C. During winter, average maximum temperatures range from 12 to 14°C, but often drop to below 10°C in mountain areas.

West Gippsland is Victoria's wettest region, with an annual rainfall average of 926 millimetres, however there is substantial variation across the region (WGCMA, 2016).

Rainfall in the Macalister catchment itself is influenced by the Great Dividing Range to the north, which contributes to the rain shadow present in the Gippsland plains (Yates, et al., 2015). Figure 2 illustrates the average annual rainfall at the Lake Glenmaggie gauge, showing a long term average of approximately 600 - 650 mm, in contrast with the Gippsland average of 926 mm (Alluvium, 2015a; WGCMA, 2016). Rainfall distribution throughout the year at this site is relatively consistent, with only a small trend towards wetter spring conditions, but overall no clear distinct wet and dry seasons (see Figure 3).

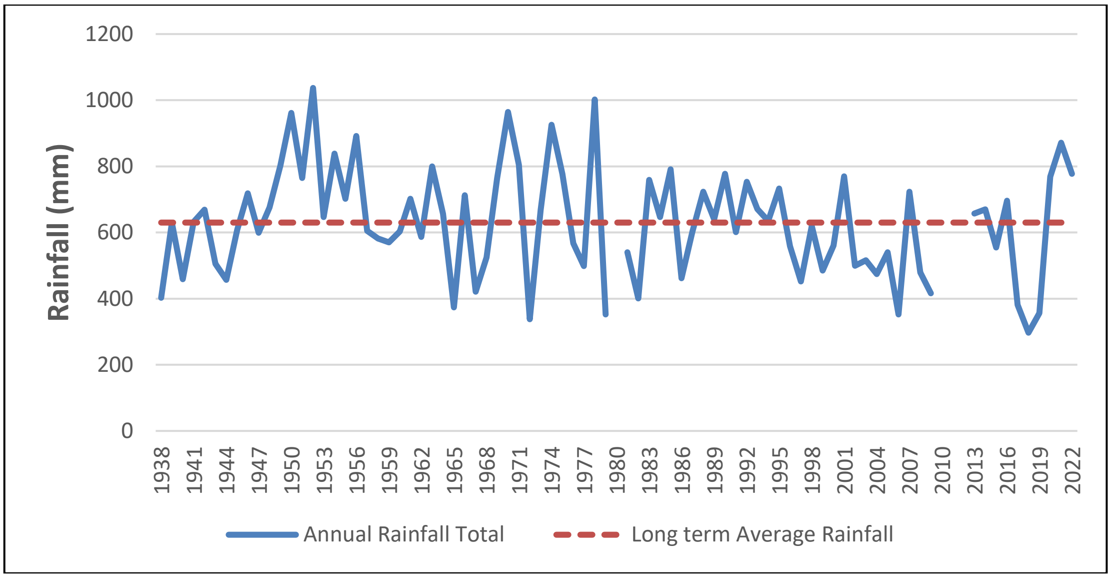

Figure 2 Long term annual rainfall data at Glenmaggie station 1938 – 2022 (85034).

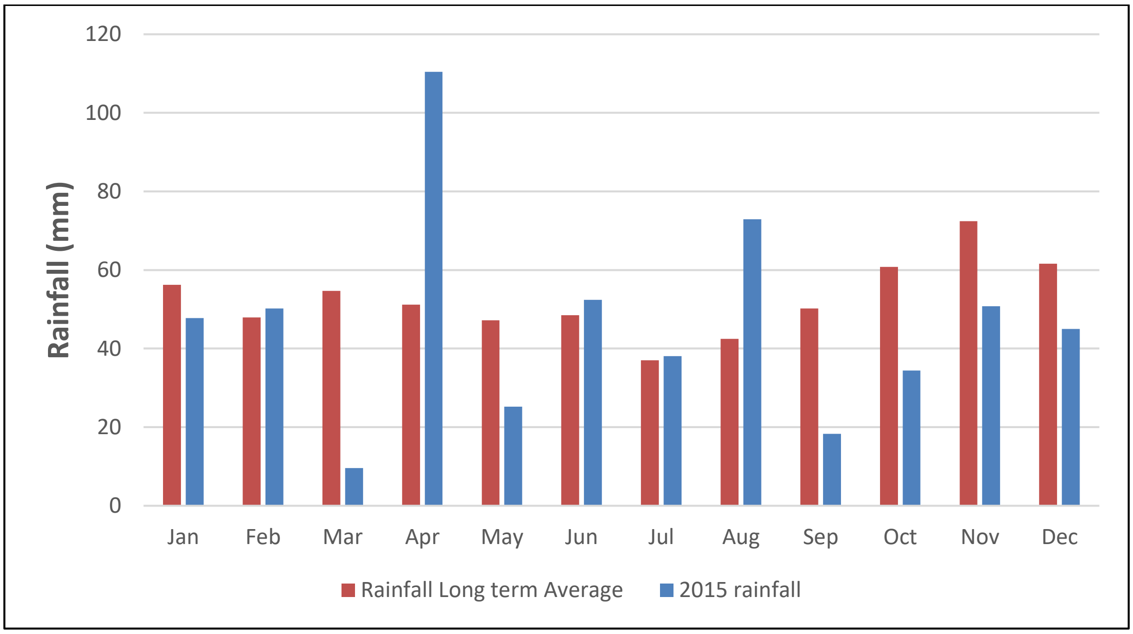

Figure 3 Long term average monthly rainfall at Glenmaggie station (85034) (1938 – 2022) and monthly rainfall data for 2015.

For comparison, in the upstream catchment harvest area for Lake Glenmaggie, using the Licola rainfall gauge (85306), the long term average annual rainfall is 713 mm, and there is a more defined wet period across the winter (June – August) and again in spring (Oct – Nov).

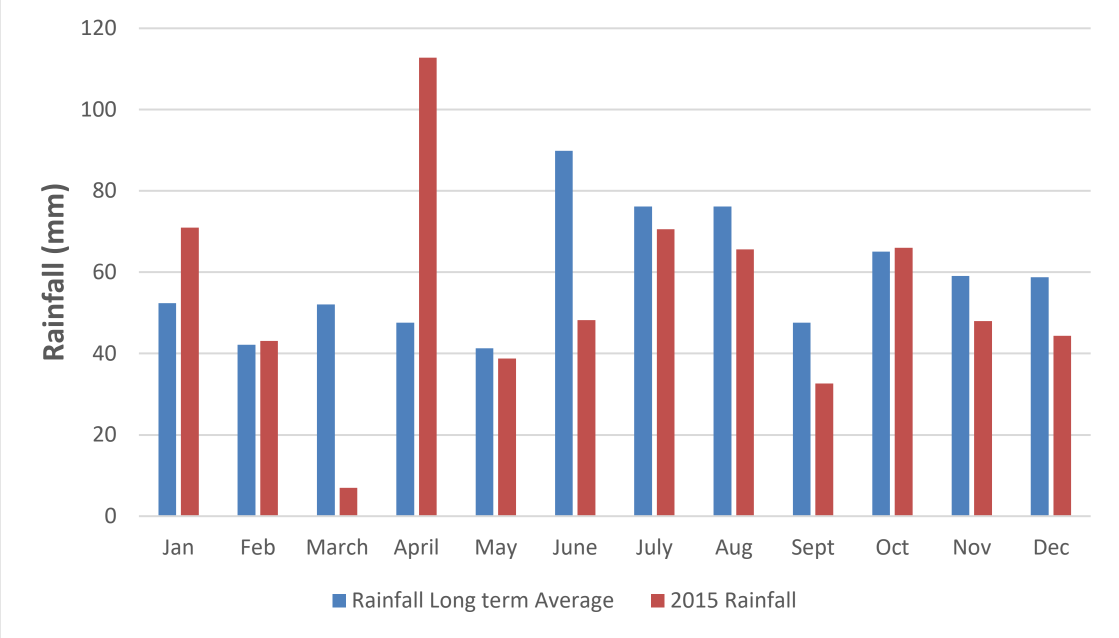

Figure 4 Long term average monthly rainfall at Licola station (85306) (2011 – 2022) and monthly rainfall data for 2015.

Climate change

Victoria's climate is highly variable; however, the trend in recent decades is towards warmer and drier conditions. Most of the rainfall and runoff in Victoria occurs during the cooler half of the year. The reductions in rainfall during this part of the year have a disproportionately large impact on water availability, because this is the time of year when a larger proportion of rainfall becomes runoff (DELWP, 2020).

Cool-season rainfall are projected to continue declining (on average) into the future by global climate models (GCMs). Future runoff in Victoria is likely to be lower, because of the projected decline in cool-season rainfall and higher potential evapotranspiration (DELWP, 2020).

Hydro-physical characteristics

Reaches 1 and 2 of the Macalister system possess the following geomorphic features:

- limited floodplain connectivity due to an entrenched channel with large capacity
- overall channel shape is characterised by steep sides and benches in some locations
- pool-riffle system with large meanders
- coarse sediment generally dominating the bed and banks, and
- significant sediment supply due to bank erosion with an increase in finer substrate downstream (Alluvium, 2015).

Figure 5 illustrates the longitudinal profile of the River. Topography ranges from 1740 m AHD in the upper portion of the catchment, to around 30 m AHD with very little relief in the lower portion of the catchment (Ecos Environmental Consulting, 2014). The river's headwaters originate from the slopes of the Great Dividing Range and flows through a narrow Quaternary floodplain before being joined by Glenmaggie Creek and entering Lake Glenmaggie (SKM, 2003).

Downstream of Lake Glenmaggie the river meanders through a rich alluvial floodplain and flows into the Thomson River near Riverslea (SKM, 2009). This floodplain is traversed by three major channel systems; Newry Creek, the contemporary Macalister River and Boggy Creek. These waterways are considered to represent the past (Newry Creek), present (existing Macalister River) and future (Boggy Creek) course of the Macalister River (CRCFE, 1999).

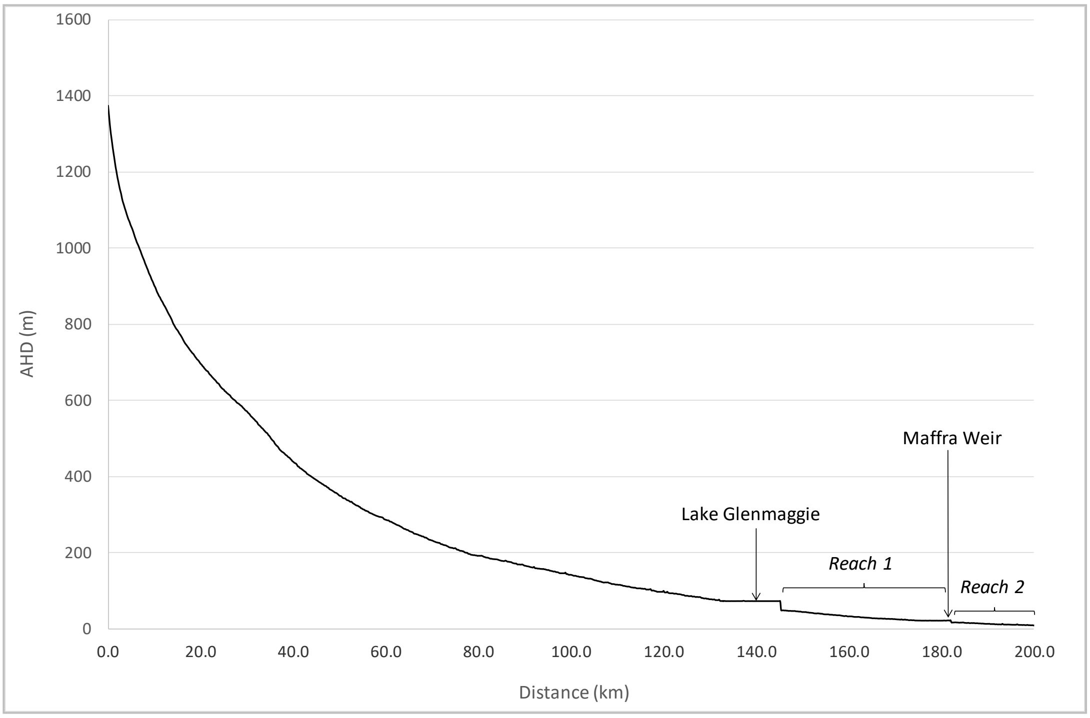

Figure 5. Long section of the entire Macalister River

Highly variable channel morphology and shape are characteristic of the Macalister River. Channel width varies from 79 m to 28 m whilst depth ranges from 7.5 m to 5.3 m from the top of reach 1 to the lower end of reach 2, respectively (CRCFE, 1999). Bankfull capacities vary from 60,000 ML/d immediately downstream of Glenmaggie to 7,500 ML/d towards the Thomson-Macalister confluence. Long term aggradation and channel adjustments are now typical for the lower Macalister River due to several meander developments and cut-offs (Alluvium, 2011).

Lake Glenmaggie

Lake Glenmaggie is the main water storage in the Macalister system separating the upper and lower Macalister River (Figure 6) managed by Southern Rural Water. The Lake has a full supply capacity of 177 GL. The Lake is a relatively small storage within a large catchment area of 1,891 km^2 when compared to other major storages (e.g., Thomson Reservoir, Blue Rock Dam). Water is harvested to supply the properties, farms and towns within the MID. The dam wall is an overfall dam with a central spillway and connection to the two main irrigation channels on either side of the river; the northern and southern channels (Southern Rural Water, 2014).

Lake Glenmaggie is considered an efficient sediment trap, introducing discontinuity to the river's natural sediment regime. As such, reach 1 (immediately downstream of Lake Glenmaggie) experiences reduced sediment loads, considered responsible for the bed armouring, channel widening and meander extensions occurring in this reach. Soil erosion potential around the floodplains of the mid to lower Macalister is large as the area is mostly comprised of highly erodible sodosols (Yates, et al., 2015). Soil erosion from Lake Glenmaggie occurs both within the storage itself and in the river channel downstream of the storage from storage releases. This erosion may have caused some downstream channel adjustment (Alluvium, 2015).

Figure 6 Lake Glenmaggie, looking downstream.

Reach 1

This reach is approximately 33km long stretching from immediately downstream of Lake Glenmaggie to the Maffra Weir pool. The channel is relatively large and un-convoluted featuring bedrock and large boulders at the beginning of the reach (Moar & Tilleard, 2010). These features allow for most floods to be contained within-bank (CRCFE, 1999). A gravel bed substratum is present for a majority of the reach (CRCFE, 1999). Channel contraction begins to occur 10 km downstream of Lake Glenmaggie, increasing the potential for overbank flows. The reach contains deep pool-riffle sequences (Figure 8), three of which have been identified as providing important refuge habitat under drought or fire conditions (SKM, 2009). The draining or blockage of many floodplain channels has altered connectivity between the main river channel and the floodplain (CRCFE, 1999).

This reach is joined by Newry Creek 4 km northwest of the Maffra township (see Figure 8); this waterway is considered a substantial source of turbidity for the Macalister River (CRCFE, 1999). The Macalister-Newry Creek confluence is located at the iconic Bellbird Corner Riverside Reserve, once cattle grazing farmland. The reserve has been rehabilitated through community efforts and is now considered an important natural asset (BCRRMC, 2015).

A number of billabongs are present between the Macalister–Newry Creek confluence and Maffra. Many are hydrologically disconnected for the majority of time and contain little to no fringing vegetation. The surrounding floodplain has been cleared for dairy farming and horticulture. However, the riparian zone fringing this reach has undergone intensive weed control (including willow removal), erosion control, riparian revegetation and fencing to exclude stock access into the main channel. In recent years, WGCMA restoration efforts have focused on maintenance of past works and rehabilitation of the Newry Creek (including SIP upgrades, fencing, weed control and revegetation).

Maffra Weir

Maffra Weir is a diversion weir characterised by a vertical lift-gated structure. Water is diverted from the weir pool into the main eastern irrigation channel which delivers water to users between Maffra and Sale. It is managed by SRW and is operational throughout the irrigation season from mid-August to mid-May. The weir is followed immediately downstream (approx. <20m) by an active stream gauging station containing a low level weir (approx. <0.5m height) (Figure 8). This low level weir is only drowned out occasionally when flows are sufficiently high. Thus, Maffra Weir itself and its associated stream gauge are barriers to fish passage (Figure 7).

In August 2022, funding for the Maffra fishway was announced, with a forecast completion date of 2027. The completion of the fishway will connect 34 kilometres of waterway, allowing fish species to travel upstream past the weir and into high-quality river habitat areas below Lake Glenmaggie.

Figure 7 Maffra Weir (right) and knife-edge weir (left)

Reach 2

Reach 2 consists of approximately 22km of highly sinuous lowland channel with a slighter grade, beginning from downstream of Maffra Weir to the confluence with the Thomson River, near Riverslea (CRCFE, 1999). The reach is a sand bed system (Alluvium, 2011) beginning at Maffra before traversing cleared agricultural floodplains (Figure 8). The main waterway in this reach is lined with an almost continuous levee bank system, hydrologically disconnecting the numerous billabongs peppered along this reach (Alluvium, 2011). However, there is a section of stream and associated billabongs with intact riverine vegetation present immediately before the Thomson-Macalister confluence (CRCFE, 1999). One good quality flood refuge habitat has been identified in this reach and consists of slow flowing runs and a deep pool located approximately halfway between the confluence and Maffra Weir (SKM, 2009).

Approximately 70% of this reach has undergone riparian works including weed control (particularly willow removal), riparian revegetation and fencing. The remaining section of this reach is heavily willow-infested with the exception of the region immediately upstream of the Thomson-Macalister confluence (Rod Johnston per comm., 14th October 2015).

Figure 8. Site conceptualisation of reaches 1 and 2 of the Macalister River, highlighting the main physical characteristics along the river.

Land status and management

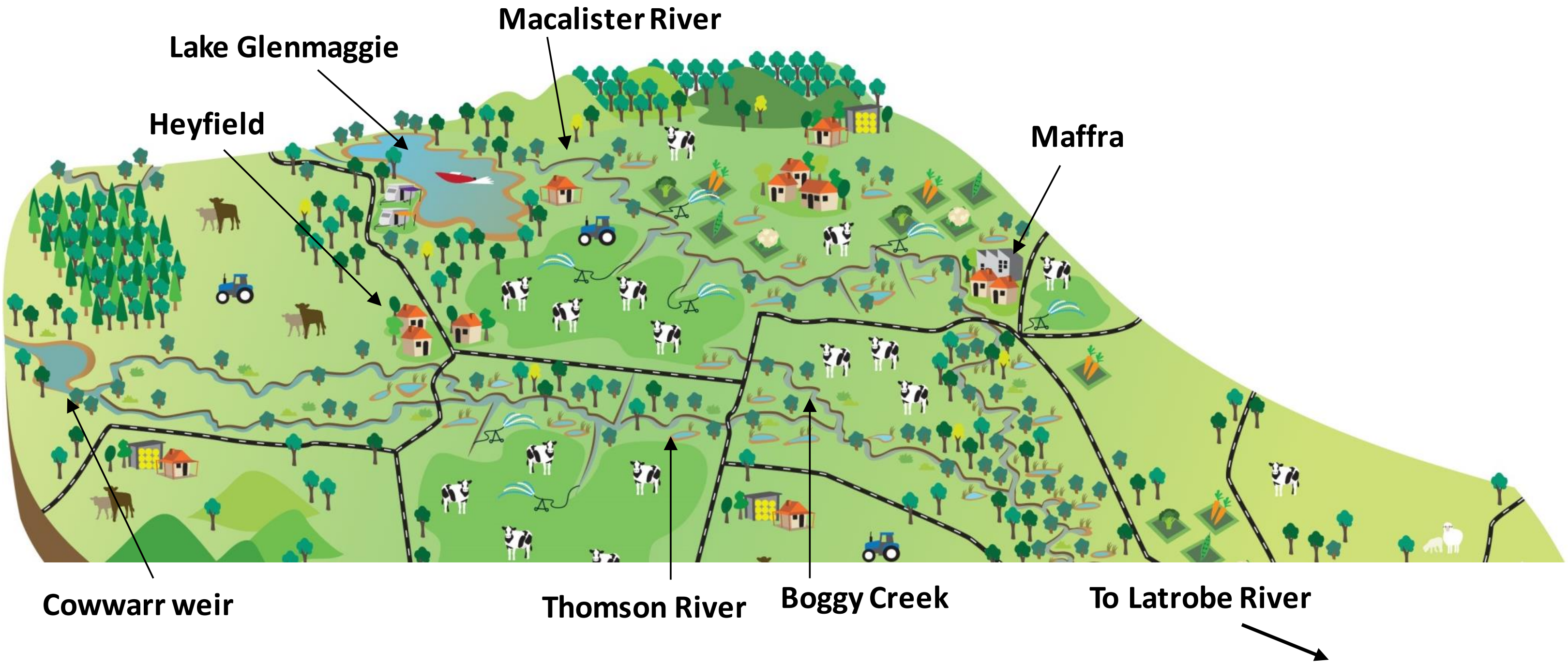

Figure 9. A conceptual model of the lower Thomson and Macalister River catchments, illustrating the various land uses. Note: diagram is not to scale and does not include all hydro-physical features or water resource infrastructure in the catchment. *Source:* WGCMA, 2014.

Irrigated and dryland agriculture are the predominating land uses of the lower Thomson-Macalister catchments, with the MID supporting a large dairy industry with smaller pockets of horticulture and beef farms (Figure 9). A small proportion of the catchment is also dedicated to urban and industrial land use.

Irrigation water and town water supply is sourced primarily from the Macalister River (through Lake Glenmaggie and Maffra Weir), but is also provided via Cowwarr Weir on the Thomson River, and is supplied via an extensive gravity fed distribution system managed by SRW (WGCMA, 2008). Irrigation water may also be pumped directly from these river systems and from groundwater. The MID 2030 program, a jointly funded initiative between government, SRW and irrigators, has been funding projects within the irrigation district to increase water supply efficiency, improve on-farm productivity, achieve significant water savings (~12.3GL), and reduce nutrient export to the Gippsland Lakes (WGCMA, 2008).

Nutrients are managed under the Macalister Land and Water Management Plan (MLWMP) which identifies strategic natural resource management actions required to protect and enhance the region's natural assets. The plan sets out a range of management actions to achieve established targets for nutrient loads to the Gippsland Lakes as well as other catchment targets.

Crown frontage along reach 1 is discontinuous and limited to a small handful of reserves. The riparian zone in this reach is largely freehold land with approximately 10 km listed as Crown frontage towards the upper and lower stretches of this reach. Despite this, the WGCMA and its predecessor, the River Trust, have been able to implement riparian restoration works (i.e. weed control, revegetation and fencing) through established agreements with landholders. This work extends continuously along this reach on both sides of the channel. Crown frontage occurs continuously along Reach 2 but is almost exclusive to the left bank. However, on-ground riparian works akin to Reach 1 have been implemented for approximately 70% of this reach on both left and right banks (Rod Johnston pers. comm. 14th October 2015).

The river boasts a number of adjoining parks and reserves, including:

- **Glenmaggie Regional Park and Glenmaggie Nature Conservation Reserve:** located around Lake Glenmaggie, these reserves contain remnant vegetation and are managed by Park Victoria;
- **Macalister River Streamside Reserve:** a small reserve located in reach 1, managed by Parks Victoria;
- **Macalister Swamp Reserve:** located in Maffra, the swamp is hydrologically disconnected from the Macalister River, and is used to retain and treat stormwater prior to discharge into the river. The reserve is also managed for its habitat and amenity values by the Wellington Shire Council with contributions from the Maffra Urban Landcare Group (Jo Caminiti, Wellington Shire Council, pers comm. 27th October 2015);
- **Bellbird Corner Riverside Reserve:** a rehabilitated scenic reserve surrounding the Macalister-Newry confluence, managed by Bellbird Corner Riverside Reserve Management Committee. There is an extensive record of flora and fauna sightings by locals including platypus (*Ornithorhynchus anatinus*), rakali (*Hydromys chrysogaster*), many species of waterbirds, frogs, insects and reptiles (BCRRMC, 2015).

Waterway management

The WGCMA co-ordinates the integrated management of water in the West Gippsland region (including the Macalister catchment) under the *Catchment and Land Protection Act 1994* (WGCMA, 2014). The WGCMA is the waterway manager for the Macalister River under the *Water Act 1989*. This role includes the responsibility to develop and implement the West Gippsland Regional Waterway Strategy (WGCMA, 2014). The agency takes a partnership approach working with communities, government agencies, Traditional Owners, and industries to maintain and improve the region's natural assets.

Significant contributions to riverine habitat preservation and rehabilitation are also made through the work of volunteers via Landcare or catchment groups such as the Bellbird Corner Riverside Reserve Management Committee and the Glenmaggie-Seaton Catchment Group. A total of 16 Landcare groups are supported by the Maffra and districts Landcare network.

Environmental water management

The roles of various agencies in environmental water management specifically, is summarised in Table 3.

Table 3. Roles of various agencies and groups in environmental water management. Note: MID = Macalister Irrigation District.

Agency/group	Role in waterway/water dependent ecology management
Minister for Water	• oversee Victoria's environmental water management policy framework • oversee the VEWH, including appointment and removal of commissioners and creation of rules ensuring VEWH manages the Water Holdings in line with environmental water management policy
State government agency: **Department of Energy, Environmental and Climate Change (DEECA)**	• manage the water allocation and entitlements framework • develop state policy on water resource management and waterway management • develop state policy for the management of environmental water • act on behalf of the Minister to maintain oversight of the VEWH and waterway managers. • implementation of the Macalister Land and Water Management Plan
Independent statutory body: **Victorian Environmental Water Holder (VEWH)**	• make decisions about the most effective use of the Water Holdings, including use, trade and carryover • authorise waterway managers to implement environmental watering decisions • liaise with other water holders to ensure co-ordinated use of all sources of environmental water • publicly communicate environmental watering decisions and outcomes
Rural water corporation: **Southern Rural Water**	• implement government policy for groundwater and surface water management in accordance with the *Water Act 1989* • work with the VEWH and the WGCMA in planning and delivering environmental water in the lower Macalister River • ensure the provision of passing flows • monitor and report on environmental flow (including passing flow) delivery and compliance • operation and maintenance of Lake Glenmaggie, Maffra Weir and the MID irrigation distribution system to deliver environmental water

Agency/group	Role in waterway/water dependent ecology management
***Waterway manager:* West Gippsland Catchment Management Authority**	• identify the regional priorities for environmental water management in the Regional Waterway Strategy (WGCMA, 2014) • In partnership with the community, identify the environmental water requirements of the Macalister system according to specific ecological objectives • identify and implement environmental works (including monitoring) that may increase the effectiveness or efficiency of environmental watering • develop and implement the Macalister River Seasonal Watering Proposal each year, which communicates the priority environmental watering action for the following year • provide critical input to management of other types of environmental water (e.g. passing flows management, Lake Glenmaggie unregulated releases) • report on environmental water management activities undertaken in the Macalister system
***Local council:* Wellington Shire Council**	• management of urban drainage networks, infrastructure and stormwater input into the system

Environmental water sources and delivery

The Environmental Water Reserve for the Macalister River refers to a number of water sources that can be used to protect and enhance the ecological health of the system. Table 4 provides a short summary of the water sources in terms of volumetric availability and associated conditions of use.

Table 4. Sources of environmental water

Nature of water source	Volume or rate of water delivery	Flexibility of management	Reach	Conditions of availability	Conditions of use
Entitlement					
Macalister River Environmental Entitlement 2010	Up to 18,690 ML/year stored in Lake Glenmaggie	Subject to carry over rules and delivery constraints	1 & 2	Includes high reliability share of 12,461 ML and low reliability share of 6,230 ML	Stored in Lake Glenmaggie. Used in accordance with the operating arrangements for the use of the environmental water holdings of the Macalister system.
Passing flows **					
Macalister River passing flows	Up to 60 ML/d	Upon agreement passing flows can be varied and savings accrued for later discretionary use	1 & 2		Passing flow savings are stored in Lake Glenmaggie. Used in accordance with the operating arrangements
Other sources					

Nature of water source	Volume or rate of water delivery	Flexibility of management	Reach	Conditions of availability	Conditions of use
Lake Glenmaggie unregulated flows	25,000 – 620,000 ML/ year#	Limited ability to manage, however SRW and WGCMA communicate regularly around ramp up and ramp down as well as any opportunities to meet ewater targets	1 & 2	Subject to dam spilling and/or management of air space and fill curve	Can provide piggy backing and wetland watering opportunities
Maffra Weir dewatering water	~500 ML after the 15th of May	Limited/no ability to manage	2	Subject to dewatering of Maffra Weir	Can provide piggy backing and wetland watering opportunities

** Passing flows are in the Southern Rural Water Bulk Entitlement

Unregulated flow volume based on SRW data for 2008-09 to 2013--14

The section below describes how each of these water sources are currently managed and delivered in the river.

Macalister River Environmental Entitlement 2010

This entitlement represents the water holdings held in Lake Glenmaggie delivered to meet specific ecological objectives. This water source offers the greatest flexibility in management. Delivery of this water is planned through the annual development of the Macalister Seasonal Watering Proposal. The *Macalister River Environmental Entitlement 2010* and the operating arrangements (WGCMA; VEWH, 2014) stipulate the conditions for managing these holdings.

Unused entitlement water may be carried over from year to year; however, this water is subject to first-to-spill rules. In most years, carryover is generally lost in winter or spring due to the Lake filling its storage by this time. As such, environmental flow releases are planned to use *all* entitlement water by spring the following water year.

Entitlement water availability is informed via three allocation announcements during the water year:

1. June: high reliability water share allocations are announced with a maximum allocation of 90%
2. February: high reliability water share allocations are reviewed with a maximum allocation of 100%
3. March: low reliability water shares are announced with a maximum allocation of 100%.

Depending on inflows, the timing of these allocation announcements may vary from the above. For example, if inflows are very high in the winter period high reliability water shares may increase to 100% in spring. The planning and delivery of entitlement water is inherently dynamic, reflecting this staggered water availability influenced by climate.

Environmental water delivery is ordered by the WGCMA and carried out by SRW. Flow releases are delivered from Lake Glenmaggie and passed through Maffra Weir. Hydrologic compliance is measured at a stream gauge located at the Maffra Weir tailwater. Flexibility is required in the timing of flow releases during irrigation season such that SRW are also able to meet consumptive water demands.

Passing flows

Passing flows are minimum releases from the water storage as part of the environmental obligations of consumptive water entitlements held by water corporations. In the Macalister system, the associated management conditions of passing flows are articulated in the *Bulk Entitlement (Thomson Macalister – Southern Rural Water) Conversion Order 2001* (2013) and the operating arrangements (WGCMA; VEWH, 2014).

Passing flows for both reaches are set at a constant 60 ML/d throughout the year. Passing flows may be reduced to a minimum of 35 ML/d if (a) inflows to Lake Glenmaggie are below a prescribed minimum as per the bulk entitlement or (b) a reduction is requested by the WGCMA in order to accrue savings that may be used as a separate environmental flow release. All water savings accrued from passing flow reductions are subject to first-to-spill rules. As such, it is important that savings are accrued after the winter/spring period and used before the new water year (i.e., before likely storage spills).

Lake Glenmaggie unregulated flows

Lake Glenmaggie is managed as a “fill and spill” storage due to the relatively small storage size (190 GL) compared to the contributing catchment area (1,891 km^2). From the beginning of the water year to spring, the Lake is filled according to a pre-determined ‘fill’ curve that is designed to reach the full supply level of 177,640 ML by a specified date. This curve is adjusted depending on the rainfall patterns during the year. Operational releases from the storage are made during this period when storage filling deviates from this fill curve (i.e., the storage fills early) and these releases are referred to as “spills”. SRW determines the hydrologic nature of these releases based on forecasted inflows/rainfall and storage levels. On average, Lake Glenmaggie will spill 9 out of every 10 years during the August to October period (SKM, 2009). This provides an opportunity for the WGCMA and SRW to collaborate so that releases meet SRW’s storage fill outcomes and may meet specific ecological objectives.

Unregulated releases from Lake Glenmaggie may be of a substantial volume and magnitude. There is potential for this release to fulfil the watering needs of specific objectives with winter or spring flow requirements. This was initially achieved in August 2015 when SRW and WGCMA worked together to shape unregulated releases from Lake Glenmaggie that met the hydrologic parameters of a winter fresh (as per flow recommendations) and fulfilled SRW’s storage filling obligations. This approach was also followed again in 2020.

Maffra Weir de-watering

Water held in the Maffra Weir pool is released over a number of days from mid-May. This water is only available for reach 2 and offers the least flexibility in terms of management.

Consumptive water delivery

Whilst water delivered from Lake Glenmaggie or Maffra Weir via the river channel for consumptive use is not theoretically considered an environmental water source, this water still has the potential to elicit positive and/or negative impacts on the river. The nature and extent of the impact hinges on the hydrologic characteristics underpinning water delivery. These impacts are difficult to manage as they are influenced by consumer demand.

Related agreements, policies, plans and reports

The agreements, policies, plans and reports that specifically relate to environmental water management in the Macalister River are summarised in Table 5.

Table 5. Projects, plans, strategies and legislative instruments relating to environmental watering in the Macalister River

Category	Title
Victorian Legislation	Victorian Water Act 1989 Catchment and Land Protection Act 1994 Flora and Fauna Guarantee Act 1988 Aboriginal Heritage Act 2006 Crown Land (Reserves) Act 1978 Planning and Environment Act 1987 Environmental Effects Act 1978 Victorian Wildlife Act 1975 Environment Protection Act 1970
Commonwealth Legislation	Water Act 2007 Environment Protection and Biodiversity Conservation Act (1999)
Entitlements	Macalister River Environmental Entitlement 2010 Bulk Entitlement (Thomson Macalister – Southern Rural Water) Conversion Order 2001
Plans and strategies	Victorian Waterway Management Strategy (DEPI, 2013) Gippsland sustainable water strategy (DEPI, 2011) Central and Gippsland Region Sustainable Water Strategy (DELWP, 2022) West Gippsland Regional Waterway Strategy (WGCMA, 2014) Macalister Land and Water Management Plan (WGCMA, 2008) Macalister Seasonal Watering Proposals (WGCMA, annual) Seasonal Watering Plan (VEWH annual) Operating arrangements for the environmental water holdings of the Macalister system (WGCMA and VEWH, 2014)
Technical studies	Environmental flow assessment for the lower Thomson and Macalister Rivers (CRCFE, 1999) Macalister River environmental flows assessment (SKM, 2003) Environmental flow options for the Thomson and Macalister rivers (TMEFTF, 2004) Macalister River environmental flows review (Alluvium, 2015) Baseflow estimation method pilot trial (GHD, 2013) Macalister Shortfalls Assessments (2019-20)

Category	Title
	Thomson Environmental Flow Review (2020) HARC Source modelling technical reports (2022)
Monitoring reports	Refuge habitat identification and mapping in the Macalister River (SKM, 2009) VEFMAP stage 5, 6 and 7 reports VEFMAP Coastal Rivers fish populations annual report 2021-22 Native Fish Report Card monitoring 2017 - 2022

3. Hydrology and water use

Surface water hydrology

The Macalister River downstream of Lake Glenmaggie is a highly regulated system. Hydrology is largely controlled by the management of Lake Glenmaggie, and to a smaller extent, Maffra Weir (Alluvium, 2015). Stream flows in the catchment follow a common pattern for Victorian streams with the high flow period beginning in May/June, peaking in September and October before declining back to the dry summer – autumn period (January to April/May) (Alluvium, 2015).

The modelled streamflow scenarios developed using the Thomson-Macalister Source model (updated by HARC and DELWP using eWater Source (version 5.10.0)) have been used to describe/illustrate the “natural/unimpacted” flow regime in the Macalister River (reaches 1 & 2), and then subsequent deviation from these patterns owing to flow regulation, water consumption (“current”) and climate change (“post-97 step change”) (HARC, 2021). These scenarios are described in Table 6.

Average annual flows for all scenarios have been summarised in Table 6 and Figure 10, with percentage difference between the current flows (assuming post-1975 climate) and other scenarios. As seen in Table 6, without the impact of storages and demands, flows are 57-75% higher than current flows, depending on the river loss assumption. The impact of post-1997 step climate change reduces flows in the Macalister River by 23-27%.

Table 6 Summary of average annual flows and impact of operations

Macalister River Reach		Average Annual Flow calculated between 1955 and 2018 (ML/yr) and percentage difference from current			
		Current (post-75)	Current (post-1997)	Unimpacted (post-1975 with losses)	Unimpacted (post 1975 no losses)
Reach 1	Lake Glenmaggie to Maffra Weir	264,123	203,908	441,392	460,929
			-23%	+67%	+75%
Reach 2	Maffra Weir to Thomson-Macalister confluence	318,330	233,263	498,458	523,902
			-27%	+57%	+65%

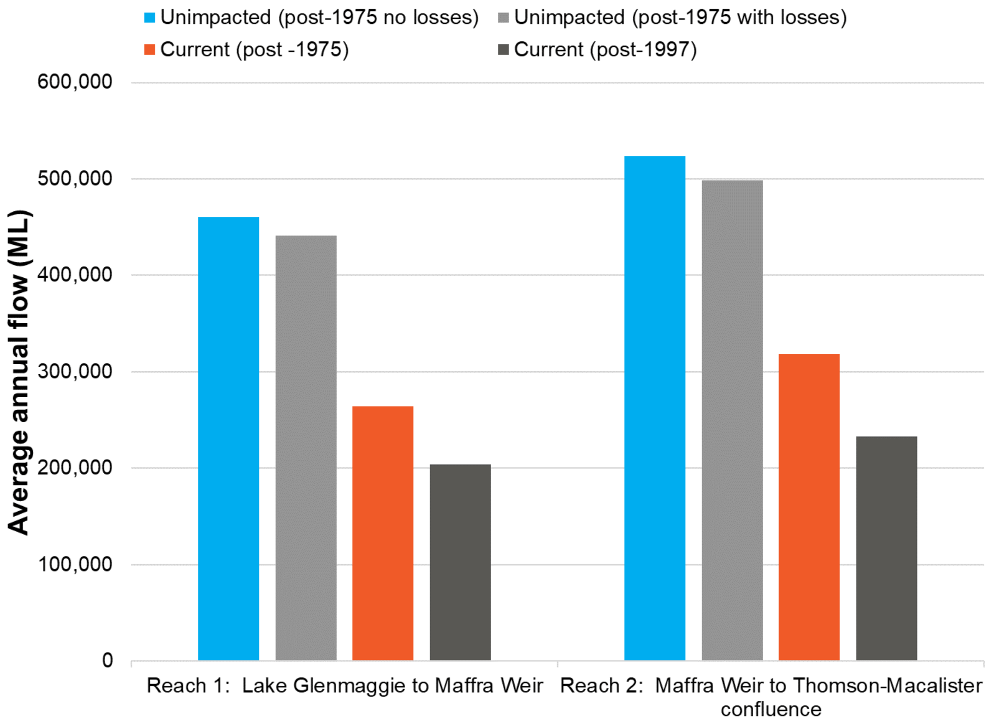

Figure 10 Average annual flows 1955 to 2018

Flow exceedance

The flow duration curve comparisons in Figure 11 and Figure 12 show that the inclusion of river losses in the unimpacted scenarios reduces flow magnitudes of less than 1,000 ML/d for reaches 1 and 2.

Comparison with flows under the current (post-1975) case shows that regulated releases, minimum passing flows and environmental flow requirements act to maintain flows higher than the unimpacted flows below 100 ML/d. The difference between low unimpacted flows (with loss) and current flows for the post-1975 climate change scenario is much greater in reach 2 (Figure 12).

The impact of climate change for current flows is more significant in reach 2 than reach 1, as seen in Figure 11 compared to Figure 12. This is due to higher regulated releases required to fill downstream irrigation orders. This is reflected in a more significant storage drawdown in Lake Glenmaggie for the post-1997 scenario when compared to post-1975 to deliver these additional flows for irrigation (Figure 13).

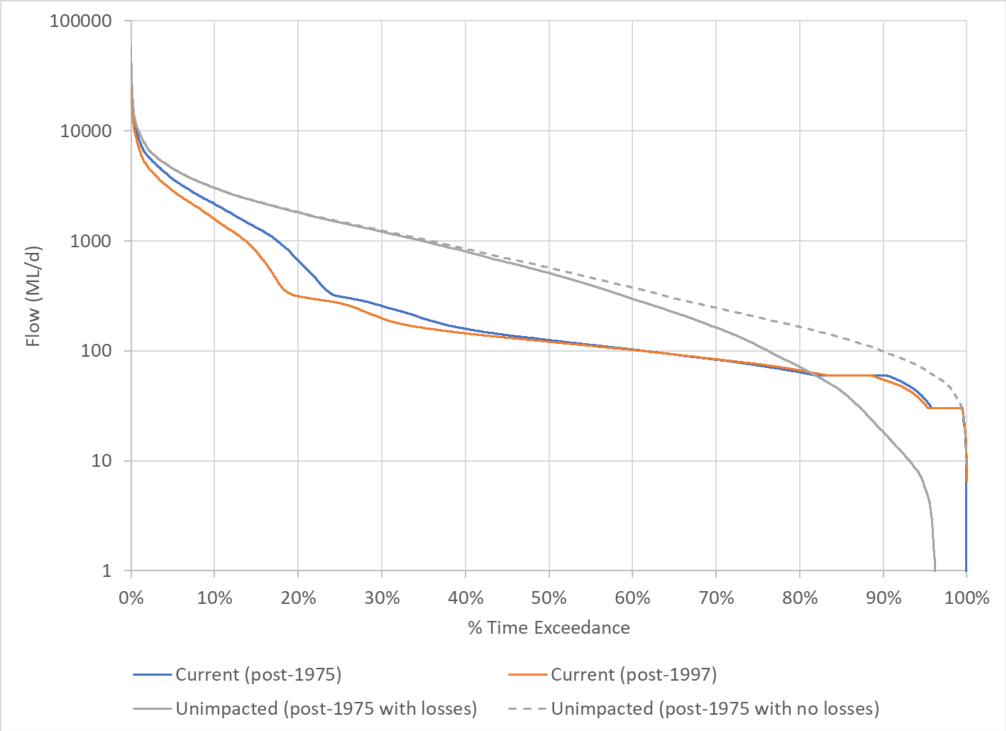

Figure 11 Flow duration curve comparison Reach 1 calculated from 1955 to 2018

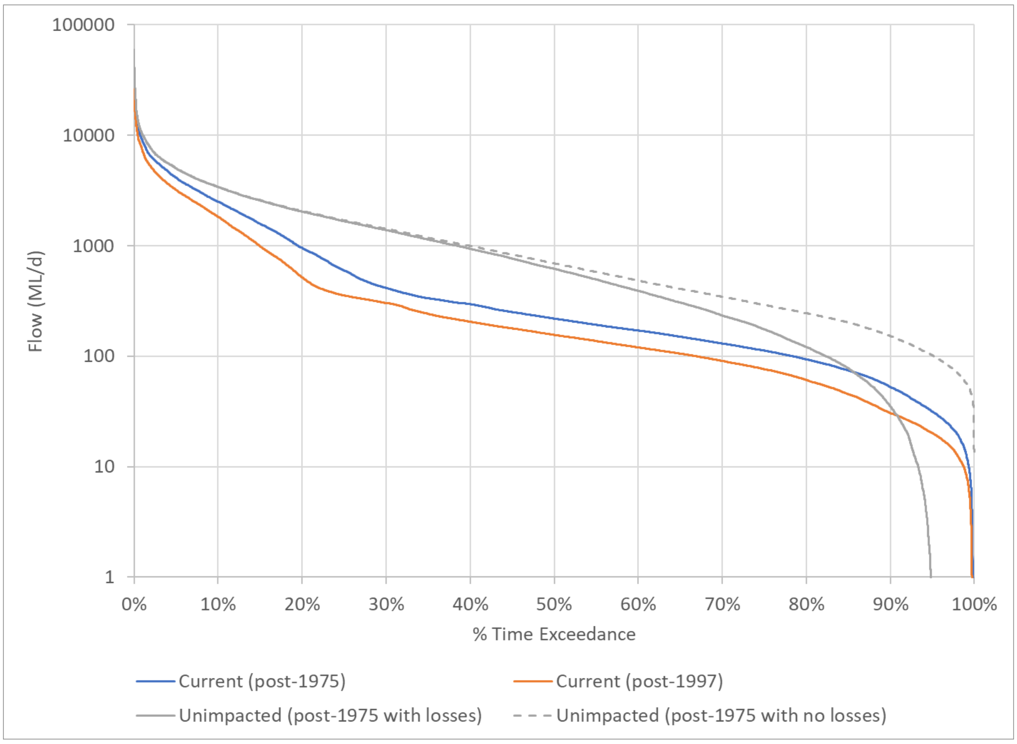

Figure 12 Flow duration curve comparison for Reach 2 calculated from 1955 to 2018

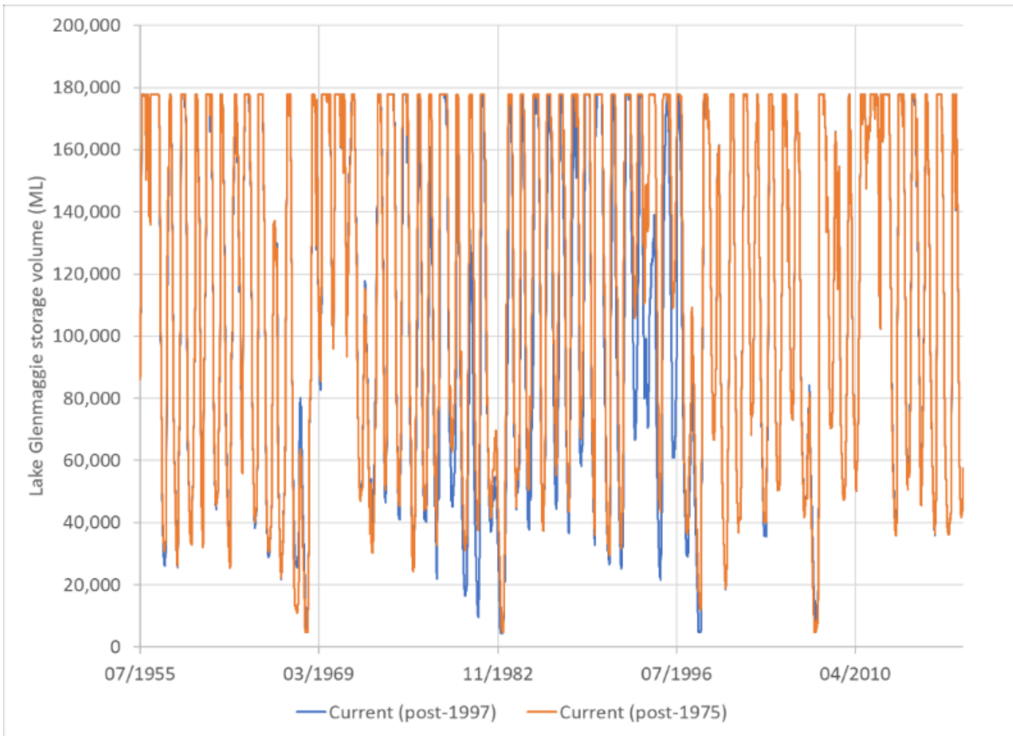

Figure 13 Lake Glenmaggie storage trace comparison between post-1975 and post-1997 climate scenarios

Average daily flows

Average daily flows have been extracted for each month. The unimpacted flow case adopted for this analysis includes all river losses downstream of Lake Glenmaggie.

As seen in Figure 14, unimpacted flows are consistently higher than current flows in both Reach 1 and Reach 2. However, the difference in flows is less significant during the irrigation months from January to March where more releases are being made from Lake Glenmaggie.

The similar magnitude of regulated releases from Lake Glenmaggie for both the post-1975 and post-1997 climate scenario is shown for Reach 1 in Figure 14, where the mean daily flow is comparable from January to March. The impact of climate change on drier months is more pronounced in Reach 2 (Figure 14).

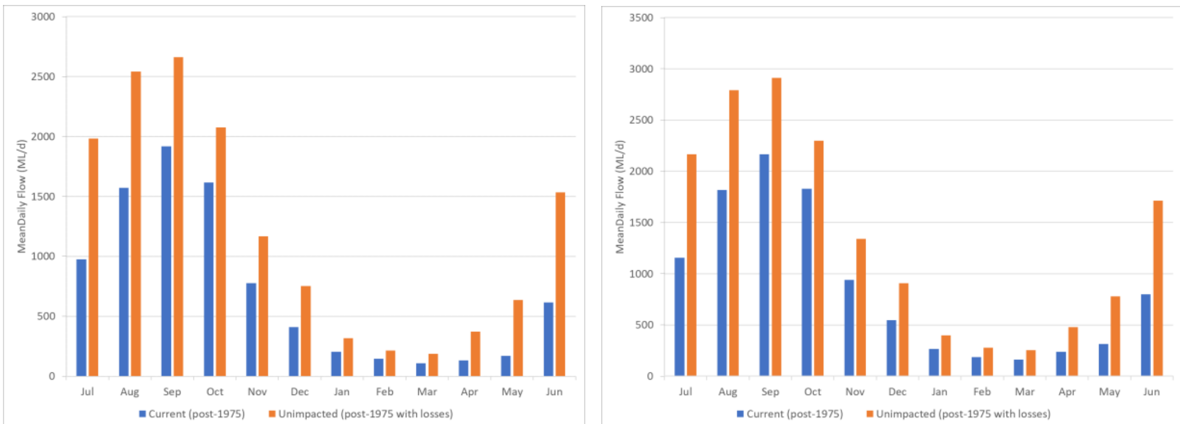

Figure 14 Mean daily flows per month comparison between current and unimpacted post-1975 flows for Reach 1 (left) and Reach 2 (right)

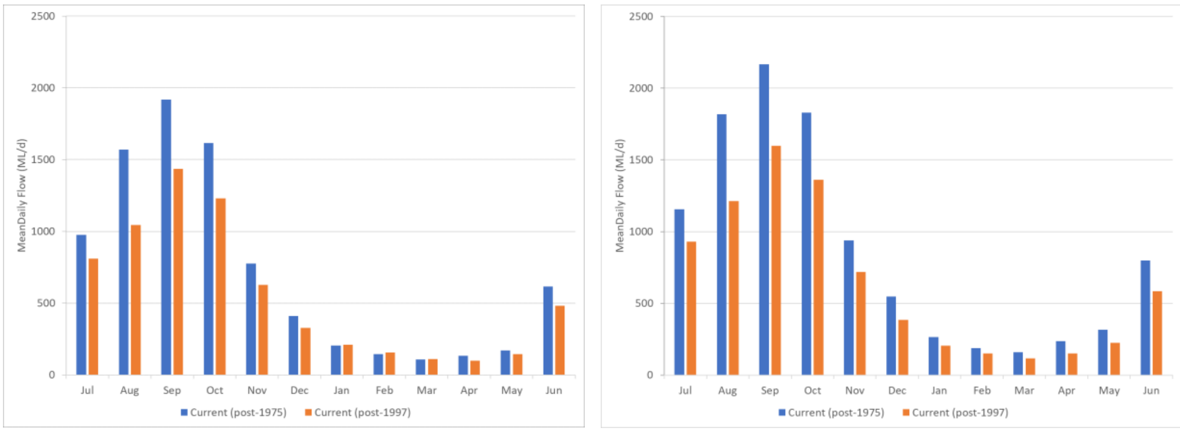

Figure 15 Mean daily flows per month comparison between current post-1975 and current post-1997 for Reach 1 (left) and Reach 2 (right)

Streamflow monitoring

Streamflow in reaches 1 and 2 of the Macalister River is measured at three established stream gauging stations, shown in Table 7. Water levels in Lake Glenmaggie and Maffra Weir are also measured.

Table 7 The streamflow gauging stations present in reaches 1 and 2 of the Macalister River.

Location	Gauge ID	Description
Macalister River at Lake Glenmaggie tailwater	225204	Measured streamflow downstream of Lake Glenmaggie. This dataset extends from 1960 – 2022.
Macalister River at Maffra Weir tailwater	225242	Measured streamflow downstream of Maffra Weir. This dataset extends from 2011 – 2022
Macalister River at Riverslea	225247	Measured streamflow just before the Thomson-Macalister confluence. This dataset extends from 2001 – 2022.

Water quality

The Macalister River is showing signs of stress due to flow regulation and reduced streamflow; along the lower reach there is evidence of a narrowing river channel with large pools of poor water quality (Alluvium, 2015).

Electrical Conductivity (EC) in the catchment is generally consistent with the pattern often seen in waterways and storages. EC tends to decrease in the wetter late autumn, winter and spring seasons due to incoming freshwater flows (Ecos Environmental Consulting, 2014). The EC observed at the Glenmaggie Creek site at the Gorge has been consistently higher than the other sites in the catchment, suggesting a potential groundwater influx that elevates EC at this site (Ecos Environmental Consulting, 2014). Salinity immediately downstream of Lake Glenmaggie is consistently very fresh (<500 uS/cm) and tends to increase with distance downstream (SKM, 2003). The pH in the catchment is generally neutral and consistent throughout the year, with the most variable site at Glenmaggie Creek at the gorge, which may be due to an influx of groundwater (SKM, 2003).

Groundwater

Since European settlement there have been significant changes to the catchment, including deforestation, drainage of low lying water logged regions, surface water extraction, farms dams and the construction of Lake Glenmaggie, all of which have altered the hydrology. Alterations to drainage and wetland hydrology (due to less frequent filling flows from reduced flooding) has caused a significant decline in wetland condition (Alluvium, 2015a). Historically, the drained wetlands were shallow freshwater marshes which were waterlogged throughout the year and surface waters (<0.5m) may be present for 6-8 months annually. Most of remaining wetlands on agricultural lands are hydrologically disconnected from the parent river and are likely to be maintained primarily by groundwater flows rather than surface water floods (Alluvium, 2015a; SKM, 2003).

The impact on the groundwater connection to the river is more subtle. The impacts of regulating the stream will influence river stage heights and movement of groundwater into the river and surface water back into the groundwater. The change in land use, and alteration of the surface water systems across the floodplain is also likely to have impacts on recharge rates to the groundwater, and subsequent groundwater levels and fluxes to the river (Alluvium, 2015a).

Groundwater level in the alluvium of the river is illustrated in Figure 16. Trends over time demonstrated a generally declining groundwater level since 1990 (Alluvium, 2015). A decadal trend of lowering groundwater levels coincides with the drought period from 2001-2007 (Figure 16). This may be attributed to reduced recharge via river flows and rainfall (Alluvium, 2015). There is a marked increase in groundwater levels during the large rainfall event in 2007, indicating the strong influence of streamflow and rainfall on the recharge of the underlying aquifer.

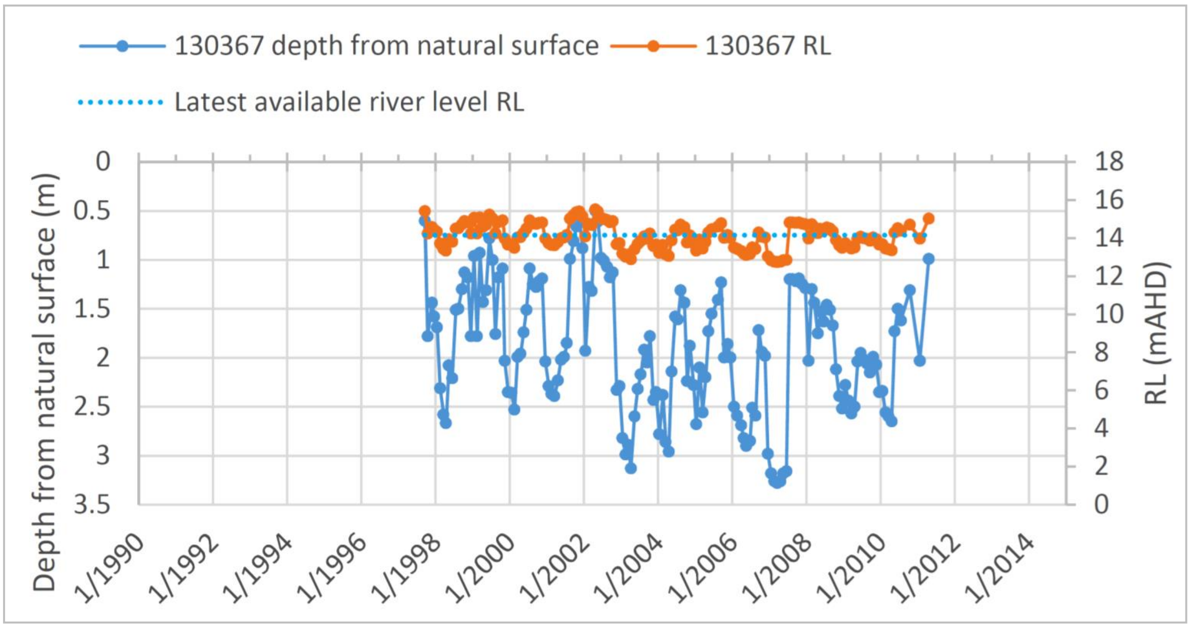

Figure 16 Groundwater hydrograph for station 130367.

Groundwater-surface water connectivity

Groundwater hydrographs in the upper Macalister catchment indicate that the dominant flow gradient is from surface water to groundwater (i.e., groundwater levels lower than the river). In Reach 2 of the Macalister River, groundwater levels are dominantly higher or equal to the river suggesting river recharge by groundwater.

Baseflow analyses conducted for the Macalister River (GHD, 2013) suggests that Reach 1 in the Macalister River loses flow to the underlying sedimentary aquifers of the alluvial plains. It is likely that while there may be localised occurrences of groundwater flux to the river, the predominant pattern is of surface water entry into the groundwater table (Alluvium, 2015). During dry years and low flow periods, the river is largely losing to groundwater, whilst in the wet years post-2010 the river is gaining from groundwater. In Reach 2, the topography is relatively flat over large areas, the potential for stream loss decreases and eventually reverses to groundwater discharge (i.e., baseflow) potential (Alluvium, 2015).

Consumptive water use

Water for consumptive use in the lower Macalister catchment is mainly harvested in Lake Glenmaggie. Whilst the full supply capacity of the Lake is 177 GL, its storage capacity is 190 GL with the airspace maintained as storage for flood mitigation (SKM, 2003). Management of the storage is described in Section 2 (Lake Glenmaggie unregulated flows – Waterway Management section).

Water rights and diversion licences in the MID are provided via high and low reliability water shares. Prior to 2008, these rights were tied to land (i.e., associated with the area of land owned). Water unbundling allowed for water rights to become independent legal entities, providing flexibility for trading (Southern Rural Water, 2013). Thus, water use data before and after unbundling is not comparable and as such, the next section describes the water use context using data from the 2008 – 09 water year to June 2015.

The average annual volume of water diverted from the Macalister River between July 2008 and June 2015 was 163,062 ML. Note that this includes actual water use and losses in the system. This diversion constitutes approximately 32% of the mean annual inflow (516,861 ML) into Lake Glenmaggie during this seven year period. This water used does not include stock and domestic demands which are unmetered and considered minor (<600 ML/yr; Gavin Prior, SRW, pers comm. 26th October 2015).

From 2010-2015, water shares increased due to savings realised from modernisation projects in the MID. In 2020-21 the SRW corporate plan states that there are 155,839 ML high reliability water shares and 74,639 ML low reliability water shares associated with the MID. These volumes exclude the environmental entitlement. High reliability water share holders also have access to a “spill entitlement” in addition to their water share. This entitlement permits the take of water when Lake Glenmaggie is spilling. The volume of the spill entitlement is determined by SRW but is capped at 62,000 ML per year (*Bulk Entitlement (Thomson Macalister – Southern Rural Water) – Conversion Order 2001*).

Groundwater use in the broader Thomson-Macalister basin is covered by three groundwater management units; the Rosedale Groundwater Management Area, the Denison

Groundwater Management Area and the Sale Water Supply Protection Area. These areas have a combined total licence volume of 62,091 ML (Southern Rural Water, 2015) and management of these resources is described in the *Catchment Statement for Central Gippsland and Moe Groundwater Catchments* (Southern Rural Water, 2014).

Environmental watering

Environmental watering activities in the Macalister River (i.e., reaches 1 and 2) prior to 2015 reflected the flow recommendations developed under previous flow assessment studies. These include the first Macalister River environmental flow assessment (SKM, 2003) and the subsequent environmental flow options project undertaken by the Thomson-Macalister Environmental Flows Task Force (TMEFT, 2004). The latter project determined the final flow recommendations for the Macalister River based on the flow recommendations provided in SKM (2003), system constraints and competing consumptive water demands.

Watering activities following the award of the *Macalister River Environmental Entitlement 2010*, largely focussed on autumn and winter events due to their relative priority compared to other watering actions. These watering activities included:

- **autumn freshes**: peaking at 350 ML/d for seven days, delivered between April to May every year to date since 2009–2010. These freshes are required to trigger downstream migration and spawning of migratory fish species, particularly Australian grayling. As migration is only possible downstream of Maffra Weir, reach 2 is the target reach for this watering activity.
- **autumn/winter baseflows:** flows at 140 ML/d delivered continuously throughout May to July each year since 2011–2012 to date. These flows are impacted through the filling of Lake Glenmaggie and are required to provide fish passage during this time and wetting of fringing vegetation. Whilst both reaches do benefit from this flow, Reach 2 is the target reach due to connectivity to downstream systems.

Flow recommendations and objectives were reviewed and updated in 2015 as part of the Macalister River Environmental Flows Review (Alluvium, 2015). Since 2015, unregulated and operational flows have provided several winter freshes (peaks >1000 ML/d), spring baseflows (maintained at 140 ML/d) and summer freshes (peaking at 350 ML/d). Bankfull flows (peaking at 10,000 ML/d) are also a flow recommendation but are not actively provided through the entitlement due to the flooding that will occur in the catchment and the large volumetric demand of the event. However, this event has been achieved via unregulated flows, as shown in Figure 17.

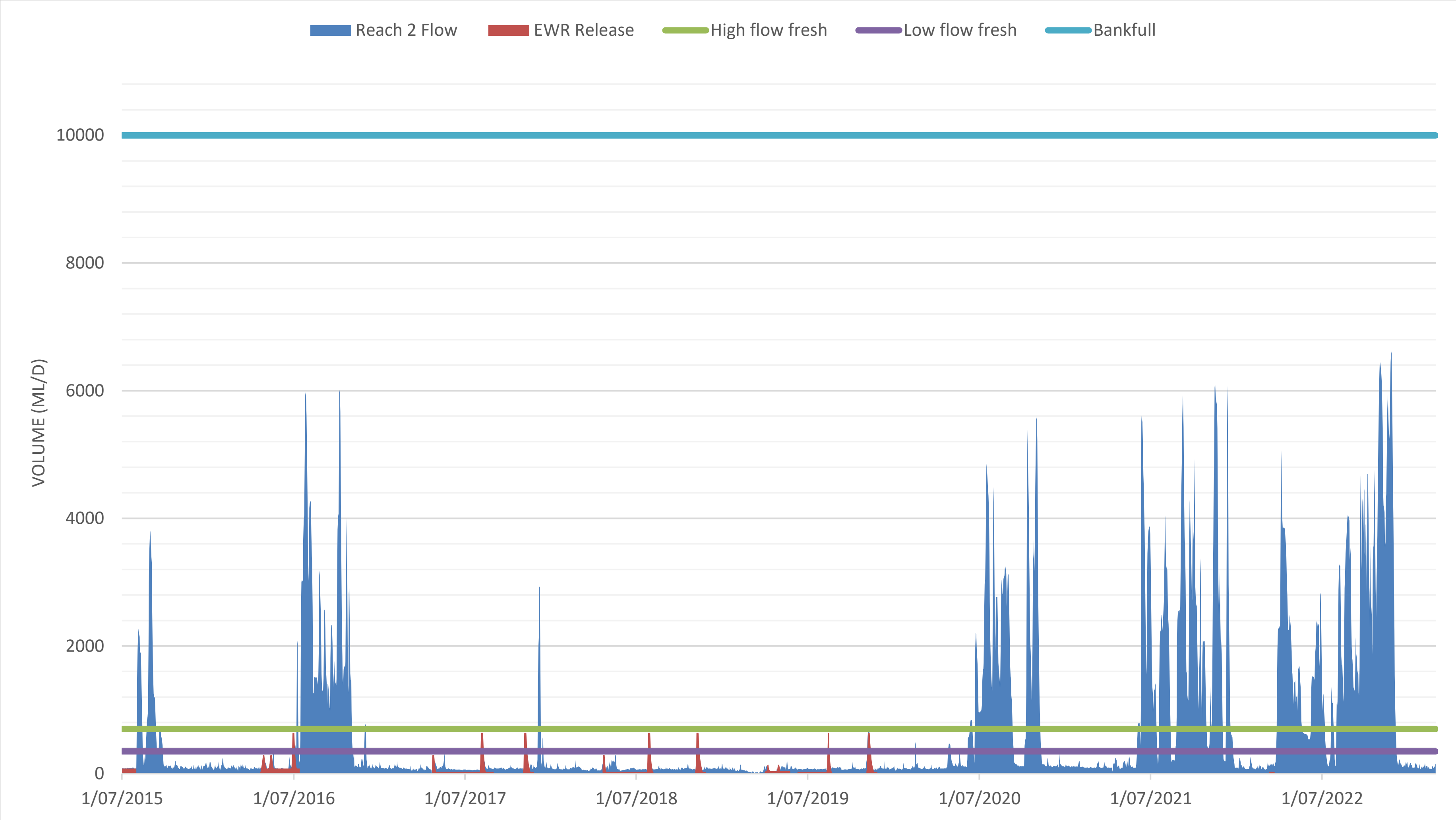

Figure 17 Hydrograph of managed and unmanaged flows occurring in the Macalister River in Reach 2 (Riverslea gauge) from July 2016 – March 2023

Environmental Flow Compliance

This environmental flow assessment takes the various Environmental Flow Recommendation (EFR) flow components and determines if they were met under a given modelled flow scenario in Reach 1 and 2. A success criteria of 80% was assumed for all reaches and scenarios. That is, a flow component is deemed to be successful if 80% of the target is delivered (HARC, 2021).

Using the Source model, compliance for 'Summer low' and 'Winter low' recommendations were calculated as the percentage of time flows are equal to or above the recommended magnitude, in the relevant months over the whole period of record. Compliance for freshes was calculated as the percentage of years when the recommended number of events occurred, which met the recommended duration. Rates of rise and fall were not considered. Compliance for annual 'Bankfull' events was calculated for the whole period of available record as the number of years which had a complying event, divided by the number of years expected to have a complying event. Compliance for multi-year 'Bankfull' events was calculated as successful if an event occurred within the multiyear period (e.g., 1 in 2 years) (HARC, 2021).

The environmental flow compliance for Reach 1 and Reach 2 has been summarised in Table 8 and Table 9 respectively. Some key observations are:

- The unimpacted flow case with river losses has lower environmental flow compliance for the summer low than for the current case where regulated releases are available during drier periods
- The unimpacted flow cases have better compliance for the summer and winter fresh and low flows compared to the current case, however, bankfull and overbank environmental flow compliance remains low, suggesting that the unimpacted flows originally used to derive these environmental flow recommendations (REALM model) were quite different to current unimpacted flows (Source model).
- Compliance in Reach 2 is higher than Reach 1 for the current and unimpacted (no losses) scenarios. This is due to the increase in flows due to interstation flows being higher than the corresponding increase in flow requirements. However, the impact of river losses reduces compliance in Reach 2.
- There is an increase in flow compliance for the current summer low flow when comparing the post-1997 scenario to post-1975 scenario in Reach 1. This is due to the drier interstation flows resulting in more regulated water being released down the system during dry periods.

Mostly complies		Greater than	95	%		
Frequently complies		Between	76	&	95	%
Often complies		Between	51	&	75	%
Occasionally complies		Between	26	&	50	%
Rarely complies		Between	5	&	25	%
Never complies		Between	0	&	5	%

Table 8 Macalister Reach 1 Environmental Flow Compliance

Flow Component	Current (post - 1975)	Current (post-1997)	Unimpacted (post-1975 with losses)	Unimpacted (post-1975 no losses)
Summer low	68%	76%	57%	89%
Summer fresh	30%	25%	97%	100%
Summer fresh 2	16%	14%	83%	84%
Winter low	47%	41%	86%	88%
Winter fresh 1	75%	67%	97%	97%
Winter fresh 2	78%	70%	95%	95%
Winter fresh 3	9%	6%	19%	19%
Bankfull	1%	1%	1%	1%
Overbank	29%	24%	42%	42%

Table 9 Macalister Reach 2 Environmental Flow Compliance

Flow Component	Current (post - 1975)	Current (post-1997)	Unimpacted (post-1975 with losses)	Unimpacted (post-1975 no losses)
Summer low	93%	84%	80%	100%
Summer fresh	79%	46%	84%	100%
Summer fresh 2	84%	79%	84%	95%
Winter low	65%	52%	90%	93%
Winter fresh 1	86%	73%	98%	98%
Winter fresh 2	80%	75%	52%	34%
Winter fresh 3	16%	17%	14%	13%
Bankfull	2%	1%	3%	3%
Overbank	54%	46%	72%	73%

Environmental water shortfalls

Work from 2015 and 2019 has identified environmental water shortfalls in the Macalister system, with only a small proportion of the flow recommendations able to be regularly delivered with the current Environmental Entitlement (EE), either due to total volume requirements or delivery constraints. With the current EE, water managers must prioritise and adaptively manage flows throughout the year. In some cases, although considered an ecologically important flow, providing a specific event may be considered a lower priority, as its volumetric demand would preclude the delivery of other higher priority watering.

The ecological objectives and corresponding EFRs for the lower Macalister River were last updated in 2015 (Alluvium, 2015). Despite the establishment of the Macalister River Environmental Entitlement 2010, past analysis has continually demonstrated that there is insufficient water for the environment available to fully deliver all EFRs. In this assessment, Reach 1 EFRs were used to determine overall shortfalls for the Macalister River, as they require typically larger volumes to achieve the required flow components thanks to the size of the channel between Lake Glenmaggie and Maffra weir. Also, once fish passage constraints at Maffra weir are removed, delivering the Reach 1 EFRs will be the priority and as such assessing Reach 1 is more reflective of long term watering plans.

With the availability of the current entitlement, the mean annual shortfall for Reach 1 has been calculated to be ~19.5 GL/yr under average seasonal conditions. The mean annual shortfall under dry conditions is approximately 28.8 GL to achieve the full EFRs (Table 10). Overall shortfalls in the Macalister River, taking into account different climate and irrigation modernisation scenarios, ranges from 19 – 29 GL (above the current EE) (Alluvium, 2019).

Table 10 Summary of mean annual shortfalls for provision of full EFRs in Reach 1, adjusting for use of the existing environmental entitlement (Alluvium, 2019)

	Drought	Dry	Average	Wet	All years
Expected annual allocation (ML/yr)	9,600	12,900	14,900	19,400	Undefined
Long-term mean annual shortfall excluding environmental entitlement use (ML/yr)	30,363	41,713	34,427	44,268	37,590
Long-term mean annual shortfall including environmental entitlement use (ML/yr)	20,763	28,813	19,527	24,868	Undefined

Notes: The 'all years' column shows the average shortfall across all years on record. The other columns show the average shortfalls across the subset of years of that specific climatic condition.

The key implication from this analysis is to fully meet the scientifically-derived EFRs for the Macalister River would require further major investment in water recovery, with the required environmental entitlement being approximately double that currently available.

For currently high priority deliverable EFRs, so those not impacted by current delivery constraints, the mean shortfalls (including the use of the current EE) ranges from 0 to 14.5 GL/yr depending on the seasonal conditions. In average years the mean shortfall is 4.2 GL/yr, in drought years 14.5 GL/yr. It is critical to note that the scientific understanding underpinning the establishment of the EFRs indicates that a management regime focused solely on meeting these 'deliverable' EFRs will not be expected to achieve all the ecological objectives established during the environmental flow study – ecosystem condition would be greatly enhanced by enabling delivery of some of those EFRs which are currently considered undeliverable.

Under existing arrangements it is not expected that the ecological objectives identified in the environmental flows study can be fully achieved. The achievement of these objectives would require major investment in water recovery and works to overcome the third-party impacts and infrastructure constraints that currently prevent managed delivery of some of the higher flow rate EFRs (Alluvium, 2019).

The Macalister EWMP focuses on delivery of a smaller suite of priority watering activities, which are adopted from the most recent EFRs. However, to fully meet and achieve the objectives and improve overall environmental condition in the Macalister would require the provision of the full suite of EFRs. An additional shortfall assessment provided information on how much additional water would be required to meet different aspects of the EFRs and identify the water needs for ecologically important increments.

Table 11 present the mean annual shortfalls for integrated results of Reach 1 and Reach 2, in years of average seasonal conditions with varying degrees of constraints on delivery (Alluvium, 2020). This shows that the existing EE appears sufficient to deliver the highest priority EFRs under average seasonal conditions. The delivery of high and medium priority EFRs would require an additional 13,529 ML/year on average, and to deliver all EFRs would require an additional 22,135 ML/year on average. When considering flows considered 'currently deliverable', the shortfall volumes are less, at 10,463 ML/year on average. Removal of the fishway constraint shows increased volumetric shortfalls, as with this constraint removed the EFRs for Reach 1 would be adopted for all fish related flow deliveries and these are higher than the recommended volumes for Reach 2.

Table 11 Total integrated shortfalls (ML/year) in Reach 1 and Reach 2 including use of existing EE under average seasonal conditions (Alluvium, 2020)

		Delivery scenario		
Suite of flow recommendations	**Climate scenario**	*No constraint (A)*	*Deliverable flows (B)*	*Fishway removal (C)*
Highest priority flow recommendations (1)	*Current*	0	-	-
	Step Change	0	-	-
Highest and medium flow recommendation (2)	*Current*	13,529	10,463	-
	Step Change	18,880	15,120	-
All flow recommendations (3)	*Current*	22,135	10,232	19,013
	Step Change	32,076	14,608	26,896

In addition to water recovery in the Macalister River the provision of fish passage at Maffra Weir, through the construction of a fishway, would increase the effectiveness of environmental flow deliveries targeted at maintaining and improving the population of native migratory and non-migratory fish species. Fish passage at this point provides access to Reach 1 (i.e., an additional 33 km of habitat up to Glenmaggie Reservoir) and unimpeded connectivity to the coast. Reach 1 offers quality habitat, with a relatively continuous riparian zone, improved water clarity, sand-cobble substrate and riffle-pool sequences. As such, re-establishing connectivity at Maffra Weir is expected to greatly improve the existing abundance, distribution and diversity of native fish species in the lower Macalister River. In August 2022, it was announced that a new Maffra weir fishway would be funded as part of the 2022/23 Victorian Budget. Design of the fishway is expected to be complete in late 2024, with construction finished by the end of 2027.

4. Ecological values of the Macalister River

The focus of this EWMP is on the preservation and restoration of the ecological values of this system. The next section will firstly describe the overall condition of the system, and then describe the ecological values classified into the main biotic constituents, conceptualising their flow-ecology links.

Overall condition of the system

The health of the Macalister River was measured under the statewide condition monitoring program; the Index of Stream Condition (DSE, 2010). The 2010 ISC assessed the entire length of the Macalister River from the headwaters to its confluence with the Thomson River. Unsurprisingly, the upper reaches of the river were found to be in good to excellent condition. The reach immediately preceding Lake Glenmaggie and reaches 1 and 2 below Lake Glenmaggie, were assessed to be in moderate condition. The condition scores for each ecosystem component assessed is provided in Table 12.

Table 12. Condition scores for reaches 1 and 2 of the Macalister River from the 2010 Index of Stream Condition assessment. Scores were out of a maximum of 10 for excellent condition and a minimum of 1 for very poor condition (DSE, 2010)

	Hydrology	Physical form	Streamside zone	Water quality	Aquatic life	Overall score[1]
Reach 1	10	9	5	8	4	31
Reach 2	10	8	6	5	4	28

[1] The overall score is out of a maximum possible of 100.

The 2010 ISC assessment assigned excellent scores for hydrology in the two reaches, however the ISC method changed between the first and second assessment, with the new method deemed inadequate and as such is not considered a strong assessment of condition. The condition of aquatic life was scored poorly for both reaches and Reach 2 was assessed as having poor water quality.

Fish

The presence, abundance and condition of fish in reaches 1 and 2 of the Macalister River have been monitored through the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) and the Native Fish Report Card monitoring program. Eleven native freshwater fish species have been recorded in the lower Macalister River (see Appendix A for a full list). Estuary perch, predominantly inhabiting estuarine waters, have also occasionally been recorded in the lower Macalister River (Alluvium, 2015).

The river is important habitat for at least six native migratory species that span the different forms of migratory behaviour. These species include short-finned and long finned eels, Australian bass, Australian grayling, Tupong, short-headed lamprey and common galaxias.

Five native freshwater species are ‘non-migratory’, although one species, Australian smelt, may have both diadromous and non-diadromous components (Crook, Macdonald, & Raadik, 2008). River blackfish is one such species, long term trends indicate substantial declines in the abundance and distribution of this species in reaches 1 and 2 (Alluvium, 2015). Similarly, the results of 2013-14 fish surveys indicated that populations of southern pygmy perch are currently small and limited in distribution (Amtstaetter & O'Connor, 2014).

Of the freshwater species, the Australian grayling (*Prototroctes maraena*) is listed as vulnerable under the *Environmental Protection and Biodiversity Conservation Act* 1999, endangered under the *Flora and Fauna Guarantee Act* 1988 (DELWP, 2022). Australian grayling has been recorded in most years of fish surveys (predominantly at reach 2), however their abundance has varied from year to year, with a generally increasing trend since the end of the Millennium drought.

Survey information from the 2021/22 VEFMAP Coastal Rivers report (Cornell, et al., 2022) detected a total of 1177 individuals, representing 11 fish species (7 native and 4 exotic) from 5 sites. In the Macalister there is a continued general trend of increasing abundance in Australian Bass, likely supported by ongoing stocking by the Victorian Fisheries Authority. There was a high abundance of Tupong recorded, likely the result of the significant recruitment event in 2021 and good survival of adult fish. Consistent high abundance in this species for the second year in a row is encouraging and highlights the importance of delivering flows to support both immigration and survival of diadromous species (Cornell, et al., 2022).

Flow-ecology linkages

The different flow-ecology links for native fish species in general as well as for the different migratory species groupings are described in Tables 13 – 16 below. An umbrella species has been used to represent the different linkages for each grouping, with additional details on variations to these linkages for other species within this group where information is available.

Table 13. The general flow-ecology links for all fish species.

Native fish: general flow requirements	
Flow-ecology link 1: *Fish passage*	Longitudinal connectivity is required throughout the year to enable local movement of fish All fish species make localised movements for access to resources, and require a minimum water depth of 20 cm to move around the channel. This is particularly important around riffle zones which may obstruct passage.
Flow-ecology link 2: *Pool habitat*	Maintenance of sufficient water depth in pools is required for habitat Pool habitats are important sources of constant in-stream habitat for fish, and require minimum water depths throughout the year to ensure habitat viability.

Table 14. The flow-ecology links for amphidromous species, as represented by Australian grayling.

Amphidromous species flow requirements	
Australian grayling *Prototroctes maraena* (EPBC listed – vulnerable)	
Species longevity	Short-lived species surviving generally to <u>3 years</u> (FIsheries Scientific Committee, 2015)
Age to sexual maturity	Sexual maturity reached at 1+ years for males and 2+ years for females (FIsheries Scientific Committee, 2015)
Migratory patterns	Obligate diadromous fish with amphidromous life history strategy (Crook, Macdonald, O'Connor, & Barry, 2006) Fish mature and spawn in fresh water and larvae drift downstream to the sea, with juveniles migrating back into fresh water (Alluvium, 2015; FIsheries Scientific Committee, 2015)
Flow-ecology link 1: *Spawning*	<u>Increases to river discharge in autumn are required to trigger downstream spawning migration of adult Australian grayling</u> Adult Australian grayling undertake a downstream migration in <u>April-May</u> to lower freshwater reaches coinciding with increases to discharge (Koster, Dawson, & Crook, 2013; Amtstaetter, O'Connor, & Pickworth, 2016). Spawning occurs in these lower freshwater river reaches (Amtstaetter, O'Connor, & Dodd, 2015). Eggs are non-adhesive and larvae hatch between 10 – 20 days. Eggs and larvae drift/disperse into marine waters (Bacher & O'Brien, 1989; (Crook , Macdonald, O'Connor, & Barry, 2006; Koster, Dawson, & Crook, 2013). If these flow requirements are not provided: • Ovarian involution occur in adult female Australian grayling in the absence of increases in river discharge (O'Connor & Mahoney, 2004) • Adults that have not arrived in the lower reaches during the increased discharge cease their migration; they may re-commence on the next flow event if within the spawning period (Koster, Dawson, & Crook, 2013).
Flow-ecology link 2: *Recruitment*	<u>Increases to river discharge in spring are required to recruit juvenile Australian grayling back into freshwater reaches</u> Australian grayling larvae remain in marine waters until approximately 4 – 6 months of age where they migrate back into freshwater as juveniles. They remain in freshwater for the remainder of their lives (Crook , Macdonald, O'Connor, & Barry, 2006; Koster, Dawson, & Crook, 2013). It is hypothesised that increases to freshwater discharge during spring and early summer (Sep–Dec) trigger this upstream migration.

Table 15. The flow-ecology links for catadromous species, as represented by Australian bass.

Catadromous species flow requirements	
Australian bass *Macquaria novemaculeata*	
Species longevity	Long-lived species surviving to 22 years (HAGR, 2014) (Human Ageing Genomic Resources, 2014)
Age to sexual maturity	Sexual maturity reached at 3+ years for males and 5–6+ years for females (Harris, 1986).
Migratory patterns	Obligate diadromous fish with catadromous life history strategy. Fish enter rivers from the sea as juveniles, and adults return to the sea or estuary to spawn (Alluvium, 2015).
Flow-ecology link 1: *Spawning*	Increases to river discharge in autumn and winter are required to trigger downstream spawning migration of adult Australian bass Adult Australian bass undertaken a downstream migration between May–August to spawn in estuarine or marine waters (Battaglene & Selosse, 1996). Gonad development, downstream migration for spawning and year class strength has been found to be correlated with high flow events (Fielder & Heasman, 2011; Growns & James, 2005).
Flow-ecology link 2: *Recruitment*	Increases to river discharge in spring and summer are required to recruit juvenile Australian bass back into freshwater reaches Australian bass post-larvae and juveniles migrate back into the estuarine and freshwater reaches, using macrophyte beds as a source of shelter (Fielder & Heasman, 2011).
Other species in the Macalister system with these requirements	Tupong (*Pseudaphritis urvillii*) Lifespan of 3 – 5 years (TSN, 2015)
	Long-finned eels *(Anguilla reinhardtii)* Lifespan up to 52 years (MDBA, 2022)
	Short-finned eel *(Anguilla australis)* Lifespan of around 35 years (VFA, 2022).
	Common galaxias *(Galaxias maculatus)* Lifespan between 2–3 years (MDBA, 2022)

Table 16. The flow-ecology links for anadromous species, as represented by Short-headed lamprey.

Anadromous species flow requirements	
Short-headed lamprey *Mordacia modrax*	
Species longevity	Considered to survive approximately 6–8 years (Baker, 2008)
Age to sexual maturity	Not known
Migratory patterns	Obligate diadromous species with anadromous life history strategy. Enter rivers from the sea as mature adults and migrate to upstream spawning grounds, with juveniles later migrating downstream to the sea (Alluvium, 2015).
Flow-ecology link 1: *Spawning*	<u>Increases to river discharge in spring and summer facilitate upstream migration of adult short-headed lamprey to spawn in freshwater reaches.</u> Adults spend most of their lives in the sea or estuaries, and then undertaken upstream migration in spring and summer to spawn (MDBA, 2022). Adults are believed to die after spawning. Juveniles migrate back to the sea over several years as they grow. Following metamorphosis, they reach the sea and become parasitic sub-adults (Baker, 2008).

Macroinvertebrates

Data on macroinvertebrates from reaches 1 and 2 are relatively sparse, with the most recent survey conducted in 2005–06. Since this time, the catchment has experienced bushfires, floods and changes to in-stream vegetation. It is likely that these events may have impacted the macro-invertebrate community, but the extent of this impact is unknown.

Previous surveys in 1997, 2002 and 2005 have been indicative of poor environmental conditions, low aquatic diversity, fewer taxa than expected and taxa that would indicate the river was in good condition, missing (Alluvium, 2015).

Flow-ecology linkages

The flow requirements for macro-invertebrates have both specific, but mainly indirect, influences on the macro-invertebrate community through changes to water quality, access to habitat and food sources. These flow requirements are summarised in Table 17.

Table 17. Flow-ecology linkages for macro-invertebrates. *Source:* Alluvium, 2015a.

Macro-invertebrates: general flow requirements	
Flow ecology link 1: Wetted habitat	<u>Baseflows throughout the year to provide continuous wetted habitat</u> The macro-invertebrate fauna in the Macalister River (mayflies, stoneflies and shrimps) require permanent wetted habitat. Baseflows maintain water levels in pools and ensure that edge vegetation is inundated.
Flow ecology link 2: In-stream food sources	<u>Short duration high freshes required to disturb food sources on hard surfaces</u> Scouring flows disturb algae/bacteria/organic biofilm present on hard surfaces. This provides a diversity of available food sources, preventing restriction to a small set of available food species. Additionally, these flows prevent the accumulation of fine sediment in habitats during low flow periods.
Flow ecology link 3: Terrestrial food source	<u>High flows that inundate channel benches and bankfull flows to move organic material from banks to the channel</u> Terrestrial organic material is a major in-stream food sources, and these larger flows provide access to this food. These flows also retain channel form and prevent sediment accumulation.

Platypus and rakali

Platypuses (*Ornithorhynchus anatinus*) and Rakali/water rats (*Hydromys chrysogaster*) are native, semi-aquatic mammals (Alluvium, 2015). Whilst there are no targeted population studies in the Macalister River on either species, data from online databases (Atlas of Living Australia, Victorian Biodiversity Atlas) indicate the species' are widely distributed throughout the Macalister River and its tributaries. However, this data is generally sparse, derived from anecdotal sightings, and more than 20 years old. There is little information on the population trends, or the current distribution, abundance, or status of platypuses and rakali in the Macalister system. State-wide eDNA surveys done through the Odonata '2021

Great Australian Platypus Search' program detected platypus above Lake Glenmaggie, however samples were unsuccessful downstream of Glenmaggie and so a positive or negative sample could not be determined. This area still remains a significant knowledge gap for the lower Macalister.

Both species are assumed to be relatively widespread throughout the Macalister system, but at a low abundance. Platypuses are predicted to be more abundant in the upper, forested reaches while rakali may be more common near population centres in the lower reaches. Both species are thought to have experienced substantial declines in the area, most recently due to severe drought conditions (Alluvium, 2015). Platypus populations are likely to be taking longer to recover and may be considered vulnerable. However, these assumptions need to be tested.

Flow-ecology linkages

Whilst there is a lack of empirical evidence on the impact of flow regimes on platypus and rakali, there are a number of general links to flow based on the species' ecology and habitat requirements. Table 18 details the key flow requirements for both species.

Table 18. Flow-ecology linkages for platypus and rakali (Alluvium, 2015)

Platypus and rakali: general flow requirements	
Flow ecology link 1: Passage	Baseflows throughout the year to provide longitudinal connectivity Baseflows to provide a minimum water depth of 10–20 cm through shallow riffle areas allows for free movement of individuals, provide protection from predators and maintain invertebrate populations. The most important periods for baseflows are during platypus juvenile emergency and dispersal period, February–June; female lactation period, October–February and mating season, August–October.
Flow ecology link 2: Protection of maternal burrows	Avoid bankfull flows during breeding season Breeding season for platypuses occurs during the summer months and is generally at a peak for rakali during this period. Bankfull flows during this period can inundate material burrows, drowning or displacing nestling platypuses. These flows during other times of the year may be beneficial by inundating adjoining wetlands and opening up new foraging areas.
Flow ecology link 3: Maintain foraging efficiency	Avoid extended high flow events to prevent alteration of foraging behaviour High flows can increase the foraging energetics of aquatic animals if they have to swim against strong currents. Whilst individuals can cope with short term high flows, extended events may lead to a loss of condition.

Birds, turtles, and frogs

The riparian vegetation corridors along the river and around some meanders and billabongs, provides habitat for a variety of birds, reptiles, and frogs. Species that have a high likely occurrence in reaches 1 and 2 and the adjoining wetlands include: Clamorous Reed Warbler, Australian Shoveler, Fork-Tailed Swift, Eastern Great Egret, Hardhead, Musk Duck, Cattle Egret, Azure Kingfisher, Little Egret, Latham's Snipe, White-bellied Sea-Eagle, White-throated Needletail, Rainbow Bee-eater, Satin Flycatcher, Nankeen Night Heron, Pied Cormorant, Royal Spoonbill, Rufous Fantail, and Common long-necked Turtle (Alluvium, 2015).

Note that whilst a few species of waterbirds are local residents, the majority are highly mobile at the continental or international scale. This means they are capable of moving into the Macalister River floodplain whenever conditions are specifically favourable and moving elsewhere when they are not (Alluvium, 2015).

No listed taxa is confined to reaches 1 and/or 2 or the floodplain habitat, as this area does not provide any crucial or limiting resources to any of them (Alluvium, 2015). Surveys of birds, turtles, reptiles and frogs have not been undertaken.

Flow-ecology linkages

Due to the number of taxa and diverse ecologies of birds, reptiles and frogs, it is not practicable to consider the variable influences of flow regimes on each taxon. The general flow requirements for most flow-dependent species are described in Table 19.

Table 19. Generalised flow requirements of birds, turtles and frogs. *Source:* Alluvium, 2015a.

Birds, turtles and frogs: general flow requirements	
Flow ecology link 1: Habitat productivity	<u>High flows to flood billabongs and lagoons to create highly productive habitats</u> Many species of waterbirds, turtles and frogs will move to inundated billabongs and lagoons due to the increased productivity from the wetting of these habitats. Species that will benefit from this wetting include deep water foragers (e.g. black swan), large waders (e.g. eastern great egret, royal spoonbill, nankeen night heron), dabblers (e.g. small grebes), fishers (e.g. azure kingfisher, white-bellied sea eagle) and the common long-necked turtle.
Flow ecology link 2: Protection of nests	<u>Avoid bankfull flows during breeding season</u> A number of birds (e.g. azure kingfisher, rainbow bee-eater, spotted pardalote) routinely or occasionally nest in soil banks, and these nests may be lost if water levels rise during the spring summer period. Similarly, the common long-necked turtle lays its eggs in terrestrial soils (above the November high water level) and inundation of nests during the breeding season, <u>November to January,</u> may result in the destruction of an annual cohort of eggs.

Vegetation

Under the Biodiversity Interactive Maps, reaches 1 and 2 of the Macalister River contain various Ecological Vegetation Classes (as per 2005 mapping), all belonging to the Gippsland Plain bioregion. Floodplain riparian woodland is the predominant EVC bordering the river channel along both reaches. Often, this EVC surrounds the offstream billabongs and lagoons adjoining the river. The EVCs that have a significant conservation status are listed in Table 20.

Table 20. Ecological Vegetation Classes with conservation significance in reaches 1 and 2 of the Macalister River.

Ecological Vegetation Class	Area (ha)		Bioregional conservation status
	Reach 1	Reach 2	
Floodplain Riparian Woodland	320	570	Endangered
Billabong wetland aggregate	3	11	Endangered
Aquatic herblands/plains sedgy wetland mosaic	3.5	Not present	Vulnerable
Deep freshwater marsh	10.5	Not present	Vulnerable
Shrubby Dry Forest	266*	Not present	Least concern
Plains Grassy Woodland*	74	Not present	Endangered
Plains Grassland	36	16	Endangered

*between Lake Glenmaggie and reach 1

One of the biggest changes noted from recent observations is the lack of in-stream vegetation in sites that were observed to contain water ribbons (*Triglochin* spp.) and charophytes (macrophytic green algae) in reach 1 and knotweeds (*Perscaria* spp.) along the banks (Alluvium, 2015; SKM, 2003). Reach 1 contains small swards of emergent non-woody macrophytes (*Bolboschoenu*s, *Cyperus* and *Schoenoplectus* spp.) and dense bands of fringing shrubs (e.g., *Acacia dealbata*, species of bottlebrush and tea-tree). Many of the woody species resulted from earlier revegetation and riparian-fencing programs. The canopy layer in Reach 1 is dominated by mountain grey gum (*Eucalyptus cypellocarpa*) and narrow-leaf peppermint (*Eucalyptus radiata*). The shrub layer includes dense stands of burgan (*Kunzea ericoides*), mountain tea-tree (*Leptospermum grandifolium*), woolly tea-tree (*Leptospermum lanigerum*) and silver wattle (*Acacia dealbata*). The zone nearest the stream contains a mix of native and exotic taxa, including *Carex* spp., *Juncus* spp., river club-sedge (*Schoenoplectus tabernaemontani*) and knotweeds. Exotic species were abundant (e.g., kikuyu **Pennisetum clandestinum*), but many sites had been successfully revegetated with native and possibly non-local eucalypts, wattles, and bottlebrushes (Practical Ecology, 2009; Alluvium, 2015). Vegetation condition was rated as 'medium-high' in the upper parts of Reach 1 (Figure 18) and 'medium-low' in lower parts where exotic taxa dominated the shrub layer (e.g. pasture grasses, blackberry) and some stock access was recorded due to fences in disrepair (Water Technology, 2015).

Figure 18. Upper site in reach 1, Macalister River (immediately downstream of Lake Glenmaggie), looking across at the left bank in the 2014 vegetation assessment (Water Technology, 2015)

Reach 2 has been found to contain little to no in-stream or fringing vegetation other than common reed (*Phragmites australis*) (Alluvium, 2015). The canopy layer contained remnant Floodplain Riparian Woodland EVC dominated by river red gum (*Eucalyptus camaldulensis*), silver wattle and tree violet (*Melicytus dentatus*) in the understorey (Figure 19; Water Technology, 2015). However, the understorey is highly exotic containing kikuyu, tradescantia and blackberry. Extensive willow control is evident since the 2009 assessment, however this opening up of the canopy layer has resulted in pasture grass expansion but may also provide the opportunity for native shrub recruitment. Due to the reduction in blackberry and willow cover since 2009, the vegetation condition was rated as 'medium-low' (Water Technology, 2015).

Figure 19. Reach 2 VEFMAP vegetation assessment site in the Macalister River (upstream of Forsythe's Lane bridge) in the 2014 survey (Water Technology, 2015)

Flow-ecology linkages

The watering requirements for vegetation are described in Table 21. These requirements are differentiated for the three different types of vegetation in the system; in-stream vegetation, fringing non-woody vegetation and fringing woody vegetation.

Table 21. Watering requirements for the different vegetation categories present in reaches 1 and 2 of the Macalister River (Alluvium, 2015)

Vegetation type	Flow component	Timing and frequency	Duration and maximum period of inundation
Flow-ecology link 1: Maintenance of adults			
In-stream vegetation (eg. Ribbonweed or Eelweed (*Vallisneria australis*), Water Ribbons (*Triglochin procerum*), pondweeds (*Potamogeton* spp.))	Low water velocity flows of sufficient depth.	Throughout the year	9–12 months
Fringing non-woody vegetation (eg. Rushes (*Juncus* spp.), twig rushes (*Baumea* spp.), clubrushes or clubsedges (*Bolboschoenus* and *Schoenoplectus* spp.), sedges (*Carex* and *Cyperus* spp.), spikerushes (*Eleocharis* spp.), sawsedges (*Gahnia* spp.))	Inundation and/or submersion of vegetation for water level variability	Preferably in spring to summer; 7–10 years in a decade. Can withstand up to 10 months without this watering.	Typically 2–6 months. Maximum period of inundation varies widely with taxa and their position along an elevational gradient from the river. Species will sort along this elevational gradient; those closest to the river will withstand prolonged inundation; those on more elevated land will withstand less. This sorting accounts for the wide variation in the duration to maintain adults. Maximum biodiversity and plant vigour is obtained with shallow and fluctuating water levels.
Fringing woody vegetation (eg. River Red Gum (*Eucalyptus camaldulensis*), paperbarks (*Melalauca* spp.), bottlebrushes (*Callistemon* spp.), teatrees (*Leptospermum* spp.))	Inundation of vegetation for water level variability	Not well known – likely to be late winter through spring, to early summer; annual frequency optimal. Various woody taxa can probably withstand an absence of inundation for a number of years (albeit with loss of plant vigour) as long as they maintain access to shallow groundwater or hyporheic water.	Not known, but likely to be < 3 months. Not known, and likely to vary widely among taxa. The position of these taxa on the stream bank indicates they are tolerant of regular or episodic but not permanent inundation.
Flow-ecology link 2: Recruitment			
In-stream vegetation	Not well known. Many taxa can establish via sexual (i.e. seed) and non-sexual (i.e plant fragments) means.		
Fringing non-woody vegetation	Not well known, but periodic drawdowns probably required to create damp areas for seeds to germinate.		
Fringing woody vegetation	Periodic drawdown or dry periods over spring to early summer to allow seed germination and the establishment of young plants.		

Water-related threats to ecological values

The major water-related threats to the ecological values of reaches 1 and 2 in the Macalister River are:

- **In-stream barriers**: two major in-stream barriers are present in the Macalister River – Lake Glenmaggie and Maffra Weir. These preclude migratory fish species residing upstream of Maffra Weir from completing their lifecycle, and limit access to freshwater habitat for species residing in Reach 1. They also modify the natural sediment regime, and limit the dispersal of propagules for the establishment of in-stream vegetation (Alluvium, 2015).
- **Introduced species**: there are a number of introduced flora and fauna species in the Macalister River. Species such as carp dominate the fish biomass, and blackberry reduce the quality of the riparian zone. These species are directly detrimental to native species through degradation of in-stream habitat quality (through increases to water turbidity), predation and increased competition for shelter and resources (Alluvium, 2015).
- **Flow regulation**: the Macalister River has significantly altered flow regime with reduced annual flow, sustained high discharges in irrigation season and reversed flow seasonality. There is also losses to lateral and longitudinal connectivity through reduced frequencies of medium and high flow events. These changes have implications for water quality, geomorphological processes and indirect and direct effects on in-stream and riparian biota (SKM, 2003).
- **Stream bed, bank and floodplain condition:** agricultural development of the Macalister floodplain has left a legacy of channel instability and riparian degradation, thereby diminishing the ecological function of the river's floodplain and adjoining wetlands (SKM, 2003).
- **Cold water/low oxygen releases from reservoir:** water releases originating from the bottom of large impoundments may be low in oxygen and temperature. These releases may increase the energetics required for thermoregulation for platypuses and rakali and may also impact on the abundance and composition of aquatic invertebrates (Alluvium, 2015).
- **Poor water quality:** pollution from agriculture, industry and urban areas degrade water quality and impacts abundance and diversity of aquatic invertebrates. Highly turbid water also limits the ability of submerged in-stream vegetation to photosynthesise and sedimentation reduces habitat quality for benthic invertebrates (Alluvium, 2015).

5. Traditional Owner Values of Wirn wirndook Yeerung (Macalister River)

The purpose of this section is to provide some context of water-dependent Traditional Owner values and objectives that can be meaningfully recognised and incorporated into the management of environmental water in the Macalister catchment, and more broadly across the West Gippsland catchment. To date, engagement with GLaWAC on water-dependent values and objectives has been through the review of flows studies, Aboriginal Waterways Assessments, representation on Environmental Water Advisory Groups (EWAGs), and through targeted meetings around annual management through the seasonal watering proposal process.

The Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) is the Registered Aboriginal Party (RAP) for the Gunaikurnai community, the Traditional Owners of Country encompassing the WGCMA, as determined by the Victorian Aboriginal Heritage Council under the Aboriginal Heritage Act, 2006 (GLaWAC - Who we are, 2022).

In recognition of the Traditional Owner perspective of connected Country, and the connected nature of the Latrobe, Thomson, Macalister rivers and lower Latrobe wetlands, the following document will cover information that is shared across all rivers and wetlands that receive environmental water deliveries in West Gippsland, rather than focusing solely on the Macalister River.

This review draws from information contained in the following publicly available reports and documents:

- GLaWAC Whole of Country Plan (GLaWAC, 2015)
- WGCMA 2022-23 Seasonal Watering Proposals (WGCMA, 2022)
- VEWH West Gippsland Seasonal Watering Plan (VEWH, 2022)
- Thomson River environmental flows and management review reports and workshops (Streamology, 2020; GLaWAC, 2020)
    - GLaWAC workshop report ‘*Watering needs of species of interest to Gunaikurnai people’*
- Macalister River environmental flows and management review (Alluvium, 2015)
- Latrobe environmental water requirement investigation (Alluvium, 2021)
- Gippsland and Central Region Sustainable Water Strategy (DELWP, 2022)

The content within is not considered to be a static reference and is open to continued review and updating as understanding, access to Country and knowledge sharing continues.

Gunaikurnai Country

With a continued connection to Country spanning more than 27,000 years, the Gunaikurnai are the Traditional Owners over much of Gippsland with approximately 1.33 million hectares extending east-west from near Warragul to the Snowy River and north-south from the Great Dividing Range to the coast and sea country (Figure 20) (GLaWAC, 2015). This area includes the Lake Wellington catchment and the Macalister River (*Wirn wirndook Yeerung*), Thomson River (*Carran Carran*), Latrobe River (*Durt- Yowan*) and the lower Latrobe Wetlands.

As stated in the GLaWAC Whole of Country Plan (2015), **"*Gunaikurnai culture and identity is embedded in Country, with the land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing seen as one. All things come from Wurruk, Yarnda and Watpootjan, the life-giving resources that form the basis of cultural practices.*"**

Gunaikurnai songlines, trade routes, cultural sites and artefacts are found throughout the Gippsland Lakes catchment, reminding the Gunaikurnai of their ancestors and reaffirming their close and continued connection to Country (GLaWAC, 2015).

The Macalister River (*Wirn wirndook Yeerung*), Thomson River (*Carran Carran*), Latrobe River (*Durt- Yowan*) and the lower Latrobe Wetlands are part of the Country of the Brayakaulung people – whose clan area extends from the current site of Sale, Providence Ponds, Avon and Latrobe rivers; west of Lake Wellington to Mounts Baw Baw and Howitt (Figure 20).

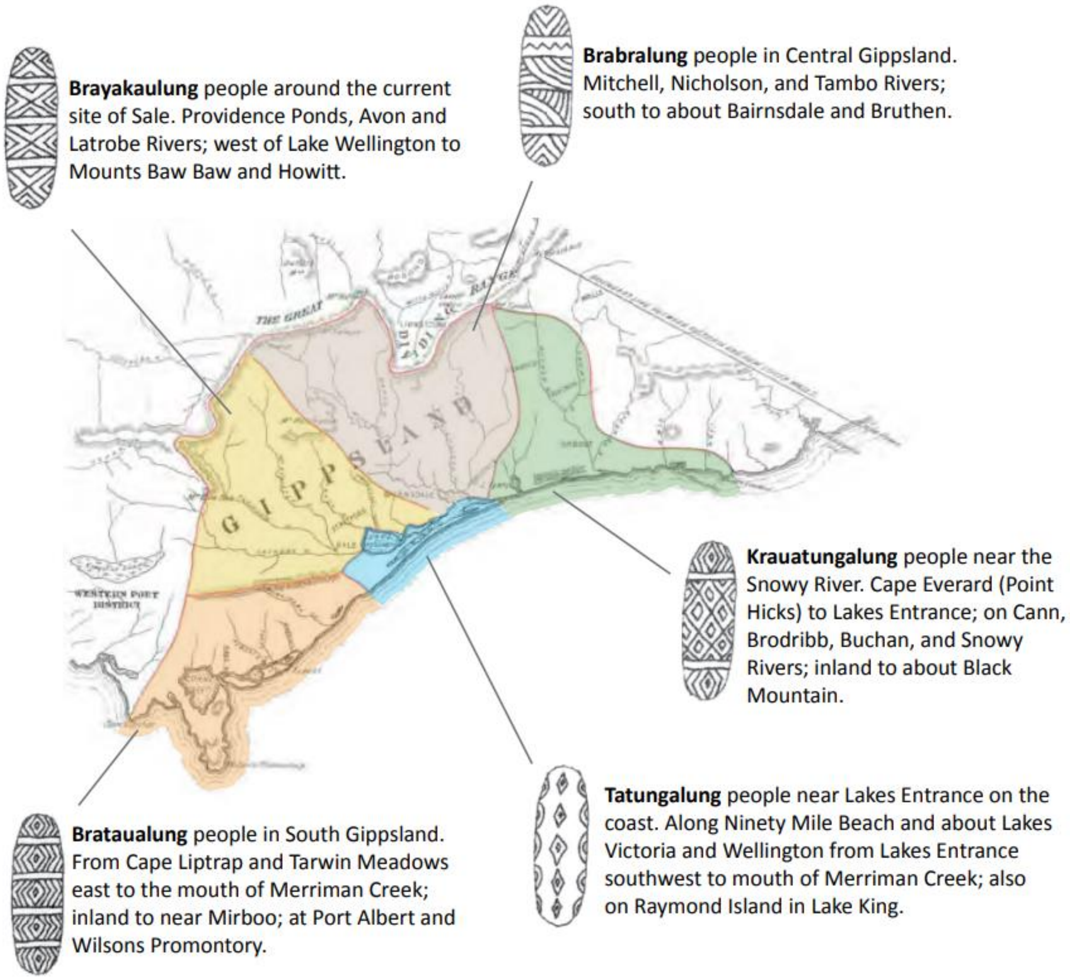

Figure 20 Gunaikurnai Five Clans, from GLaWAC Whole of Country Plan (2015)

Wirn wirndook Yeerung (Macalister River)

"Traditionally the Macalister River is very important to the Gunaikurnai people. It is a pathway that connects from the Alps to the heart of Gippsland. It is a pathway to ceremonial grounds and a known special men's place to Elders. Its traditional name is *Wirn wirndook Yeerung*. *Yeerung* is the men's totem" (VEWH, 2022).

There are many sites of cultural significance near the River and in and around Lake Glenmaggie. Bundalaguah near the confluence of the Macalister and Thomson rivers was the preferred site for a mission in the mid-1860s, before it was set up at Lake Tyers in 1863 after pressure from the white settlers saw Bundalaguah as a site quashed (GLaWAC, 2020).

Significant cultural heritage sites and artefacts have also been found in and around Newry Creek, a paleo-channel of the Macalister River.

Carran Carran (Thomson River)

The Thomson River is known traditionally as "*Carran Carran*" meaning "brackish water". Fish such as *Tambun* (perch) and *Kine* (bream) would have been plentiful and important food sources for the Gunaikurnai people. *Carran Carran* was an important *Quarenook* (meeting place), and a place to *mia mia* (camp). *Carran Carran* is known to have had a lot of native raspberries on the banks, which was an important resource for the Gunaikurnai people. In the past, gatherings were held on the Thomson, using the plentiful resources (GLaWAC, 2020).

Today the majority of *Carran Carran* is inaccessible to the Gunakurnai, making it very difficult to read Country and assess the health of the River through a cultural lens. It is estimated about 80 per cent of the waterway is inaccessible due to being on privately held land. As a result, not much cultural heritage surveying has been undertaken, nor has it been possible to meet and yarn along the River (GLaWAC, 2020).

Durt-Yowan (Latrobe River) & lower Latrobe Wetlands

The *Durt-Yowan* is an important resource for the Gunaikurnai people. Numerous registered Aboriginal cultural heritage sites and values such as scarred trees, artefact scatters, earth features and shell deposits are located along the river and tributaries (VEWH, 2022).

Culturally, the lower Latrobe wetlands are an important site. Dowd Morass is of high cultural significance with over thirty registered indigenous cultural heritage sites such as scarred trees, artefact scatters, earth features and shell deposits (WGCMA, 2022). The lower Latrobe Wetlands represent an important *Quarenook* (meeting place).

Cultural objectives and environmental water linkages

While the primary purpose of environmental watering is to support environmental objectives, these may align with cultural objectives (e.g., meeting some requirements of totem species, improved fishing or hunting opportunities, support of cultural events).

Through flow study reviews and the development of EWMPs, alignment and linkages between environmental water and Traditional Owner water dependent objectives have started to be better understood, particularly through annual planning. Next steps are to better reflect where these already occur, and to highlight where there are opportunities to better achieve water-dependent cultural objectives in annual planning.

The WGCMA also plans to review and update monitoring and knowledge gap assessments, incorporating Traditional Owner objectives, working with GLaWAC to include values and challenges that can be included in State and local programs and studies.

Previously, GLaWAC have identified both holistic and specific indicators and principles of river health when considering the management of environmental water and health of rivers and the estuaries:

- A **seasonal flow regime** with wet and dry periods is an important element of healthy Country
- Maintaining **water quality** is also a sign of healthy Country in the river and estuary reaches
- Providing **deep enough freshwater** in the wetlands to support appropriate habitat conditions for important plants and animals.
- Controlling **pest species** – important part of healthy country
- Presence of keystone species: If *Boran* (pelicans) and *Tuk* (musk duck) are living and breeding there, it is a sign Country is healthy.
- *Balagen* (Platypus) are also important keystone species. *Balagen* are considered an umbrella species, with their presence being a sign Country is healthy.
- It is important to maintain and restore freshwater habitat to support native fish populations for fishing and hunting. In particular, species of significance including *Noy yang* (eels), Australian Bass, River Blackfish, Estuary Perch and *Kine* (Black Bream), and crayfish.
- *Loombrak* (Water Ribbons, *Triglochin sp*) is an important plant for food and basket weaving, as well as being a food source for animals and nesting areas for birds and habitat for fish and frogs.
- Many other reeds and grasses are also used for basket weaving; emergent vegetation is relevant to river reaches, the estuary and the wetlands
- Water quality indicators such as suspended solids and turbidity are also important across the river systems.
- Cormorants can be a good indicator of water quality – indicative of food availability, which in turn reflects water quality
- Native vegetation in the riparian zone is very important, including wattles (for multiple purposes and as part of the GLaWAC calendar)

Previously identified high level watering requirements to support cultural values and uses include:

- more water needs to go down *Wirn wirndook Yeerung* (Macalister River) between Lake Glenmaggie and Lake Wellington, to improve water quality, including the threat of salinity, and to support plants and animals with cultural values and uses.
- timing of environmental watering planned in partnership with GLaWAC to support a seasonal flow regime and wet and dry periods that embody healthy Country. This includes providing

increased water depth to promote downstream fish migration and spawning, deeper water pools to prevent water quality degradation, and more variation in water level to better mimic natural conditions

- maintaining freshwater supply to the Latrobe River estuary, Dowd Morass, Sale Common and Heart Morass, and associated freshwater habitats. The lower Latrobe wetlands are an important resource for the Gunaikurnai
- providing connectivity between reaches and onto floodplains to support dependent plants and animals with cultural values and uses of significance to the Gunaikurnai
- maintaining water quality to support the health of native plants and animals with cultural values and uses of significance to the Gunaikurnai (VEWH, 2022).

To determine the watering needs from a cultural perspective, resourcing and access has to be provided to understand where cultural heritage sites are intact and engage with Gunaikurnai Community on cultural values and uses (GLaWAC, 2020).

6. Socio-economic values of the Macalister River

Recreational values

There are at least four reserves along the Macalister River that provide basic facilities allowing visitors to enjoy the river. Lake Glenmaggie and its surrounding recreational reserve is used for boating, swimming, recreational fishing and other watersports (SRW, 2014). Reaches 1 and 2 of the Macalister River have traditionally been used by locals as a place for swimming, recreational fishing, kayaking, and wildlife watching. Often, these activities are enjoyed by local landholders accessing the river frontage adjoining their private land (Alluvium, 2015). Bellbird Corner Riverside Reserve is also an important reserve for seeing native wildlife and is frequented by local avid bird watchers and wildlife photographers (BCRRMC, 2015).

Economic values

Water resources harvested from the Macalister River make significant contributions to the region’s economy. Lake Glenmaggie provides approximately 90% of the water used in the MID. From 2007 estimates, the irrigated agriculture in the MID generates around $650 million (SRW, 2007). The dairy industry in the MID produces around 400 million litres and grosses approximately $500 million each year (SRW, 2007). Commercial horticulture in the MID, thrives from the river’s water supply and is expected to expand overtime, changing future water demands. It is evident that the local employment rates and the growth/maintenance of this region’s economy hinges heavily on the water resources harvested from this river.

Shared benefits

As part of annual water planning, shared benefits are identified. Table 22 below summarises the shared benefits identified in the 2022-23 WGCMA Seasonal Watering Proposal (WGCMA, 2022).

Table 22 Macalister River Shared benefits review for 2022-23.

Who?	Shared benefit
Locals and other visitors from outside the region	Watering that refreshes waterholes, particularly over summer, may improve the water quality key waterholes and thus the swimming conditions. Freshes throughout the year, also increase the longitudinal connectivity of the river, improving kayaking conditions
Recreational fishers/anglers	Planned winter and spring freshes encourage the spawning and recruitment of Australia bass, a popular recreational fish species

Landholders with river frontage & public land	Watering in autumn and spring helps to maintain bankside vegetation, preventing erosion and potential land loss. This watering complements any on-ground riparian rehabilitation works also undertaken as part of the WGCMA's Waterway Strategy

7. Management objectives

Macalister River vision statement

The following vision statement for the Macalister River (reaches 1 and 2) sets the overarching guiding principle for management of this river. This vision statement was established with the Macalister PAG:

"In partnership with the community, we will preserve and enhance habitat to support native water dependent plants, animals and the ecological character of the Macalister River and floodplains for current and future generations."

Management objectives

The next section describes the template for environmental water planning and delivery in the Macalister River. This template is defined by water dependent ecological values (referred to as values for short), ecological outcomes, ecological flow objectives and flow recommendations. Figure 21 illustrates how these terms are related and link to non-flow related factors.

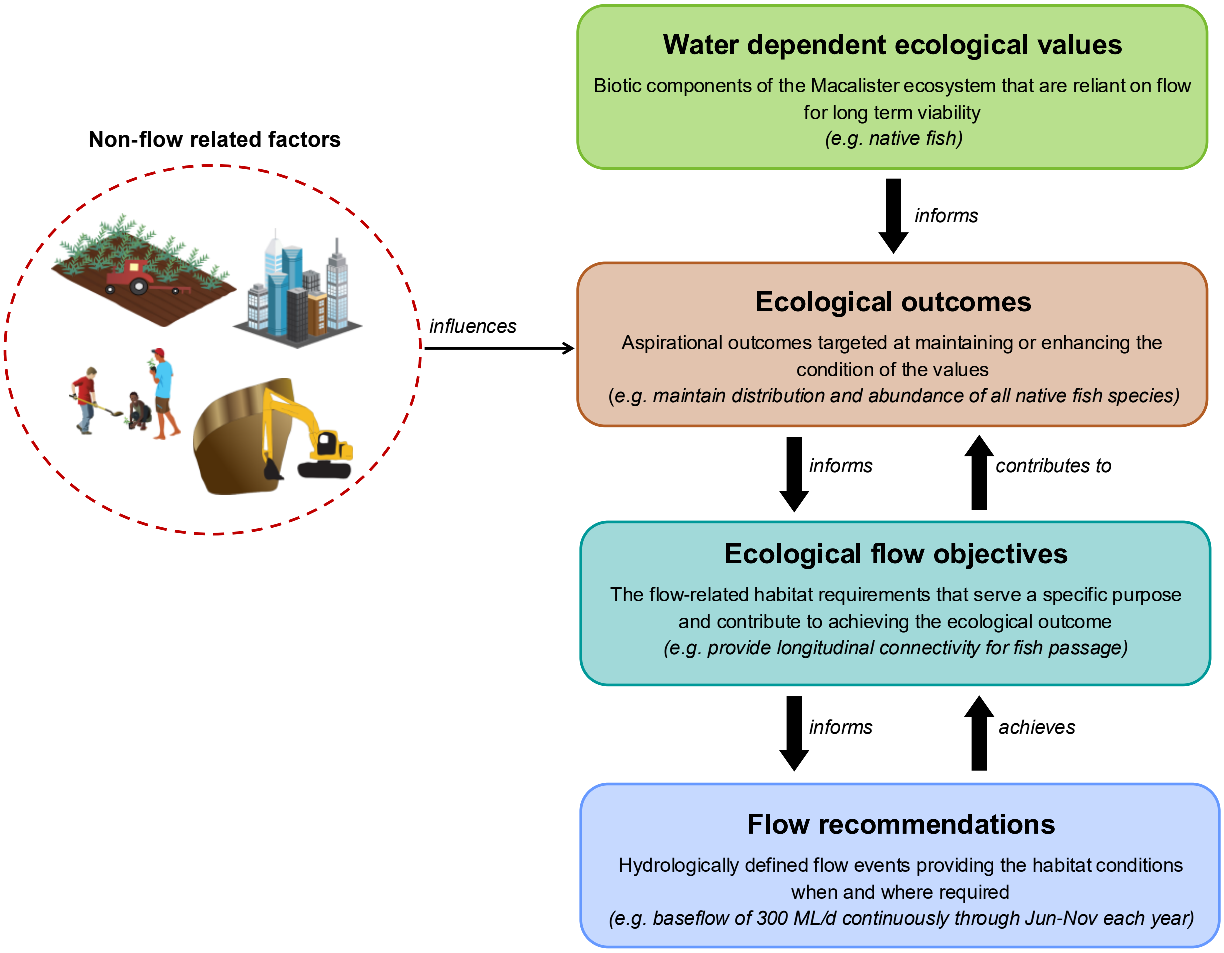

Figure 21. Linkages between values, outcomes, ecological flow objectives and flow recommendations.

Water dependent ecological values

The water dependent ecological values of reaches 1 and 2 of the Macalister River have been classified into five categories; native fish, macroinvertebrates, platypus and rakali, birds/turtles/frogs, and native vegetation. For most categories, this includes numerous species of flora and fauna. However, it is not practical to develop customised flow recommendations for *all* species, especially given that the flow-ecology link is not fully understood for many flora and fauna. As such, each value category has been considered through a combination of the groupings below:

- *Single species:* for species' with conservation significance (e.g. Australian grayling) or species identified as an important value by the Macalister PAG or the community at large
- *Functional groups:* to distinguish different flow-related requirements (e.g., fringing vegetation versus in-stream vegetation) within the value category
- *Broad category* if the flow-related requirements are mutually shared across the category given current local knowledge constraints (e.g., platypus and rakali).

Physical form was also included an as additional category to these biotic values. Though not a value in and of itself, physical form is representative of the broader abiotic components required by these biotic constituents.

Ecological outcomes and ecological flow objectives

Ecological outcomes were developed for all values during the Macalister environmental flows study (Alluvium, 2015) based on:

- ecological outcomes previously identified in the Macalister River environmental flows assessment (SKM, 2003);
- regional waterway priorities (WGCMA, 2014);
- conceptual models of the flow-ecology links;
- ecological values articulated by the Macalister PAG; and
- expert input from the Environmental Flows Technical Panel (EFTP).

Ecological flow objectives were developed based on the conceptual flow-ecology links described in Section 4. Whilst ecological flow objectives contribute directly to an ecological outcome, meeting the ecological flow objectives in isolation is unlikely to achieve the ecological outcome. This is because the outcome is influenced by non-flow related factors that necessitate other forms of management intervention. The ecological objectives for the Macalister River are:

- Improve spawning and recruitment opportunities for migratory fish species (including Australian grayling; Short-finned Eel; Australian Bass and Tupong)
- Improve the distribution and abundance of Australian grayling
- Maintain the distribution and abundance of all expected native fish species
- Reinstate native submerged vegetation
- Improve native emergent (non-woody) vegetation

- Maintain fringing native woody vegetation in the riparian zone
- Maintain the abundance and number of functional groups of macroinvertebrates
- Improve the abundance of platypus and rakali

Table 23 lists all the ecological outcomes and ecological flow objectives identified during the Macalister environmental flow study (Alluvium, 2015). Note that in some instances multiple objectives may be linked to a particular ecological outcome or vice versa.

Table 23. Ecological outcomes and the relevant ecological flow objectives identified for all water dependent ecological values in reaches 1 and 2 of the Macalister River.

<table>
<tr><th>Ecological objective</th><th>Target</th><th>Expected Watering Effects</th></tr>
<tr><td colspan="3">FISH</td></tr>
<tr><td>By 2032, improve the distribution and abundance of Australian grayling from baseline (2008/9)</td><td>• By 2032 there is evidence of regular recruitment (minimum 1 out of 4 years) of Australian grayling
  • Representatives in the young-of-year or juvenile size classes detected regularly in annual fish surveys</td><td rowspan="2">• Provide continuous access to hydraulic habitat through <u>sufficient water depth in pools</u>
• Provide continuous <u>longitudinal connectivity</u> for fish passage through sufficient depth over riffles (min. depth 0.2 m)</td></tr>
<tr><td>By 2032, improve the distribution and maintain the abundance of all 11 expected native fish species from baseline (2008/9)</td><td>• By 2032 there is evidence of improved distribution in native fish, and evidence of recruitment across all sites of the Macalister River
  • Representatives in the young-of-year size class regularly detected in annual fish surveys
  • Presence of expected migratory species above and below the Maffra Weir fishway</td></tr>
<tr><td>By 2032, improve spawning and recruitment opportunities for expected 6 native migratory fish species from baseline (2008/9)</td><td>• By 2032 there is evidence of recruitment (i.e. successful spawning) through detection of young-of-year native fish every 2 out of 3 years for expected migratory species
  • Representatives in the young-of-year or juvenile size classes detected in annual fish surveys</td><td>• Provide annual flows cues through <u>increasing water depth</u> to promote <u>downstream migration and spawning</u> for Australian grayling (April-May), tupong (May-Aug) and Australian bass (May-Aug)
• Provide annual flows cues through <u>increasing water depth</u> to promote <u>upstream migration</u> of adult anadromous species (e.g. short-headed lamprey), and recruitment of juvenile catadromous (e.g. tupong, common galaxias, Australian bass, short and long-finned eels) and amphidromous species (e.g. Australian grayling)(Sep-Dec)</td></tr>
<tr><td colspan="3">MACROINVERTEBRATES</td></tr>
<tr><td>Maintain the abundance and number of functional groups of macroinvertebrates</td><td>• By 2032, there is semi-regular monitoring of macroinvertebrates to better understand abundance and diversity</td><td>• Provide permanent <u>wetted habitat</u> through <u>sufficient water depth in pools</u> (1 m)
• Once every two years provide flows with <u>sufficient shear stress</u> (>1.1 N/m^2)# to <u>scour sediment and disturb biofilms for food</u> sources
• <u>Once every two years Inundate higher benches</u> to move organic material into the channel to <u>provide habitat</u>
• <u>Three times per year Flush pools</u> to <u>improve water quality</u>
• <u>Three times per year Increase wetted area</u> to provide <u>increased wetted habitat</u></td></tr>
</table>

Ecological objective	Target	Expected Watering Effects
PLATYPUS AND RAKALI		
By 2032, improve the abundance of platypus and rakali	• By 2032, there is semi-regular monitoring of platypus and rakali populations along the Macalister River	• Maintain refuge habitats and Provide longitudinal connectivity for local movement , through sufficient depth over riffles (min. depth 0.2m) • Avoid bankfull flows during breeding season (Oct-Mar)to improve breeding opportunities* • Avoid extended high flow events (>X days?) to enable foraging*
BIRDS, TURTLES, FROGS		
Maintain the abundance of frog, turtle and waterbird communities	• By 2032, there is semi-regular monitoring/surveys of frog, turtle and waterbird communities along the Macalister River	• Once every two years (July- Oct) Wet low lying areas on the floodplain to provide habitat and food sources
VEGETATION		
Re-instate submerged aquatic vegetation	• By 2032, understand the limiting factors preventing in-stream vegetation establishment in the Macalister system in order to identify management options.	• Provide continuous baseflows (Dec-May) with low water velocity and appropriate depth to improve water clarity and enable establishment of in-stream vegetation • Provide flow variability that Inundates a greater area of stream channel (increasing water depth) to limit terrestrial vegetation encroachment (June-Nov)
Improve native emergent (non-woody) vegetation	• By 2032, evidence of improvement in non-woody native vegetation from the 2009 baseline (VEFMAP)	• Provide flow variability that Inundates a greater area of stream channel (increasing water depth) to limit terrestrial vegetation encroachment • Three times a year Inundate low benches to provide water level variability and facilitate longitudinal dispersal of emergent vegetation (Dec-Mar)
Improve fringing woody vegetation in the riparian zone	• By 2032, understand the changes and causes of change to fringing vegetation over time, in order to identify management options.	• Once a year (Sep-Oct) Inundate mid-level benches to provide water level variability and submerge fringing vegetation • Once a year (Sep-Dec) Inundate higher benches to provide water level variability and submerge woody vegetation • Once every two years Inundate to top of bank to disturb and reset fringing vegetation

Ecological objective	Target	Expected Watering Effects
PHYSICAL FORM		
Improve physical habitat	• By 2032, review of refuge areas and channel modelling to determine if flow requirements are adequately met.	• Maintain a continuous minimum depth in pools to allow for turnover of water and slow water quality degradation • Expose and dry lower channel features for re-oxygenation • Three times per year provide a minimum depth over riffles and duration (2 days) to Flush pools to improve water quality • Provide flows with sufficient shear stress (>1.1 N/m^2)[#] to flush fine sediment from interstices to improve geomorphic habitat • Inundate to top of bank to maintain gross channel form and prevent channel contraction

[#] Shear stress of 1.1 N/m^2 is required to mobilise coarse sand sediments as per Fischenich, 2001.

Flow recommendations

Defining hydrologic parameters

Flow recommendations were developed for each of the ecological flow objectives (Table 23). Flow recommendations are characterised by five hydrologic parameters; seasonality (or timing), magnitude, duration and intra and/or inter-annual frequency (i.e. events per year and/or minimum occurrence over multiple years). The sources of information used to define these parameters in all flow recommendations are documented in Table 24.

Table 24. The sources of information used to define the hydrologic parameters that make up a flow recommendation.

Parameter	Metric for measurement	Information sources
Target flow magnitude	Average daily flow in ML/d	1D and 2D hydraulic modelling* to link magnitude to hydraulic targets in the ecological flow objective (e.g. wetting of a defined area, minimum water depth).
Seasonality	Time of year in months	Life cycle traits and understanding of flow-ecology link via conceptual model (if known)
Duration (days)	Number of days	Life cycle traits and understanding of flow-ecology link via conceptual model (if known) OR The duration range of the flow event in the unimpacted flow scenario (Section 3.1)
Frequency (intra and inter)	Number of events per year (intra) or number of events in a defined multi-year period (e.g. one of two years)	

*Further detail on the development and implementation of the hydraulic models is provided in Alluvium, 2015.

To build in management flexibility for different climatic conditions, duration and frequency were also defined according to four climate scenarios; drought, dry, average or wet. These reflect the changing aims of flow management based on water availability (Figure 22), from avoiding critical losses and protecting refuge habitat in drought & dry conditions to maximising reproductive and recruitment opportunities in average and wet years. The assumptions informing scenario selection, in terms of annual water planning, are to be reviewed in 2023.

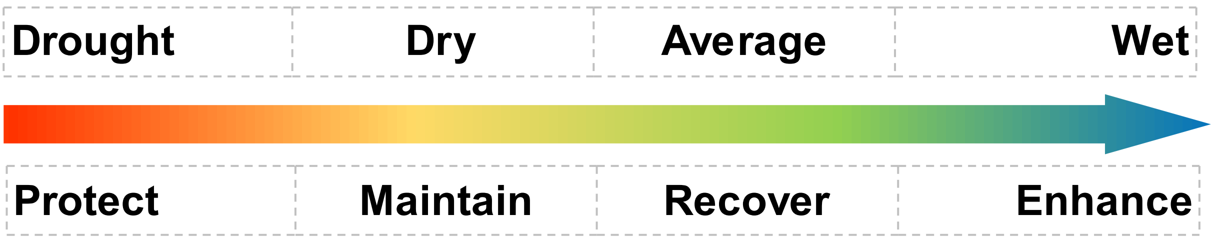

Figure 22. The changing aims of flow management under varying climatic conditions.

Flow recommendations for ecological flow objectives

Flow recommendations may cater for multiple ecological flow objectives (e.g. flushing waterholes for macroinvertebrates will also wet fringing vegetation). Conversely, there are instances in which more than one flow recommendation was established to accommodate the variations within a specific ecological flow objective (e.g. flow cues for Australian grayling spawning are different to those for Tupong).

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Table 25 details the flow recommendations for reach 1 and 2 that relate to each of the ecological flow objectives. Due to the difference in channel shape between reach 1 and 2, the target magnitude for a flow recommendation varies between the reaches. As such, there are also variations between the duration of the event. In terms of implementation of the flow recommendation, the magnitude and duration appropriate for the reach targeted for the prioritised ecological flow objective will be chosen.

Table 25. Flow recommendations for the ecological flow objectives established for reach 1 (R1) and reach 2 (R2) of the Macalister River. Ne: DRT = drought; AVG = average. *Source:* Alluvium, 2015b.

	Ecological flow objective	Magnitude (ML/d)	Timing	Duration	Frequency
Baseflows					
Vegetation	Provide flows with low water velocity and appropriate depth and to improve water clarity and enable establishment of in-stream vegetation	R1 90 R2 35	Dec – May	Continuously for 6 months	1/yr
Physical form	Maintain a minimum depth in pools to allow for turnover of water and slow water quality degradation				
	Expose and dry lower channel features for re-oxygenation				
Fish	Provide habitat through sufficient water depth in pools	R1 90 R2 35	All year	Continuously for 6 months	1/yr
	Provide longitudinal connectivity for fish passage (min. depth 0.2 m)				
Macro-invertebrates	Provide permanent wetted habitat through sufficient water depth in pools (1 m)				
Platypus & rakali	Provide longitudinal connectivity for local movement (min. depth 0.2m) and maintain refuge habitats				
Vegetation	Inundate a greater area of stream channel (increasing water depth) to limit terrestrial vegetation encroachment	R1 320 R2 300	Jun – Nov	Continuously for 6 months	1/yr

Freshes					
Fish	Provide flows cues through increasing water depth to promote upstream migration and recruitment of juvenile catadromous species (*for short-finned and long-finned eels*)	R1 350 R2 140	Dec – May	R1 DRT 3* DRY 5 AVG 10 WET 20	DRT 1/yr DRY ≥1/yr AVG ≥1/yr WET ≥1/yr
Macro-invertebrates	Flush pools to improve water quality				
	Increase wetted area to provide increased wetted habitat			R2 DRT 20* DRY 40 AVG 40 WET 60	
Vegetation	Inundate low benches to provide water level variability and facilitate longitudinal dispersal of emergent vegetation				
Fish	Provide flows cues through increasing water depth to promote downstream migration and spawning (*for Australian grayling)*	R1 350 R2 140	Apr - May	R1 DRT 3* DRY 3 AVG 5 WET 5	DRT 1/yr DRY 1/yr AVG ≥1/yr WET ≥1/yr

				R2 DRT 3* DRY 5 AVG 15 WET 25	
Fish	Provide flows cues through <u>increasing water depth</u> to promote <u>downstream migration and spawning</u> (*for Australian bass and tupong)*	R1 1,500 R2 700	May – Aug	R1 DRT 3* DRY 5 AVG 10 WET 20 R2 DRT 3* DRY 5 AVG 15 WET 25	DRT 1/yr DRY 1/yr AVG ≥1/yr WET ≥1/yr

Vegetation	Inundate mid-level benches to provide water level variability and submerge fringing vegetation	R1 1,500 R2 700	Sep – Oct	R1 DRT 3 DRY 5 AVG 10 WET 20 R2 DRT 3 DRY 5 AVG 15 WET 25	DRT 1/yr DRY 1/yr AVG ≥1/yr WET ≥1/yr
Fish	Provide flows cues through increasing water depth to promote upstream migration of adult anadromous species, and (*e.g. short-headed lamprey*), and recruitment of juvenile catadromous (*e.g. tupong, common galaxias, Australian bass*) and amphidromous species (*e.g. Australian grayling*)	R1 1,500	Sep – Dec	R1 DRT 3 DRY 5 AVG 10 WET 20	DRT 1/yr

		R2 700		R2 DRT 3 DRY 5 AVG 15 WET 25	DRY 1/yr AVG ≥1/yr WET ≥1/yr
Macro-invertebrates	Provide flows with <u>sufficient shear stress</u> (>1.1 N/m²)# to <u>scour sediment and disturb biofilms for food</u> sources	R1 2,500 R2 1,500	Sep – Dec	DRY 5 AVG 10 WET 20	DRY ≥1/yr AVG ≥1/yr WET ≥1/yr
Vegetation	<u>Inundate higher benches</u> to provide <u>water level variability</u> and <u>submerge woody vegetation</u>				
Macro-invertebrates	<u>Inundate higher benches</u> to move organic material into the channel to <u>provide habitat</u>	R1 3,000 R2 1,500	Any time of year	DRY 1 AVG 1 WET 2	DRY 1/yr AVG 1/yr WET 1/yr
Physical form	Provide flows with <u>sufficient shear stress</u> (>1.1 N/m²)# to <u>flush fine sediment from interstices</u> to improve geomorphic habitat				
Bankfull#					

Birds, turtles, frogs	Wet low lying areas on the floodplain to provide habitat and food sources	R1 & R2 10,000	Any time of year	AVG 1 WET 1	AVG 1/yr WET 1/yr
Vegetation	Inundate to top of bank to disturb and reset fringing vegetation				
Physical form	Inundate to top of bank to maintain gross channel form and prevent channel contraction				

* Minimum duration of the total event including ramp up and ramp down should be 6 days.

Bankfull flows are included as part of the flow recommendations as they are important for a number of water dependent values. However due to the large volumetric demand of these events and the high likelihood of flooding private land and damaging infrastructure, these events are not considered when prioritising watering actions each year.

Two additional flow recommendations have been added since those outlined in Alluvium (2015), these are detailed below:

- **Autumn fresh in M2 to trigger Australian grayling spawning**: the recommended magnitude for this event is 140 ML/d, however irrigation releases are generally of this magnitude during this time. Australian grayling require a rise in flow to commence downstream migration (Koster et al. 2009) and as such, the M1 magnitude for this event (350 ML/d peak) has been adopted. The recommended duration of this event will vary depending on the climatic scenario, but a minimum of six days is recommended before the event begins to ramp down.
- **Summer-Autumn protecting baseflows:** Drought conditions in 2018-19 saw reduced passing flows in reach M2, due to reduced inflows to Lake Glenmaggie. With reduced flow and decreasing water quality, a formal variation to use environmental water was required to keep the river flowing and maintain water quality. As such, it is now written into drought and dry scenarios to protect these baseflows and avoid catastrophic events such as critical drops in water quality and fish deaths.

8. Implementing an environmental watering regime

The environmental watering actions to be carried out from year to year will vary depending on the prevailing climatic conditions, water availability, and the antecedent hydrology the river reaches have experienced. Thus, prioritisation of environmental watering actions is inherently adaptive and will be managed as such through the Macalister Seasonal Watering Proposal using climate scenario planning and habitat provision assessment. The next section will discuss habitat provision assessment in planning and prioritising environmental watering actions.

Planning and prioritisation of watering events

The habitat assessment approach

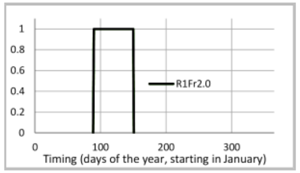
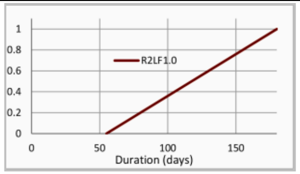
The hydrologic parameters that characterise a flow recommendation combine to provide a specific flow-based habitat required to meet an ecological flow objective. However, it is recognised that the relationship between the habitat condition and changes to the hydrologic parameter varies depending on the objective and the flow-ecology linkage. Traditionally, when the timing, duration or magnitude of a flow event (i.e. from unregulated or consumptive releases) does not sit within the specifications of the flow recommendation, it is assumed that there was no habitat provided and thus no ecological benefit. In reality, this is not the case. In many instances, there may be *some* habitat provided even if the flow event deviates from the recommended range. Documenting the extent of potential benefit is important for ongoing flow management. This means that habitat provision can be assessed under various flow scenarios and holistically as per the total flow regime encompassing the unregulated, environmental and consumptive flows. Assessment of habitat provision, as opposed to compliance with hydrologic parameters alone, provides a more meaningful result that maybe used to:

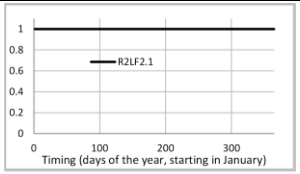
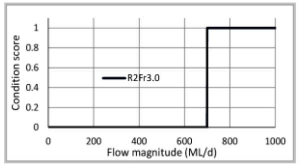
- highlight where values are passively receiving their flow-related habitat requirements through consumptive water delivery or unregulated flows; and
- highlight values that are not receiving their flow-related habitat requirements; and
- prioritise environmental watering actions accordingly.

Habitat provision assessment can be undertaken on any time step – be it monthly, annually (via Seasonal Watering Proposals) or to compare flow scenarios.

A series of habitat preference curves that relate habitat condition to changes in flow magnitude, duration and timing were developed for each flow recommendation (for a full list refer to Appendix D). Curves were developed by the EFTP based on their conceptual understanding (or where available, specific findings) of the ecology-flow link. Three types of habitat condition responses were identified and are described in Table 26. Note that whilst most curves in Table 26 illustrate only one discrete response, a habitat preference curve may be made up of any combination of these responses.

Table 26. Habitat preference curves: capturing habitat conditions responses to changes in flow magnitude, timing or duration. Habitat condition (y-axis) is rated from a maximum of 1 (i.e., parameter meets the optimum range and provides maximum habitat) to 0 (i.e. parameter does not offer any habitat benefit).

Response	Relevant example ecological flow objective	Habitat preference curve
Binary: habitat condition is fully provided if the hydrologic parameter is within a defined range. Outside this range, no habitat is provided.	Provide flows cues through increasing water depth to promote downstream migration and spawning for Australian grayling, tupong and Australian bass	 *Australian grayling* spawning occurs within a very restricted window of time between April to May. Monitoring has found that the provision of this flow requirement outside this period does not elicit any marked spawning response.
Incremental: habitat condition increases or decreases with a change in the hydrologic parameter.	Provide flows with low water velocity and appropriate depth and to improve water clarity and enable establishment of in-stream vegetation	 These flow conditions are ideally required for 172 days. However the benefit for in-stream vegetation establishment is increases with duration when it is >55 days.

Response	Relevant example ecological flow objective	Habitat preference curve
No response: habitat condition does not change with the hydrologic parameter (up to a point or for the full range of the parameter).	a) Provide longitudinal connectivity for local movement (min. depth 0.2m) and maintain refuge habitat for platypus and rakali b) Provide flows cues through increasing water depth to promote downstream migration and spawning for Australian grayling, tupong and Australian bass	 a) The provision of this flow event is independent of season and will provide the maximum habitat condition, regardless of when it is delivered during the year.  b) *Australian bass* spawning migration requires flows >700 ML/d to provide the right habitat conditions. Flows <700 ML/d will not provide any habitat conditions to trigger spawning. However, flows >700 ML/d will continue to provide the optimum habitat conditions to elicit spawning behaviour.

Habitat provision can then be assessed using any daily flow time series (e.g., measured streamflow) and these habitat preference curves. Flow events from the time series are evaluated on a daily time step using eWater's Ecological Modeller platform. Flow events in the time series are given a habitat provision score by multiplying the habitat condition values achieved as determined by the magnitude, duration and timing preference curves (Figure 23). This delivers a habitat provision time series for a specific ecological objective (Figure 24).

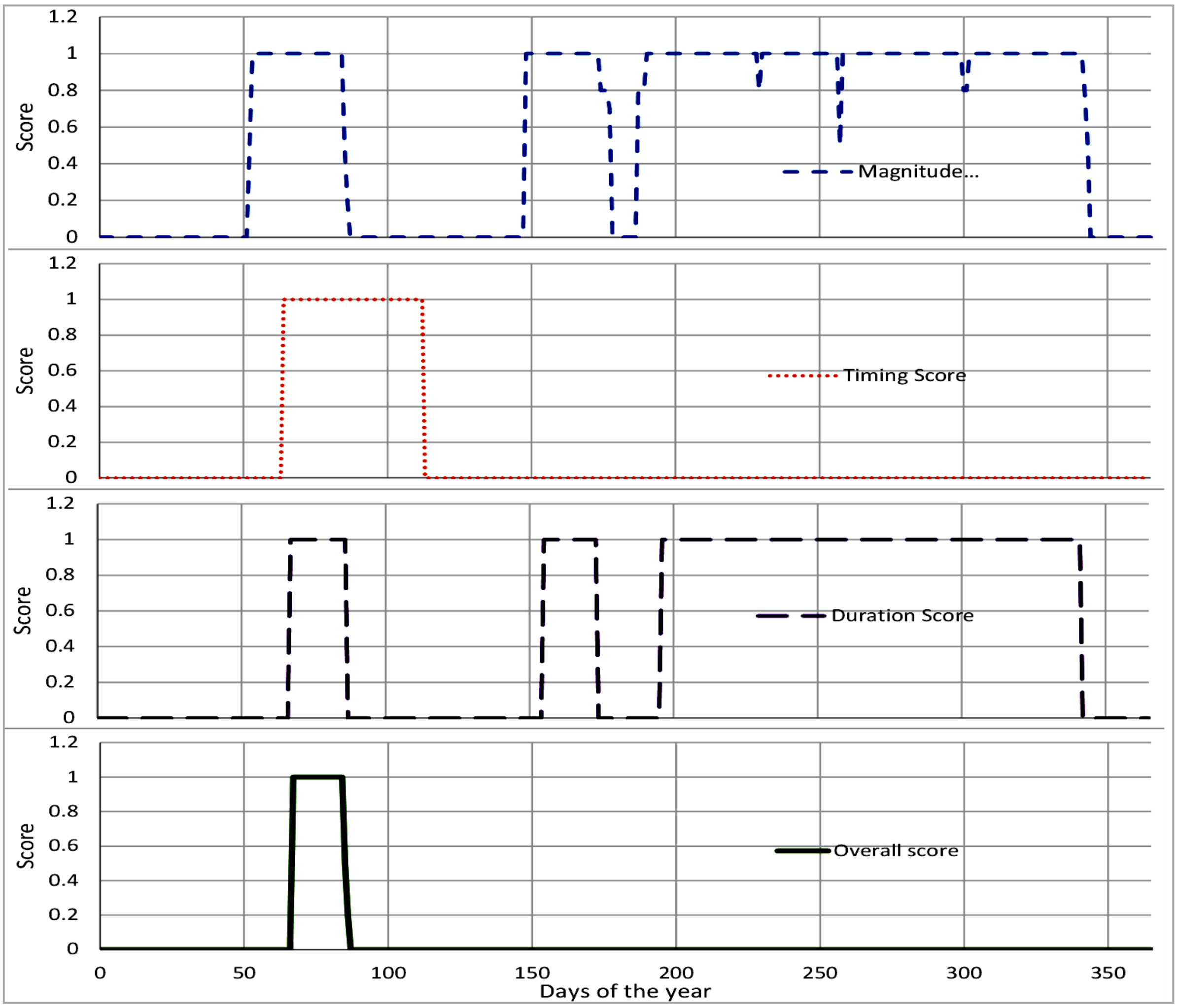


Figure 23. Habitat provision assessment: how daily flow time series and habitat preference curves are combined to quantify the extent of habitat provided for an ecological flow objective. *Source:* Alluvium, 2015c.

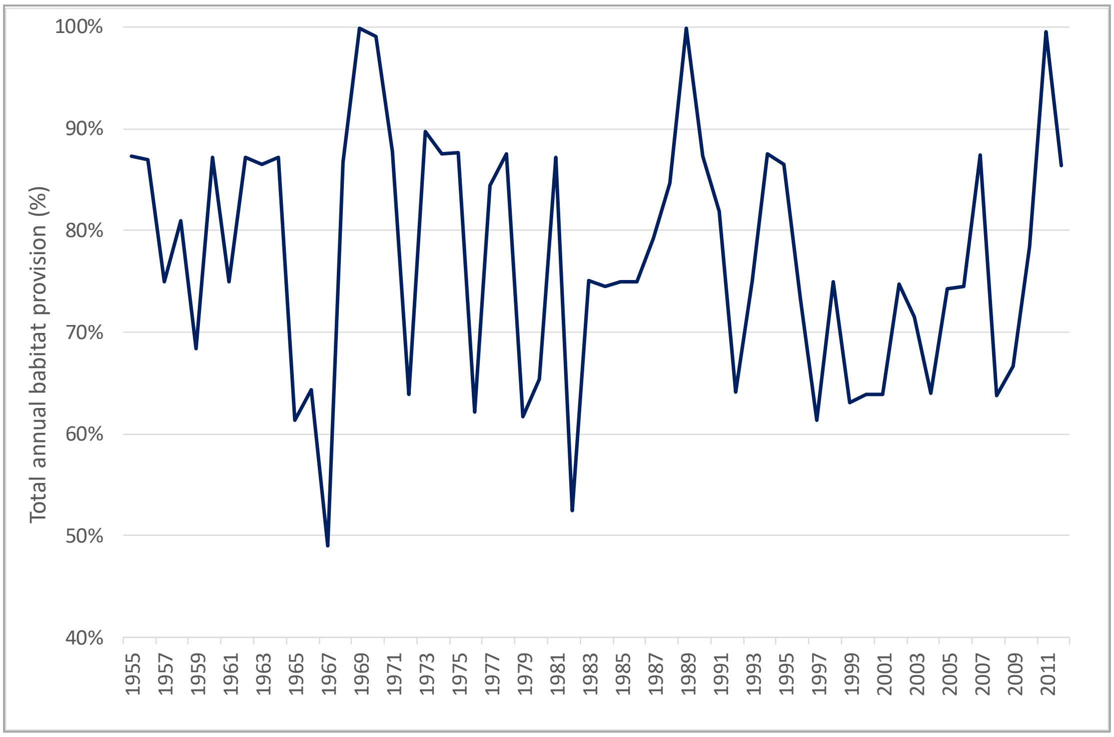


Figure 24. Habitat provision time series showing the change in flow-habitat conditions required for the upstream migration of juvenile catadrmous species (short-finned and long-finned eels). Note that these times series can be developed for any time step including daily and monthly.

Habitat provision time series may be overlayed with information on the inter-annual frequencies of habitat required (as informed by conceptual models described in Section 4), to determine whether habitat needs to be provided actively through environmental watering or is not critical. These forms of data are to be used in the future for prioritisation of environmental watering actions in seasonal watering proposals and monthly review of the ecological flow objectives that have been provided through the existing flow regime (including unregulated, consumptive and environmental releases).

Scenario Planning

In administering the environmental water reserve for the Macalister River, the West Gippsland Catchment Management Authority use several decision support tools:

- Data and reports from monitoring programs within the systems
- Latest scientific knowledge/understanding relevant to the systems
- System understanding and emerging issues
- Climatic predictions
- Flow modelling and scenario evaluation tool
- Ecological condition
- Historical environmental flow compliance
- Entitlement allocation

This information is used to determine the current and predicted watering operation scenario and flow deliveries for the systems throughout the watering year. Implementation of watering actions will be undertaken collaboratively with Southern Rural Water (SRW), such that events are delivered within the appropriate time frame.

Releases will be determined based on water availability, and seasonal conditions.

There are two key allocation announcements throughout the year:

1. In July, High Reliability Water Share (HRWS) allocations are announced with a maximum allocation of up to 100% depending on availability of water stored in the Thomson drought Reserve.
2. December 15th HRWS allocations are reviewed, due to the end of the spilling period with a maximum allocation of 100%.

Four scenarios have been identified for the Macalister River: drought, dry, average, and wet. The following indicators, summarised in Table 27, have been incorporated into each of the annual planning scenarios for the Macalister River.

Allocations to the Macalister River environmental entitlement are a good indicator of water availability for delivering water in the Macalister River downstream of Lake Glenmaggie, and likely irrigation deliveries along the river, but are a lagging indicator of both reservoir spills and minimum passing flow reductions, which makes allocations a poor indicator for these two aspects of flow in the river. It was also noted that designated “drought” years were occurring in the year following the years widely understood to be actual drought years, and not within the actual drought years. This is because allocation is based not only on inflows, but also on volume in storage, with volume in storage typically very low at the end of a drought year. Allocations are therefore a lagging indicator of spills and passing flow reductions, reflecting conditions which have already passed. Passing flow reductions and (to a lesser extent) spills are however a function of river flow conditions. Therefore, the likelihood of spills and passing flows reductions should be linked to the probability of exceedance of annual inflows, not allocations.

Table 27 Climate scenario summary for the Macalister River

<table>
<tr><th colspan="2"></th><th colspan="4">Drought</th><th colspan="4">Dry</th><th colspan="4">Average</th><th colspan="4">Wet</th></tr>
<tr><td colspan="2">Environmental Objectives</td><td colspan="4">PROTECT</td><td colspan="4">MAINTAIN</td><td colspan="4">RECOVER</td><td colspan="4">ENHANCE</td></tr>
<tr><td rowspan="9">Expected River Conditions</td><td>Lake Glenmaggie inflow POE (%)</td><td colspan="4">≥90%</td><td colspan="4">66-90%</td><td colspan="4">33-66%</td><td colspan="4">≤33%</td></tr>
<tr><td rowspan="3">Lake Glenmaggie inflow (GL/yr)</td><td colspan="2">Min</td><td colspan="2">57%</td><td colspan="4">103%</td><td colspan="4">118%</td><td colspan="4">136%</td></tr>
<tr><td colspan="2">Average</td><td colspan="2">83%</td><td colspan="4">113%</td><td colspan="4">126%</td><td colspan="4">155%</td></tr>
<tr><td colspan="2">Max</td><td colspan="2">103%</td><td colspan="4">118%</td><td colspan="4">136%</td><td colspan="4">200%</td></tr>
<tr><td>Passing Flows</td><td colspan="4">Likely reduced passing flow volumes based on inflows: 35-60 ML/d or natural (as per the Bulk Entitlement Rules)</td><td colspan="4">Likely reduced passing flow volumes based on inflows: 35-60 ML/d or natural (as per the Bulk Entitlement Rules)</td><td colspan="4">Passing flows 60 ML/d</td><td colspan="4">Passing flows 60 ML/d</td></tr>
<tr><td>Unregulated Flows</td><td colspan="4">No unregulated flows</td><td colspan="4">Low likelihood of reservoir spill/s, volume dependent on rainfall; up to minor flood level

Spills most likely in to occur in winter/spring</td><td colspan="4">Reservoir spill/s in spring likely, volume dependent on rainfall; minor to moderate flood level

Spills most likely in to occur in winter/spring</td><td colspan="4">Reservoir spill/s likely anytime during the spill period, volume dependent on rainfall; moderate to major flood level</td></tr>
<tr><td>Consumptive Water</td><td colspan="4">Low consumptive water delivery throughout the irrigation season (15 Aug – 15 May) – most of this water diverted downstream of Maffra Weir. Water availability a likely constraint on irrigation deliveries.</td><td colspan="4">High consumptive water delivery from late spring (post-spill period) to end of irrigation season, predominantly during the warmer months – most of this water diverted downstream of Maffra Weir</td><td colspan="4">Moderate to high consumptive water delivery from later spring (post-spill period) to end of the irrigation season, predominantly during the warmer months – most of this water diverted downstream of Maffra Weir</td><td colspan="4">Low demand for consumptive water delivery from late spring (post-spill period) to end of irrigation season. Rainfall likely to reduce the need for irrigation deliveries.</td></tr>
<tr><td rowspan="2">Median flow (ML/d)</td><td>Summer</td><td>Autumn</td><td>Winter</td><td>Spring</td><td>Summer</td><td>Autumn</td><td>Winter</td><td>Spring</td><td>Summer</td><td>Autumn</td><td>Winter</td><td>Spring</td><td>Summer</td><td>Autumn</td><td>Winter</td><td>Spring</td></tr>
<tr><td>78</td><td>62</td><td>89</td><td>82</td><td>129</td><td>88</td><td>114</td><td>167</td><td>104</td><td>84</td><td>190</td><td>653</td><td>95</td><td>97</td><td>252</td><td>827</td></tr>
</table>

Environmental water shortfalls

It has previously been acknowledged that there is an environmental water shortfall in the Macalister River, when comparing the volume of water required to provide all flow recommendations against the volume available in the *Macalister River Environmental Entitlement 2010* (maximum allocation of 21 GL). Volumetric assessments of shortfalls are described in more detail in Section 3, estimating that to provide the full suite of EFRs under average seasonal conditions would require an additional 19,500 ML/yr i.e., in excess of the existing environmental entitlement. A higher volume would be required during dry years (averaging 28,800 ML/yr). Therefore, significant further investment in water recovery is therefore required to fully meet the EFRs for the Macalister River.

- **Meeting shortfalls through unregulated releases**: it is possible for shortfalls during the winter and spring period to be provided for through the shaping of unregulated releases from Lake Glenmaggie. This strategy, whilst not entirely reliable from year to year (although Lake Glenmaggie tends to spill in most years), is an opportunistic approach. To make this approach functional, SRW will need to contact the waterway manager (WGCMA) when forecasting such a release, so that both organisations can collaborate to (a) deliver a watering action and (b) meet SRW's storage filling curve objectives.
- **Trading water from other systems:** there is potential for environmental water from other systems to be traded, using the VEWH's trading framework. This method will only constitute a short-term transfer of water to address temporary shortfalls during a particular water year.
- **Purchase of more environmental water:** the current environmental entitlement may be increased to address some of this shortfall. This option provides for a permanent transfer of water.
- **Recovering water savings from the MID modernisation projects:** there are approximately 12.3 GL of water savings expected from the rollout of modernisation projects across the MID, some of these savings could be recovered to boost the existing environmental entitlement.

The Central and Gippsland Region Sustainable Water Strategy, released in 2022, has specific policies actions which relate to the future management of environmental water in the Macalister River (DELWP, 2022), these are summarised here:

- **Policy 8-10:** Return water to the *Wirn wirndook Yeerung* (Macalister River) in the short term. By 2026, the Victorian Government will return 1.7 GL of water for the environment to improve waterway health (achieved through completion of Phase 3 of MID2030)
- **Policy 8-11:** Return water to the *Wirn wirndook Yeerung* (Macalister River). By 2032, the Victorian Government will return up to an additional 10.9 GL of water for the environment to improve waterway health (achieved through a combination of substituting river water for manufactured water in the longer term, and through potential water savings accrued from irrigation modernisation).
- **Action 8-15**: Build the Maffra Weir fishway to improve native fish migration, breeding, and diversity in the *Wirn wirndook Yeerung* (Macalister River). Completion of the detailed design by 2024, and construction of the fishway by 2027.

9. Managing risks to achieving objectives

Risk management is a core discipline that assists in making correct and informed decisions; a qualitative risk assessment was undertaken for this EWMP focussing on risks to the water dependent values and the risks associated with environmental water management. Table 28 details the assessment matrix used and Table 29 provides an overview of the risks and contingency planning to manage these risks.

Table 28. Risk assessment matrix.

Likelihood	Consequence				
	Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Almost certain (5)	Low	Med	High	Extreme	Extreme
Likely (4)	Low	Med	High	Extreme	Extreme
Possible (3)	Low	Med	Med	High	Extreme
Unlikely (2)	Low	Low	Med	High	Extreme
Rare (1)	Low	Low	Low	Med	High

Table 29. Risk contingency planning.

Risk description	*Likelihood*	*Consequence*	*Risk rating*	Mitigation Strategies
Threats to water dependent ecological values and their ecological outcomes				
In-stream structures such as Lake Glenmaggie and Maffra weir impede fish passage and compromise longitudinal connectivity provided through environmental watering and prevent upstream and downstream migration for diadromous species distributed in reach 1.	Almost certain	Major	Extreme	• Funding to evaluate, design and construct fish passage at Maffra Weir will greatly enhance connectivity • In the interim, reach 2 will be the target reach for all environmental watering actions that target longitudinal connectivity and migratory flow cues in reach 2
In-stream structures (i.e. Lake Glenmaggie) greatly reduce the source of propagules required to re-instate in-stream vegetation.	Almost certain	Moderate	High	• Funding will be sought for projects to investigate types of management intervention required to assist re-establishment of in-stream vegetation
In-stream structures (i.e. Lake Glenmaggie) continues to alter the natural sediment regime of the system, impacting on physical habitat.	Almost certain	Moderate	High	• The sediment trapping nature of Lake Glenmaggie is unlikely to change • Erosion around Lake Glenmaggie may be managed by SRW through erosion control measures
Introduced fish species such as common carp, degrade in-stream habitat (increasing water turbidity) and outcompete native fish for resources.	Almost certain	Major	Extreme	• A broad scale successful method to control carp populations has yet to be found, as such, this risk is unlikely to change
Increasing horticulture in the district exacerbates nutrient and sediment loads in runoff, impacting on stream water quality.	Possible	Moderate	Medium	• Water quality in the MID is currently managed under the Macalister Land and Water Management Plan, and changes to land use and thus runoff will be incorporated and managed under this plan
Grazing continues to impact on riparian vegetation and physical habitat	Possible	Major	High	• The WGCMA have done extensive work to revegetate the riparian zone and build in fences for stock exclusion • This work will be continued, and monitoring of previous work will indicate where maintenance may be required
Introduced vegetation species such as blackberry and willow, degrade riparian habitat and outcompete recruitment and establishment of native plants.	Possible	Moderate	Medium	• Continue with weed control programs for all river reaches • Monitor and maintain previous work, identifying key problem areas
Modernisation projects in the MID reduce groundwater recharge in the system, impacting on groundwater dependent ecosystems such as the river itself, adjoining wetlands and riparian vegetation	Possible	Major	High	• There is little knowledge on the extent of groundwater reliance of the river, it adjoining wetlands and riparian vegetation • Monitoring to quantify these relationships is important to identify any possible changes as a result of these modernisation projects • A regional GDE program will be scoped and established to measure such relationships for important and/or highly impacted GDEs in the West Gippsland region

Risk description	***Likelihood***	***Consequence***	***Risk rating***	**Mitigation Strategies**
Threats associated with environmental water delivery				
Environmental watering degrades water quality from localised erosion associated with flow releases, releases from the bottom of the storage	Unlikely	Moderate	Medium	• Stratification is unlikely to occur Lake Glenmaggie due to the relatively small size of the storage combined with its annual emptying and filling routine • However, the effect of environmental watering on water quality is not known, and event-based water quality monitoring is required to quantify the relationship between flow releases and water quality
High freshes during platypus breeding season inundate burrows	Possible	Major	High	• Little is known on the abundance, distribution and breeding locations of platypus in the Macalister River • Funding for a monitoring program to understand their distribution and breeding locations will inform where and when high freshes need to be delivered/avoided • eDNA survey of Reach 1 and 2 to determine presence/absence of platypus
Release volume is insufficient or exceeds required flow at target point.	Unlikely	Minor	Low	• Storage operator aims to meet required flow at target point as a minimum. Flows are typically slightly higher than required.
Delivery constraints due to storage management/maintenance and/or irrigation releases. This leads to lower releases than required leading to potential loss of biota.	Unlikely	Moderate	Medium	• Ongoing dialogue with Storage Operators to schedule maintenance works. • Provide storage operators with flexibility in timing of event when events are scheduled during irrigation season.
Environmental account is overdrawn	Unlikely	Minor	Low	• Storage operator to maintain daily accounts and provide provisional weekly accounts
Environmental release causes flooding of private land	Unlikely	Moderate	Low	• All watering actions to be considered are below flooding risk (i.e. bankfull flows will not be considered)

10. Environmental water delivery constraints

There are a number of constraints associated with the delivery of environmental water in the Macalister system. These constraints and their implications are described in Table 30.

Table 30. Environmental water delivery constraints for the Macalister River.

Constraint	Description	Implications for environmental watering
Fish barrier at Maffra weir	• Maffra Weir is operational for nine months of the year and is a fish barrier that inhibits movement of fish species out of and into Reach 1 (Lake Glenmaggie to Maffra weir) during this time • The presence of a low level stream gauge weir downstream of Maffra weir is only drowned out during high flows • These sequential barriers have meant that fish in reach 1 are trapped and unable to complete their life cycle • A fishway for Maffra Weir has been announced, due for completion 2027	• Lack of fish passage at this weir reduces the effectiveness of freshes that trigger migration and spawning and baseflows that provide a continuous period of longitudinal connectivity • Removal of this barrier will greatly increase the ecological benefit of these watering actions
High reliability and low reliability water allocations	• There are three allocation announcements throughout the water year; June - HRWS (max. of 90%), February - remaining HRWS, and March - LRWS (max. 100%) • During this time the climate scenario may change from a wet winter/spring to a dry summer/autumn, impacting on the LRWS allocations	• If during the water year, the climate condition changes from wet/average to dry/drought, there may be insufficient water to deliver priority watering actions that occur later in the water year • Changes to the climatic conditions will need to be assessed monthly, using long term weather forecasts, antecedent conditions and SRW advice • There is potential to use passing flow savings accrued during late spring/summer to deliver flow events later in the year and thereby buffer any major, unforeseen changes in the climatic condition
Lake Glenmaggie outlet capacity constraints	• Flow release from Glenmaggie weir can be made through the hydropower plant or the environmental offtake on the northern irrigation channel • The capacity at the hydropower gate is limited by the volume of water in the weir due to changes in head pressure • Releases from the environmental offtake are limited in the northern channel as a large volume of irrigation orders will reduce the outlet capacity share available for environmental water	• Environmental watering events planned for release within the irrigation season (i.e. spring, summer and autumn), may not be released if large irrigation orders overlap with the release timing • Providing the storage operator flexibility on the exact timing of the environmental water release will ensure that environmental watering events are still delivered within the irrigation season

Constraint	Description	Implications for environmental watering
Maffra Weir outlet capacity constraints	• Environmental water delivered to Maffra Weir are released using sluice gates and/or the opening of the weir gate • As the water level in the weir pool needs to be maintained at a constant height, release of environmental water delivered from Lake Glenmaggie is done incrementally with the weir gate opening and closing automatically to re-adjust for the pool height	• This release mechanism may cause significant fluctuations in the downstream water level throughout the day – compromising the intention of the flow release (especially when it is a baseflow release) • SRW is currently investing in a project that will improve flow measurement and delivery at Maffra Weir
Inundation of private land	• Bankfull and overbank flows are not currently considered a priority for environmental deliveries due to the risk of flooding adjoining property • releases from Lake Glenmaggie shall not exceed 1500 ML/d without development of a detailed risk and flood assessment.	• Environmental deliveries will target in-channel EFRs only • Where possible environmental deliveries can piggy-back on operational releases to achieve bankfull outcomes – planning and process will involve the VEWH, SRW and WGCMA

11. Demonstrating outcomes: monitoring

Monitoring activities in the Macalister system may be classified using the VEWH's (2015) monitoring classification system illustrated in Figure 25.

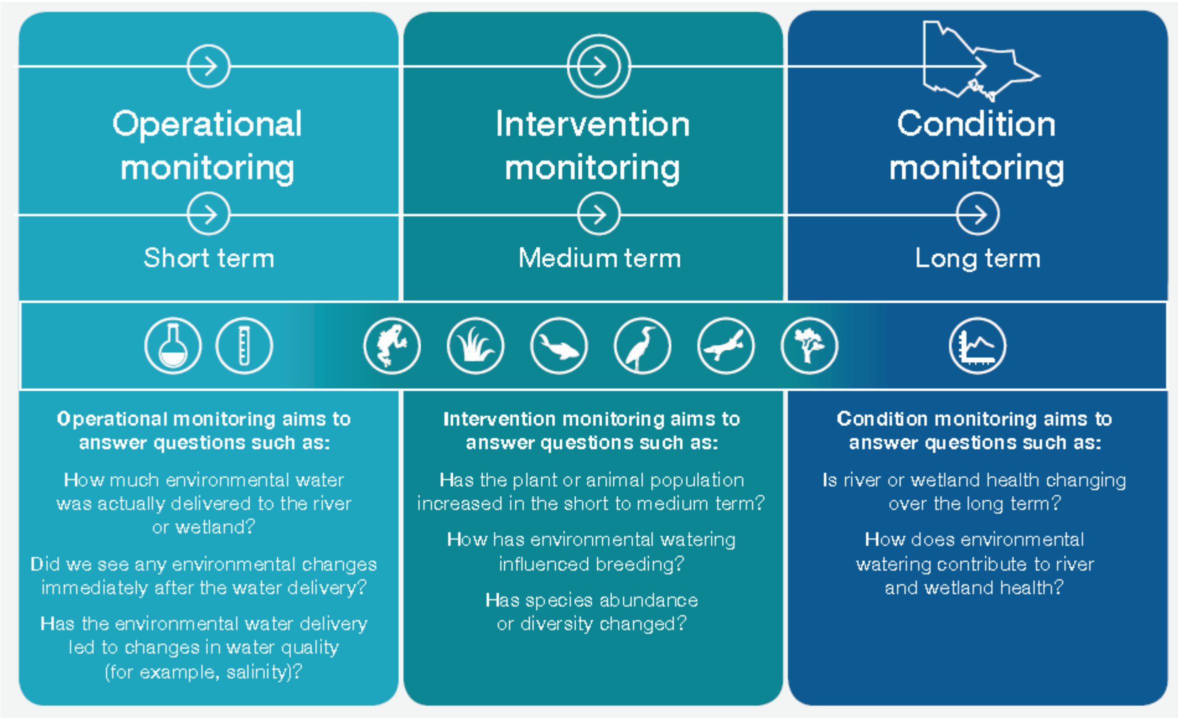


Figure 25. The different types of monitoring. *Source:* VEWH, 2015.

To date, monitoring in the Macalister system has primarily focussed on operational and condition monitoring encompassing the following activities:

Operational monitoring

Hydrologic compliance to minimum passing flows and environmental watering release orders is assessed using measured gauge data at the Maffra Weir tail gauge (225242). The Riverslea gauge is also used to monitor Reach 2 flows on a monthly basis. This data is also used to assess whether flow recommendations were inadvertently met through unregulated flows or consumptive water delivery.

In dry-drought conditions, spot water quality monitoring may also be carried out in Reach 2 to monitor dissolved oxygen levels. This information can then be used to determine if a fresh or baseflow needs to be provided.

Intervention monitoring

Annual VEFMAP fish surveys conducted in the Thomson River and other coastal, regulated systems with the same or similar water dependent values will provide transferrable knowledge to inform environmental water management for the Macalister River. These surveys give a snapshot of the fish population, also identifying if recruitment has occurred. This information feeds into the annual planning process as deliveries can be prioritised, for example to support young-of-year.

The Native Fish Report Card program focuses on the collection of long-term information on the condition of native recreational fisheries across the state. The program commenced in 2017, collecting information on various indicators of fish population health including abundance, year-class distribution for specific fisheries and target recreational species and priority threatened species. The Macalister River has been prioritised as a key fishery where monitoring will focus on Australian bass and Australian grayling.

Whilst this program is not directly targeted at environmental watering responses, it has the ability to supplement the native fish surveys collected under VEFMAP. It may also prove useful to understand the status of Australian bass in the river. Australian bass is considered a flow dependent species that is targeted during winter and spring freshes, but there are still large knowledge gaps associated with flows required to trigger spawning and recruitment responses.

Condition monitoring

Under the Victorian Environmental Flows Assessment Program (VEFMAP), a number of condition monitoring programs have been implemented for the Macalister River (reaches 1 and 2). Monitoring programs are repeated condition assessments over a long timeframe to capture spatio-temporal changes to the condition and health of various ecosystem components. To date, the following components have been monitored:

- Fish: distribution, species diversity, abundance, length to weight ratios in annual surveys conducted over the last decade;
- Riparian vegetation (no in-stream vegetation): monitored species diversity, floristic composition and coverage in three assessments spanning a six year period;
- Macro-invertebrates: community composition, diversity and compliance to State Environmental Protection Policy (SEPP) objectives; and
- Physical habitat: characterisation of the physical characteristics of the river channel including channel shape, substrate composition, in-stream habitat classifications undertaken twice over a four year period.

Fish surveys have also been carried out through the Native Fish Report Card annual surveys, targeting Australian Bass and Australian grayling from 2017 – 2022.

12. Recommendations

Addressing knowledge gaps

Current understanding of the ecology of the Macalister system and its relationship to the river's hydrology will continue to improve overtime with monitoring, research and management experience. Table 31 outlines the important knowledge gaps identified for this system that, if addressed, will improve and refine flow management of this river. Alongside each knowledge gap are activities identified to address the gap, including monitoring, desktop analysis or investigative technical studies (Alluvium, 2015).

Table 31. Knowledge gaps and activities to address these gaps, including monitoring requirements.

Knowledge gap	Description	Activities to address knowledge gap
Biotic		
Platypus and rakali	Little information on current distribution and abundance on platypus and rakali in the Macalister system. Current distribution data is largely from anecdotal sightings in the Victorian Biodiversity Atlas – these indicate both species are widely distribute throughout the system, but some of this data is more than 20 years old. Little quantitative data on the flow requirements of both species, the impacts of regulated flow regimes on their populations and food sources (benthic macroinvertebrates).	**Presence/Absence assessment** • eDNA surveys to detect platypus signals in the lower Macalister **Condition monitoring** • Targeted population study to delineate distribution and abundance in the system **Intervention monitoring** • Understand the response of platypuses and rakali to variable flow regimes with particular focus on very low and very high flows • Determine optimal flow regimes by quantifying habitat availability and benthic productivity at different flows • Identify environmental factors that influence timing of reproduction and reproductive success • Identify drought refuges and determine minimum flows required to maintain these refuges • Determine minimum flows required to maintain longitudinal habitat connectivity along the entire river Monitoring efforts could focus on instances of significant threat including bankfull flows during breeding, continuous high flow period, poor water quality events and areas with poor riparian vegetation.
Diadromous fish species (e.g. Australian grayling, eels,	Need greater understanding on how flow affects movement (e.g. the hydraulic characteristics of physical habitat that influence swimming ability)	**Intervention monitoring** • Use telemetry (tagging) techniques to monitor movement of these species

Knowledge gap	Description	Activities to address knowledge gap
tupong and Australian bass)		• Statistically analyse movement data with overlayed hydraulic and hydrologic information
Australian bass spawning behaviour	Need further understanding on how specific mechanisms of flow influence spawning success for this species – do freshes in autumn and winter improve spawning conditions through stimulating primary productivity in the marine habitats that increase food sources for larval bass?	**Intervention monitoring** • Monitoring of primary productivity rates, Australian bass spawning behaviour in spawning habitats is required • This data needs to be analysed with streamflow to identify correlations between flow event characteristics and spawning success
Flows for resident fish species (e.g. River Blackfish)	Need further understanding of how environmental deliveries can impact or influence the survival and population structure of resident native fish species Also, need to reassess location and quality of refuge pools along the Macalister and how their condition can be maintained – before, during and after extreme events (i.e. drought, fire and flood).	• Resurvey channel and assess refuge pool conditions and risks in the Macalister River • eDNA surveys for presence/absence of resident fish species • Research into low flow and channel conditions on native fish species – re-test flow recommendations for suitability
In-stream vegetation	Anecdotal information indicates that the river did support in-stream submerged vegetation previously. However, these extensive beds are now absent. There is a need to understand the limiting factors preventing in-stream vegetation establishment in this system in order to identify management actions that may support its re-instatement.	**Condition monitoring** • Map current presence of any remnant in-stream vegetation **Intervention monitoring** • Monitoring to determine whether submerged vegetation establishes in the main river channel • if establishment fails – determination of the causative factors such as water quality (turbidity) monitoring in both reaches over the long term and relationships to flow
Fringing vegetation	Fringing vegetation in the system has changed considerably over time. For example, abundant and healthy beds of common reed are now rare. There is little understanding on when they have disappeared and what has caused this loss.	**Desktop analyses** • Analyse historical documents (e.g aerial photographs, and supplementary photographs from the local community) to determine where and when riparian vegetation has changed to obtain a visual and guiding template of what the river "should" look like **Intervention monitoring** • Monitoring of vegetation response (including in-stream vegetation response) from areas that have received complementary works to areas that have not

Knowledge gap	Description	Activities to address knowledge gap
Macro-invertebrates	The current structure of the macro-invertebrate community in the river is unknown. There is no information on the impact of the bushfires and floods over the last decade on the abundance and diversity of functional groups, since last survey in 2005 – 06.	**Condition monitoring** • Macro-invertebrate surveys to capture what is present in the system and what has changed is required • eDNA surveys to get an indication of current community assemblages
Abiotic		
Water quality	The relationship between environmental watering in the Macalister River and water quality is not well understood. High turbidity events have been observed, however, it is not known if these events are due to a flow release or other channel or land use factors.	**Operational monitoring** • Event-based water quality monitoring to identify the change to water quality (nutrients, turbidity, EC, DO) before during and after environmental flow releases
Floodplain lagoons, billabongs and creeks	These are an important feature of the Macalister River and have the potential to provide valuable bird, turtle and frog habitats. However, due to flow regulation and modification of the hydrological connection of these billabongs to the river, these habitats only receive water during overbank flood events. There may be opportunities to deliver to particular sites with upgrades to irrigation infrastructure (e.g. Newry Creek).	**Technical study** • An investigative study to identify alternative means of watering these habitats would mean that the environmental entitlement water would provide benefit to a greater part of the system and enhance its ecological value • Technical studies to determine delivery requirements of tributaries, billabongs, etc • Surveys to identify species assemblages at sites of interest
Physical habitat provision	1D hydraulic models were used to determine low flow recommendations, however there are limitations to these modelled results particularly for minimum fish passage depth requirements at riffles.	**Field investigation** Ground truthing of modelled outputs with observations during specific flow events will confirm that these minimum depth requirements are adequately met at all riffle zones along the river.
Technical		
Streamflow measurement	Accurate streamflow measurement devices in the Macalister River (particularly for reach 2) are lacking. The existing Riverslea stream gauge in the lower end of reach 2 is not considered accurate due to the backwater influences from the Thomson River. The Maffra Weir tailwater gauge is similarly, unreliable.	**Operational monitoring** • Installation of more reliable stream gauges (particularly in reach 2), will greatly help in flow management, increase system understanding and allow for reliable compliance assessment
Habitat provision assessment	Habitat provision assessment provides meaningful output for environmental watering prioritisation. However, the established habitat preference curves from Alluvium (2015) are a first attempt at articulating the relationship between flow parameters and habitat based largely on conceptual understandings.	**Technical study** • Build on the established approach to develop a systematic and rigorous assessment approach • Document sources of information, areas of uncertainty to target knowledge gaps underpinning habitat preference curves

Knowledge gap	Description	Activities to address knowledge gap
Climate change	Little is known about the impacts of climate change on the ecology of the Macalister system. Currently, climate change consideration is limited solely to volumetric reductions in modelled streamflow data.	**Technical study** • Evaluate the impacts of modified streamflow and changes to the seasonality of flows on the Macalister ecosystem to identify vulnerable ecosystem components and opportunities for environmental watering to mitigate any impacts.

Complementary works

To maximise the ecological benefit of environmental watering in the Macalister River, there are also a number of on-ground works that may be undertaken to contribute to the overall achievement of the ecological outcome (where flow and non-flow related management interventions are required). These include:

1. Re-instatement of fish passage at Maffra Weir

Maffra Weir is major barrier to fish passage, whereby passage is only available during a short window of time when the weir gates are open (3 months of the year), and flows are sufficiently high to drown out the stream gauging weir immediately downstream.

Annual fish surveys in the Macalister River show that the distribution of Australian grayling and tupong, both diadromous species, are generally downstream of Maffra Weir (Amtstaetter et al., 2015). Furthermore, individuals located upstream of Maffra Weir are trapped between Lake Glenmaggie and Maffra Weir, with migratory species unable to complete their lifecycle. Providing fish passage at Maffra Weir will enable migratory species in reach 1 to complete their life cycle and opens up 33 km of better quality in-stream habitat for fish species currently residing in reach 2.

2. Protection of off-stream billabongs

Both reaches of the Macalister River contain a number of off-stream billabongs and lagoons that no have little to no fringing vegetation and are often impacted by cattle grazing. Weed control, fencing, revegtation and erosion controls works in key billabongs will provide these habitats a chance to recover and restore the habitat values that are important for many biota including birds, turtles and frogs.

3. Weed control, revegetation and fencing

An extensive length of reaches 1 and 2 has already undergone weed control, revegetation and fencing. This work should continue for the remaining sections, on both sides of the bank to restore riparian habitat, reduce grazing pressure on the river, minimise rates of channel encroachment and long term avulsion, and increase the resistance of channel form to floods (Alluvium, 2011).

4. Re-snagging of river channel

Re-snagging the channel with large woody debris will increase the diversity of the in-stream habitat, through the introduction of different flow paths and velocities and also provides refuge and shelter for many fauna species. This is considered particularly important for reach 1.

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Appendix A: Fish survey records

Table A. Fish species recorded in the reaches 1 and/or 2 of the Macalister River during fish surveys undertaken as part of the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP).

Common name	Scientific name	R1	R2
River blackfish	*Gadopsis marmoratus*	✓	
Southern pygmy perch	*Nannoperca australis*	✓	
Flat-headed gudgeon	*Philypnodon grandiceps*	✓	✓
Dwarf flat-headed gudgeon	*Philypnodon grandiceps*	✓	✓
Australian smelt	*Retropinna sp. 2*	✓	✓
Short-finned eel	*Anguilla australis*	✓	✓
Long-finned eel	*Anguilla reinhardtii*	✓	✓
Short-headed lamprey	*Mordacia mordax*	✓	✓
Common galaxias	*Galaxias maculatus*	✓	
Australian grayling	*Prototroctes maraena*	✓	✓
Australian bass	*Percalates novemaculeata*	✓	✓
Tupong	*Pseudaphritis urvillii*	✓	✓
Estuary perch	*Percalates colonorum*	✓	
Carp	*Cyprinus carpio*	✓	✓
Goldfish	*Carassius auratus*	✓	✓
Gambusia	*Gambusia affinis*	✓	✓
Redfin perch	*Perca fluviatilis*	✓	✓
Brown trout	*Salmo trutta*		✓

Appendix B: List of water dependent fauna (excl. fish) in the Macalister River

Group	Common name	Scientific name
Frogs	Victorian smooth froglet	*Geocrinia victoriana*
	Common froglet	*Crinia signifera*
Reptiles	Gippsland water dragon	*Physignathus lesueurii howitii*
	Common long-necked turtle	*Chelodina longicollis*
Birds	Masked lapwing	*Vanellus miles*
	Red-kneed dotterel	*Erythrogonys cinctus*
	Black-fronted dotterel	*Elyseyornic melanops*
	Grey teal	*Anas gracilis*
	Little black cormorant	*Phalacrocorax sulcirostris*
	Little pied cormorant	*Microcarbo melanoleucos*
	White faced heron	*Egretta novaehollandiae*
	Australian shelduck	*Tadorna tadornoides*
	Purple swamphen	*Porrphyrio porphyrio*
	Black swan	*Cygnus atratus*
	Dusky moorhen	*Gallinula tenebrosa*
	Australian white ibis	*Threskiornis molucca*
	Australian wood duck	*Chenonetta jubata*
	Australian pelican	*Pelecanus conspicillatus*
	Eurasian coot	*Fulica atra*
	Pacific black duck	*Anas superciliosa*
	Royal spoonbill	*Platalea regia*
	Australasian shoveler	*Anas rhynchotis*
	Magpie goose	*Anseranas semipalmata*
	Eastern great egret	*Ardea modesta*
	Australasian bittern	*Botaurus poiciloptilus*
	White-bellied sea eagle	*Haliaeetus leucogaster*
	Pied cormorant	*Phalacrocorax varius*
	Great cormorant	*Phalacrocorax carbo*
	Hoary headed grebe	*Poliocephalus poliocephalus*
	Musk duck	*Biziura lobata*
	Yellow-billed spoonbill	*Platalea flavipes*
	Chestnut teal	*Anas castanea*
	Hardhead	*Aythya australis*
	Australiasian grebe	*Tachybaptus novaehollandiae*
	Straw-necked ibis	*Threskiornis spinicollis*
	White-necked heron	*Ardea pacifica*
	Cattle egret	*Ardea ibis*
	Pink-eared duck	*Malacorhynchus membranaceus*

Group	Common name	Scientific name
	Blue-billed duck	*Oxyura australis*
	Swamp harrier	*Circus approximans*
	Intermediate egret	*Ardea intermedia*
	Latham's snipe	*Gallinago hardwickii*
Mammals	Grey-headed flying fox	*Pteropus poliocephalus*
	Southern myotis	*Myotis macropus*
	Common bent-wing bat	*Miniopterus schreibersii*
Macroinvertebrates	Waterboatmen	*Micronecta*
	Stick caddis	*Triplectides*
		Notalina
	Non-biting midges	*Chironominae*
	Mayflies	*Atalophlebia*
	Water treaders	*Microvelia*
	Freshwater shrimp	*Paratya australiensis*
	Baetids	*Baetidaw Genus 1*
	Sleeping bag caddis	*Anisocentropus*

Appendix C: List of water dependent flora in the Macalister River

Common name	Scientific name
	Acacia dealbata
	Acacia floribunda
	Acacia implexa
	Acacia longifolia
	Acacia mearnsii
	Acacia melanoxylon
	Acacia mucronata
	Acacia spp.
Southern Varnist Wattle	*Acacia verniciflua*
	Acaena novae-zelandiae
	Acaena ovina
	Adiantum aethiopicum
	Alisma plantago-aquatica
	Alisma spp.
	Allocasuarina littoralis
	Allocasuarina spp.
	Alternanthera denticulata s.l
Joyweed	*Alternanthera spp.*
Mistletoe	*Amyema spp.*
	Asteraceae spp.
	Atriplex prostrata
	Atriplex semibaccata
	Atriplex spp.
Wallaby grass	*Austrodanthonia caespitosa*
	Austrodanthonia racemosa var. racemosa
	Austrodanthonia setacea
	Austrodanthonia spp.
	Austrostipa scabra subsp. falcata
Veined spear-grass	*Austrostipa rudis subsp.nervosa*
Spear-grass	*Austrostripa spp.*
Tall club-sedge	*Bolboschoenus fluviatilis*
	Boraginaeceae spp.
Daisy	*Brachyscome spp.*
	Bursaria spinosa
	Callistemon paludosus
	Callistemon rugulosus
	Callistemon sieberi

Common name	Scientific name
	Callistemon spp.
	Calochlaena dubia
	Calystegia spp.
	Calystegia marginata
	Calystegia silvatica
	Calytrix tetragona
	Carex appressa
	Carex breviculmis
	Carex fascicularis
	Carex gaudichaudiana
	Carex spp.
	Cassinia aculeata
	Cassinia longifolia
	Cassinia spp.
	Centipeda cunninghamii
	Centrolepis spp.
	Cheilanthes austrotenuifolia
	Chenopodium glaucum
	Chloris sp.
	Chrysocephalum semipapposum
	Clematis aristata
	Clematis spp.
	Convolvulus erubescens
	Coprosma hirtella
	Coprosma quadrifida
	Crassula helmsii
	Crassula sieberiana s.l.
	Crassula spp.
	Crepis spp.
	Cyperus ludicus
	Daviesia leptophylla
	Daviesia spp.
	Derwentia derwentiana
	Dianella caerulea s.l.
	Dichanthium sericeum subsp. sericeum
	Dichondra repens
	Dipodium spp.
	Dodnaea spp.
	Einadia nutans
	Einadia nutans subsp. nutans
	Einadia trigonos subsp. trigonos

Common name	Scientific name
	Eleocharis sphacelata
	Elymus scabrus
	Elymus scaber var. scaber
Upright Panic	*Entolasia stricta*
	Eragrostis brownii
	Eragrostis sp.
	Eucalyptus camaldulensis
	Eucalyptus cypellocarpa
	Eucalyptus globulus
	Eucalyptus ovata
	Eucalyptus radiata s.l.
	Eucalyptus tereticornis subsp. mediana
	Eucalyptus viminalis subsp. viminalis
	Eucalyptus spp.
	Euchiton involucratus s.l.
	Euchiton sphaericus
	Euchiton spp.
	Exocarpos cupressiformis
	Exocarpos spp.
	Glycine clandestina
	Glycine tabacina
	Glycine tabacina s.l.
	Glycine spp.
	Gonocarpus humilis
	Goodenia ovata
	Goodenia spp.
	Goodia lotifolia
	Gratolia peruviana
Gippsland hemp bush	*Gynatrix macrophylla*
	Gynatrix pulchella s.l.
	Gynatrix spp.
	Heichrysum luteoalbum
	Helichrysum leucopsideum
	Hemarthria uncinata var. uncinata
Pennywort	*Hydrocotyle spp.*
	Hypericum gramineum
	Indigofera australis
	Isachne globosa
	Isolepis inundata
	Juncus amabilis
	Juncus articulatus

Common name	Scientific name
	Juncus australis
	Juncus flavidus
	Juncus gregiflorus
	Juncus holoschoenus
	Juncus spp.
	Kunzea ericoides spp. agg.
	Lachnagrostis filiformis
	Lachnagrostis filiformis var. 1
	Lepidosperma laterale
	Lepidosperma spp.
	Leptospermum brevipe
	Leptospermum grandifolium
	Leptospermum laniger
	Leptospermum lanigerum
	Leptospermum spp.
	Lomandra filiformis
	Lomandra longifolia
	Luzula meridionalis var. flaccida
	Lycopus australis
	Melaleuca ericifolia
	Melaleuca spp.
Tree violet	*Melicytus dentatus s.l.*
	Mentha X rotundifolia
	Microlaena stipoides
	Microlaena stipoides var. stipoides
	Oxalis exilis
	Oxalis perennans
	Pandorea pandorana
	Panicum spp.
	Paspalidium spp.
	Pelargonium spp.
	Persicaria decipiens
	Persicaria hydropiper
	Persicaria praetermissa
	Persicaria prostrata
	Persicaria subsessilis
	Persicaria spp.
	Phragmites australis
	Phyllanthus gunnii
	Pimelea axiflora
	Pimelea linifolia ssp. linifolia

Common name	Scientific name
	Pittosporum undulatum
	Plantago debilis
	Plantago major
	Poa labillardierei
	Poa spp.
	Pomaderris aspera
	Poranthera microphylla
	Prostanthera rotundifolia
	Prostanthera spp.
	Pseudognaphalium luteoalbum
	Pteridium esculentum
	Pterostylis nutans
	Pulternaea sp.
	Rubus parvifolius
	Rumex brownii
	Schoenoplectus tabernaemontani
	Schoenoplectus validus
	Schoenus maschalinus
	Schoenus spp.
	Senecio glomeratus
	Senecio hispidulus s.l.
	Senecio minimus
	Senecio quadridentat
	Senecio quadridentatus
	Senecio spp.
	Sigesbeckia orientalis subsp.
	Solanum aviculare
	Solanum linearifolium
	Solanum prinophyllum
	Stellaria flaccida

Appendix D: Habitat preference curves

Reach 1

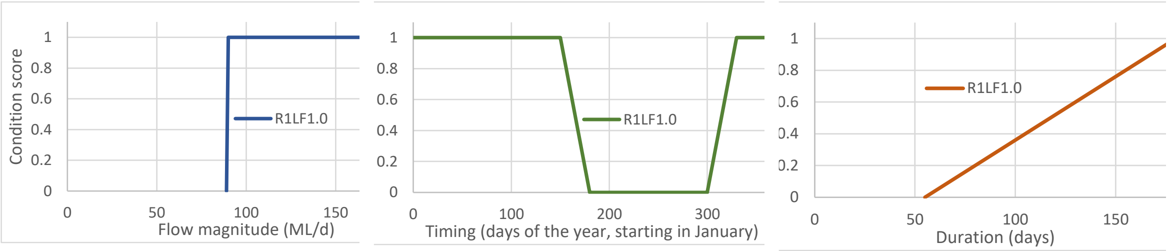

Figure A. Habitat preference curves for model R1L1.0 (low flow Dec – May for physical habitat and vegetation values)

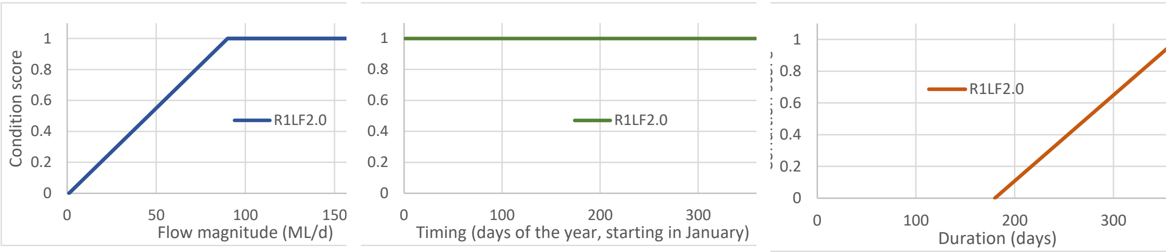

Figure B. Habitat preference curves for model R1L2.0 (Low flow required all year for habitat for fish, macroinvertebrate and platypus values

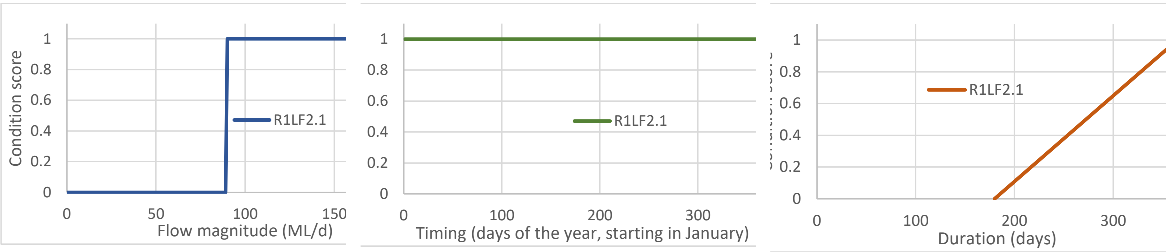

Figure C. Habitat preference curves for model R1L2.1 (low flow all year for local movement of fish, macroinvertebrate and platypus values)

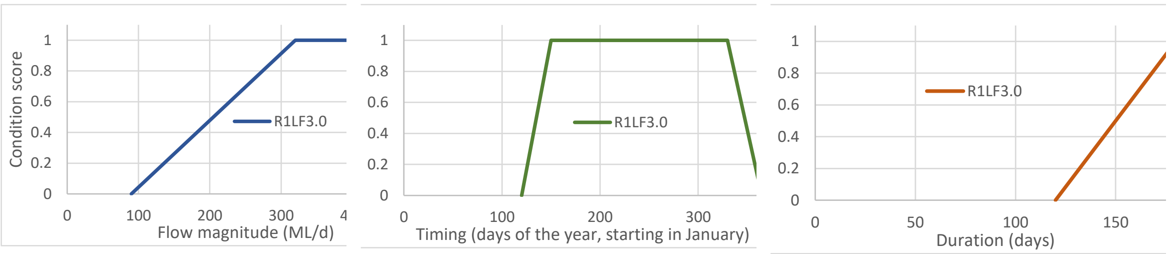

Figure D. Habitat preference curves for model R1LF3.0 (low flow Jun-Nov for vegetation values)

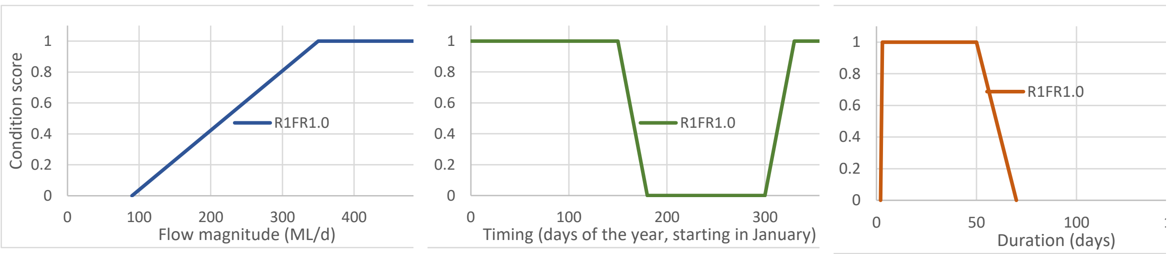

Figure E. Habitat preference curves for model R1FR1.0 (fresh Dec - May for water quality, macroinvertebrate and vegetation values)

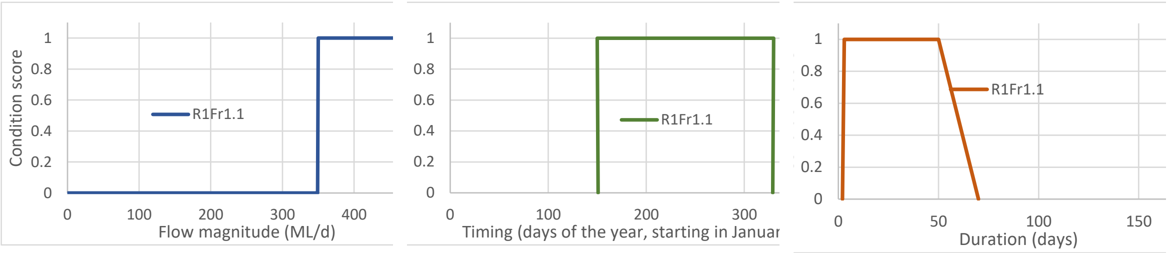

Figure F. Habitat preference curves for model R1FR1.1 (fresh Dec - May for migration of eels)

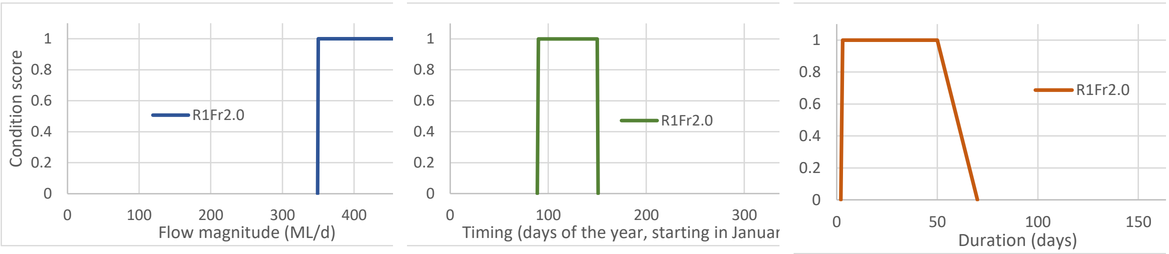

Figure G. Habitat preference curves for model R1FR2.0 (fresh April - May for grayling migration)

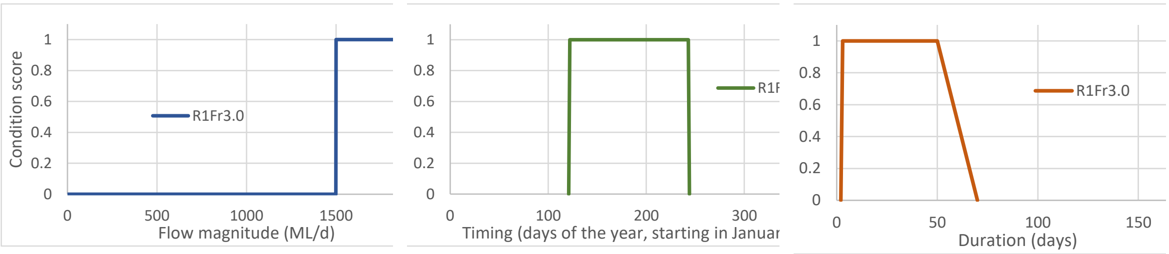

Figure H. Habitat preference curves for model R1FR3.0 (fresh May - Aug for tupong and bass migration)

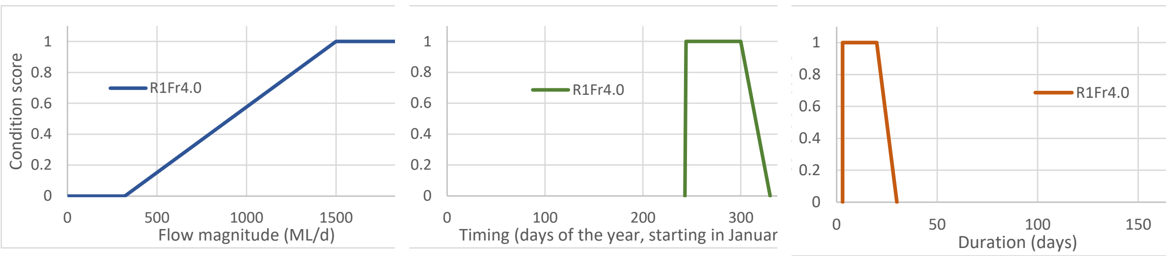

Figure I. Habitat preference curves for model R1FR4.0 (fresh Sep – Oct for vegetation values)

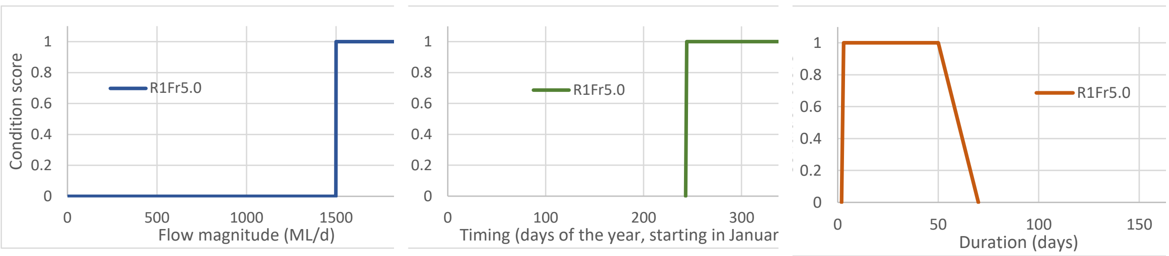

Figure J. Habitat preference curves for model R1FR5.0 (fresh Sep – Dec for fish recruitment)

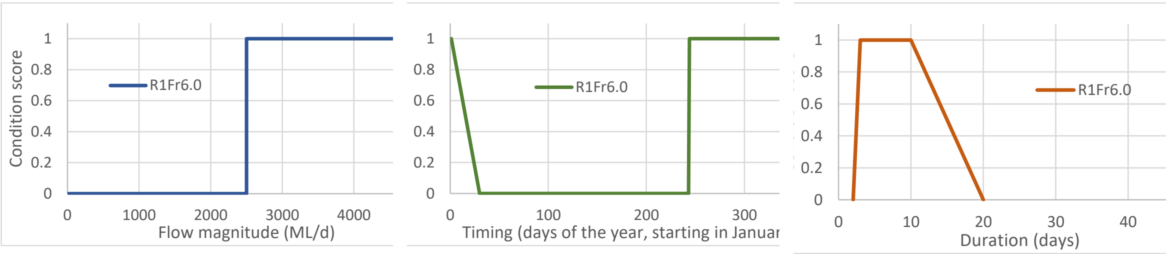

Figure K. Habitat preference curves for model R1FR6.0 (fresh Sep – Dec for vegetation and macroinvertebrate values)

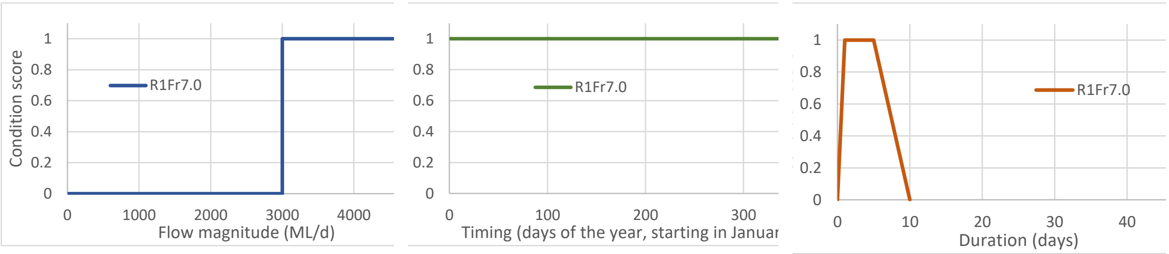

Figure L. Habitat preference curves for model R1FR7.0 (fresh anytime for geomorphology and macroinvertebrate values)

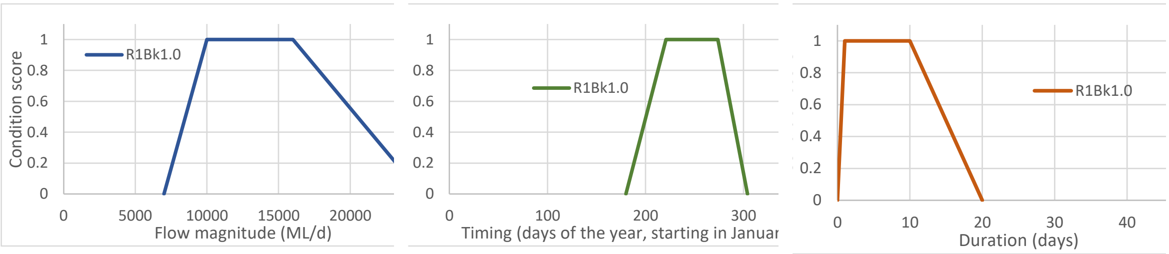

Figure M. Habitat preference curves for model R1BK1.0 (bankfull July - Oct for vegetation, geomorphology, frog, bird and turtle values)

Reach 2

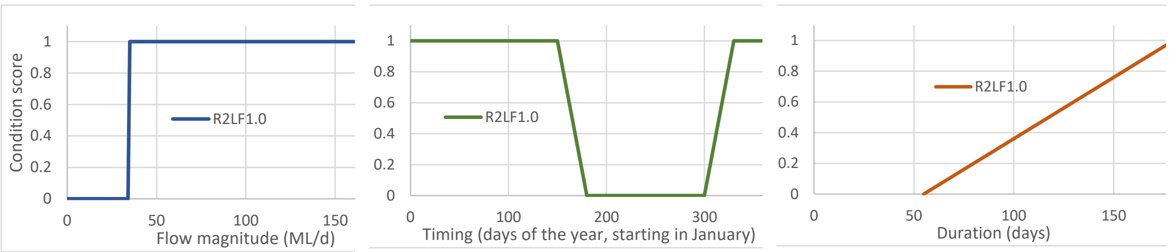

Figure N. Habitat preference curves for model R2L1.0 (low flow Dec – May for physical habitat and vegetation values)

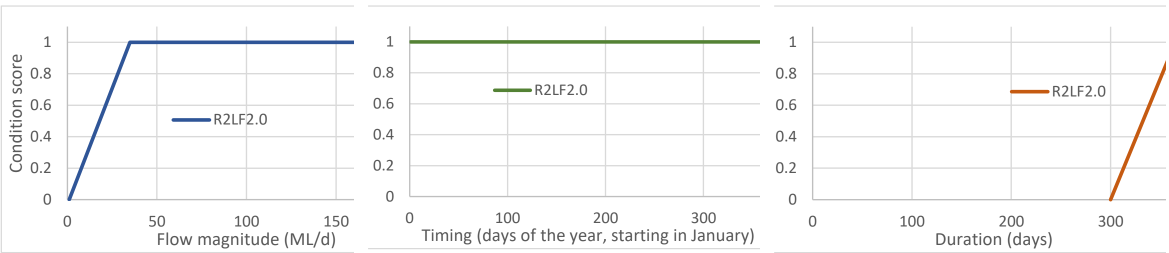

Figure O. Habitat preference curves for model R2L2.0 (Low flow required all year for habitat for fish, macroinvertebrate and platypus values

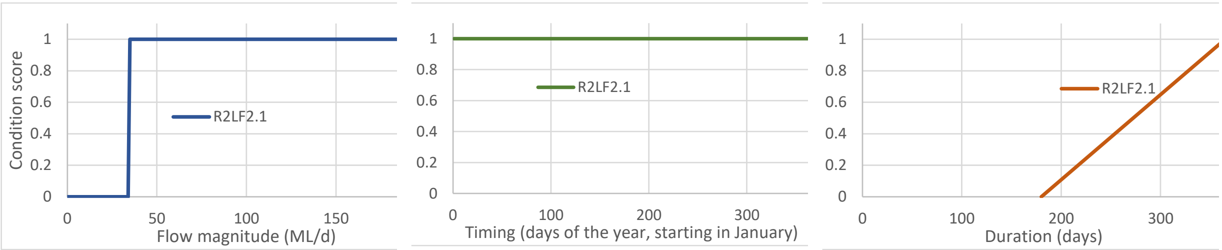

Figure P. Habitat preference curves for model R2L2.1 (low flow all year for local movement of fish, macroinvertebrate and platypus values)

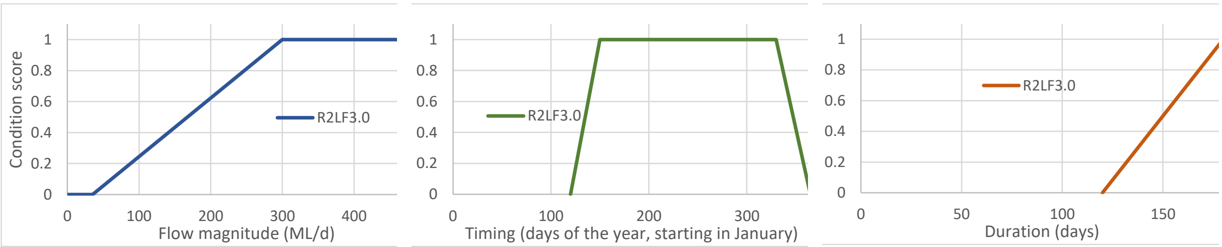

Figure Q. Habitat preference curves for model R2LF3.0 (low flow Jun-Nov for vegetation values)

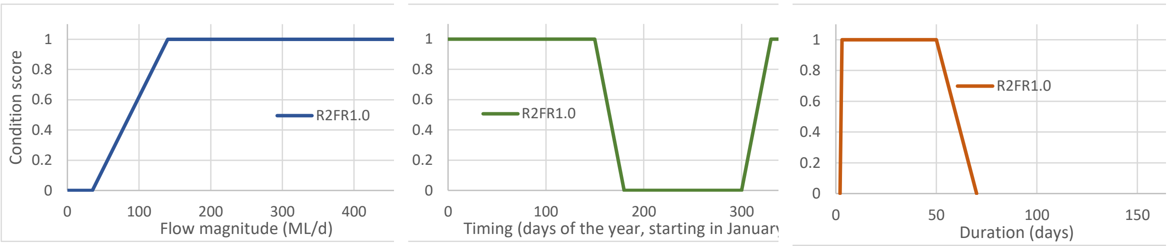

Figure R. Habitat preference curves for model R2FR1.0 (fresh Dec - May for water quality, macroinvertebrate and vegetation values)

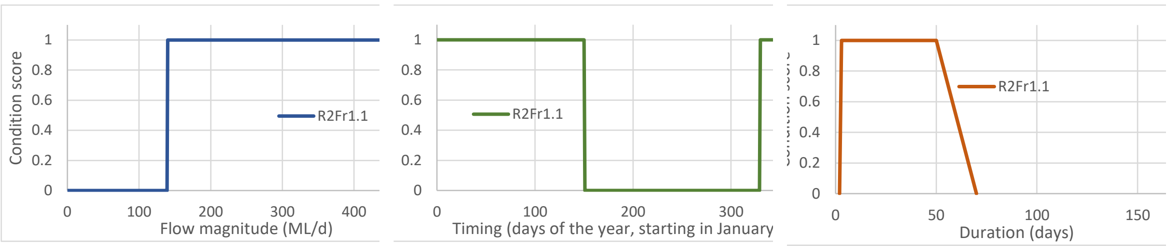

Figure S. Habitat preference curves for model R2FR1.1 (fresh Dec - May for migration of eels)

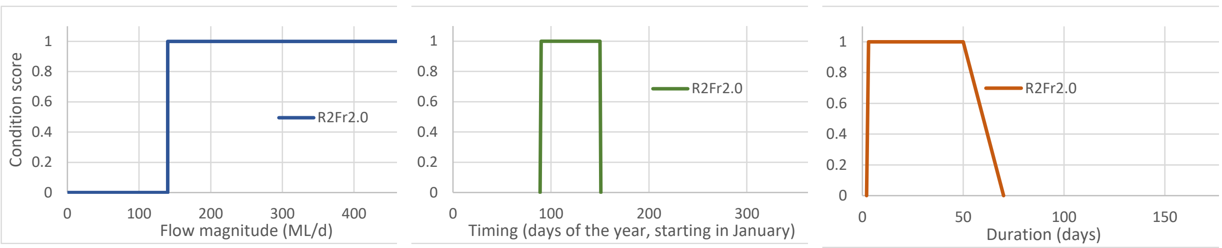

Figure T. Habitat preference curves for model R2FR2.0 (fresh April - May for grayling migration)

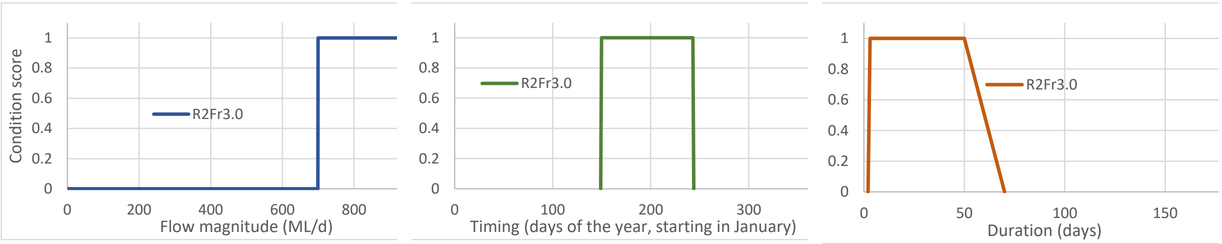

Figure U. Habitat preference curves for model R2FR3.0 (fresh May - Aug for tupong and bass migration)

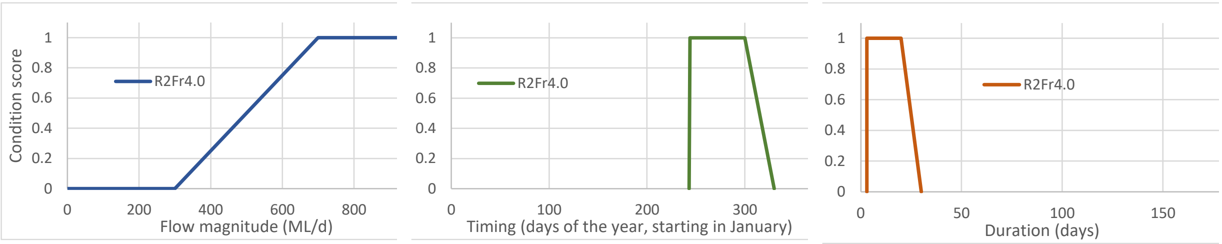

Figure V. Habitat preference curves for model R2FR4.0 (fresh Sep – Oct for vegetation values)

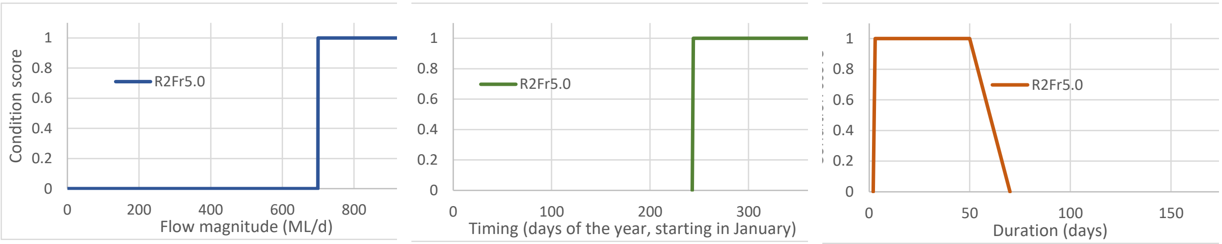

Figure W. Habitat preference curves for model R2FR5.0 (fresh Sep – Dec for fish recruitment)

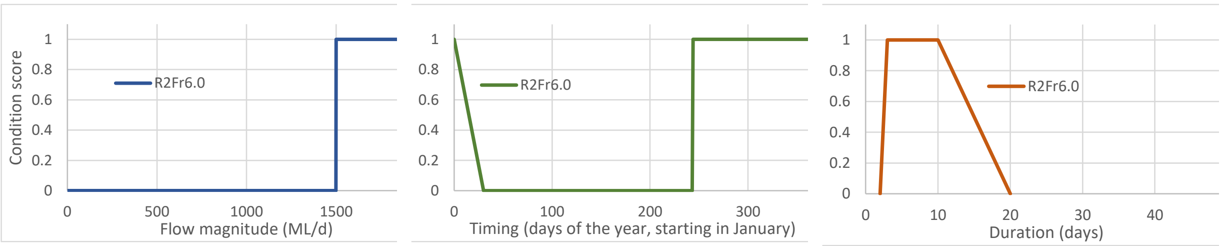

Figure X. Habitat preference curves for model R2FR6.0 (fresh Sep – Dec for vegetation and macroinvertebrate values)

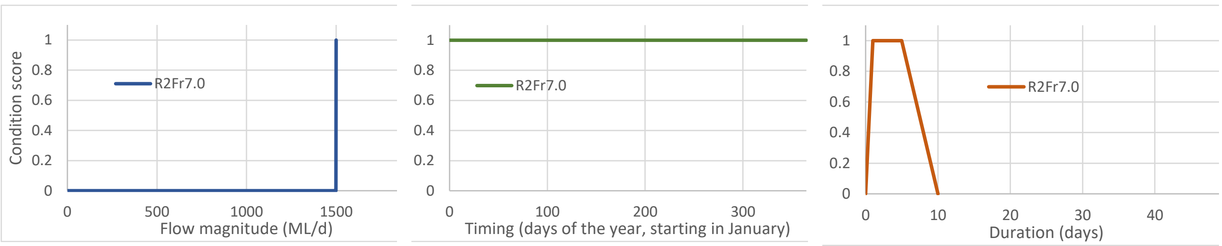

Figure Y. Habitat preference curves for model R2FR7.0 (fresh anytime for geomorphology and macroinvertebrate values)

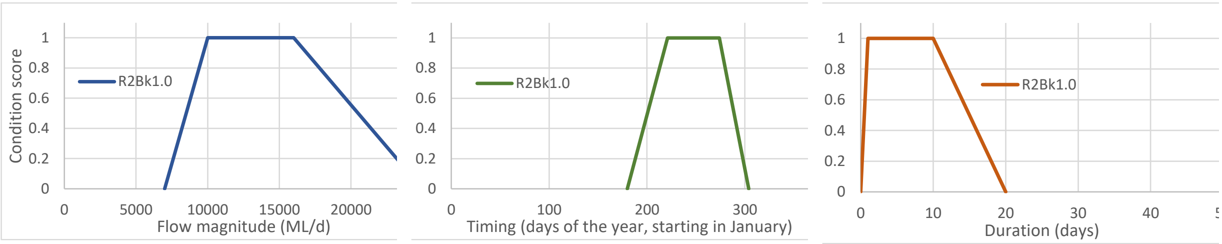

Figure Z. Habitat preference curves for model R2BK1.0 (bankfull July - Oct for vegetation, geomorphology, frog, bird and turtle values