WEST GIPPSLAND CATCHMENT MANAGEMENT AUTHORITY

Macalister River Environmental Water Management Plan

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Glossary of terms and abbreviations

DELWP	Department of Environment, Land, Water and Planning The new Victorian government department established in late 2014 that is now responsible for the state's water portfolio.
Diadromous fish	Fish that migrate between freshwater and marine habitats at some stage during their lifecycle
Ecological flow objectives	The flow-related habitat requirements that serve a specific purpose and contribute to achieving an ecological outcome. These objectives are measureable.
Ecological outcomes	Aspirational values aimed at improving or maintaining the condition of water dependent ecological values. These outcomes may be measureable over the long term.
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.
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*.
Environmental watering action	Refers to the delivery of a flow recommendation using water from the *Macalister Environmental Entitlement 2010.*
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	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 has recently been updated in 2013 since its original release in 2002.
Flow recommendations	Hydrologically defined flow events characterised by five parameters; magnitude, duration, seasonality (i.e. time of year) and intra and/or inter annual frequency. Together, the recommendations describe the full suite of flow events that would be present under a natural flow regime for a system. Flow recommendations were determined with the Macalister eflows project.
Habitat assessment approach	Testing whether the flow-related habitat requirements specified under the ecological flow objectives have been provided overtime at a frequency that does not compromise the long term integrity of a water dependent ecological value. This approach uses habitat preference curves and habitat provision time series to undertake the assessment.
Habitat preference curves	Curves describe the relationship between habitat condition for a particular value and changes to a hydrologic parameter (i.e. timing, duration or magnitude).
Habitat provision time series	A time series showing the extent of habitat provided as it applies to a particular input flow time series. It multiplies the relevant habitat preference curves relevant to an ecological value.

Macalister Eflows project:	The technical 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 flow 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.
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.
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.
Vision statement	A long term goal reflective of community and government aspirations for the welfare of the Macalister River.
Water dependent ecological values	Biotic 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 categorised by species, community or functional groups.
WGCMA	West Gippsland Catchment Management Authority The waterway manager for all waterways within the West Gippsland region, including the Macalister River.

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Executive summary

The Macalister River Environmental Water Management Plan (EWMP) is a long term guiding document that stipulates the ecological outcomes, objectives and water requirements for the Macalister River downstream of Lake Glenmaggie.

The EWMP has been developed using the principles identified in the established vision statement for the 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 these 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), technical studies and community input.

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 outlines the main socio-economic values of the Macalister River. This includes its significance to traditional owners and its existing recreational values. The river is also recognised for its significant economic contributions to the local and statewide economy.

Section 5 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 6 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 7 discusses the habitat provision approach to be implemented for future planning and prioritisation of environmental watering actions. This approach uses a combination of habitat preference curves to establish habitat time series, allowing for assessment of partial habitat provision. This section also highlights the need to quantify the environmental water shortfall in the system, and suggests different mechanisms to address shortfalls.

Section 8 presents results from a qualitative risk assessment focussing on the risks to water dependent ecological values and environmental water management.

Section 9 identifies the delivery constraints for environmental watering in the system whilst **Section 10** summarises the types of monitoring that have been undertaken in reaches 1 and 2 to inform environmental water management.

Section 11 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 *newly revised 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 from flow regulation
2. Quantify the *environmental water shortfalls* for the system and explore options to reconcile some of this 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. Continue and *strengthen community engagement* through environmental water management and increase community advocacy for the welfare of the river

1.0 Introduction

1.1 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;
- 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 system.

The EWMP will serve as a guiding document for the WGCMA, Victorian Environmental Water Holder (VEWH) and the Department of Environment, Land and Water Planning (DELWP) 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 on 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 into the Thomson River • 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

1.2 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 (Alluvium, 2015a – c; herein referred as the Macalister Eflows project) updated the environmental flow recommendations for the Macalister River 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 shortfalls, priorities, monitoring requirements and knowledge gaps. The project was implemented in tandem with the EWMP development.

2. ***Updated hydrologic modelling:*** Prior to the EWMP development, the available REALM modelling data for the Macalister River consisted of monthly averages for current and un-impacted flow scenarios. To facilitate the hydrologic assessment required in (1), monthly values were disaggregated to create a daily flow time series (Jacobs, 2015). A modelled daily flow time series was also created for a current climate change scenario.

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 during the implementation of the Macalister Eflows project and the EWMP development so that the content in the EWMP was consistent 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 DELWP, WGCMA, SRW and the VEWH. The Steering Committee oversaw the Macalister Eflows project 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.

1.3 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.

The roles of the Macalister PAG and the Steering Committee in the Macalister Eflows project (Alluvium, 2015a–c) 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 (3) 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 (3) from Macalister Eflows study • Draft EWMP

2.0 Site overview

2.1 Site location

The Macalister River is located 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.

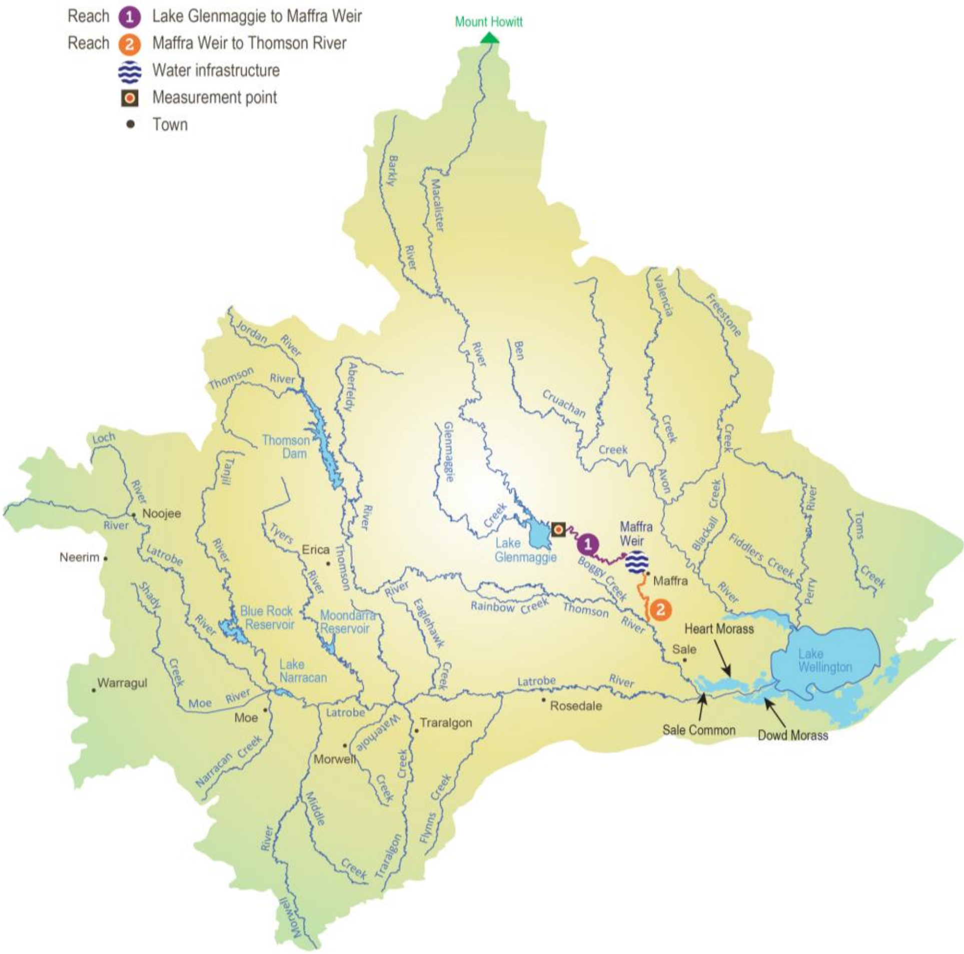


Figure 1. The Macalister River within the broader Latrobe catchment, including reaches 1 and 2 (highlighted). ***Source:*** **VEWH, 2014**

2.2 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, respectively, 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 cleared alluvial floodplains surrounding the lower Macalister River are part of the Macalister Irrigation District (MID). This is the largest irrigation district south of the Great Dividing Range comprising of 53,000 ha (extending from downstream of Lake Glenmaggie to Sale). Over half of this is irrigated land, with 90% dedicated to pasture (SRW, 2015c). The Macalister River is the main source of irrigation water for the MID, and is also used to supply potable water to the nearby towns of Coongulla, Maffra, Stratford, Heyfield and Glenmaggie (Gippsland Water, 2015).

2.2.1 Climate

Climate in the greater Gippsland Basin is considered temperate as per the Koppen-Geiger climate classification (Yates et al., 2015). Temperatures in the region range from between 13 – 24°C in summer and 5 – 14°C in the winter.

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 Lake Glenmaggie, illustrating a long term average around 600 mm in contrast with the Gippsland average of 835 mm (Alluvium, 2015a; Yates et al., 2015). Rainfall distribution throughout the year is relatively consistent, with no clear distinct wet and dry seasons (see Figure 3).

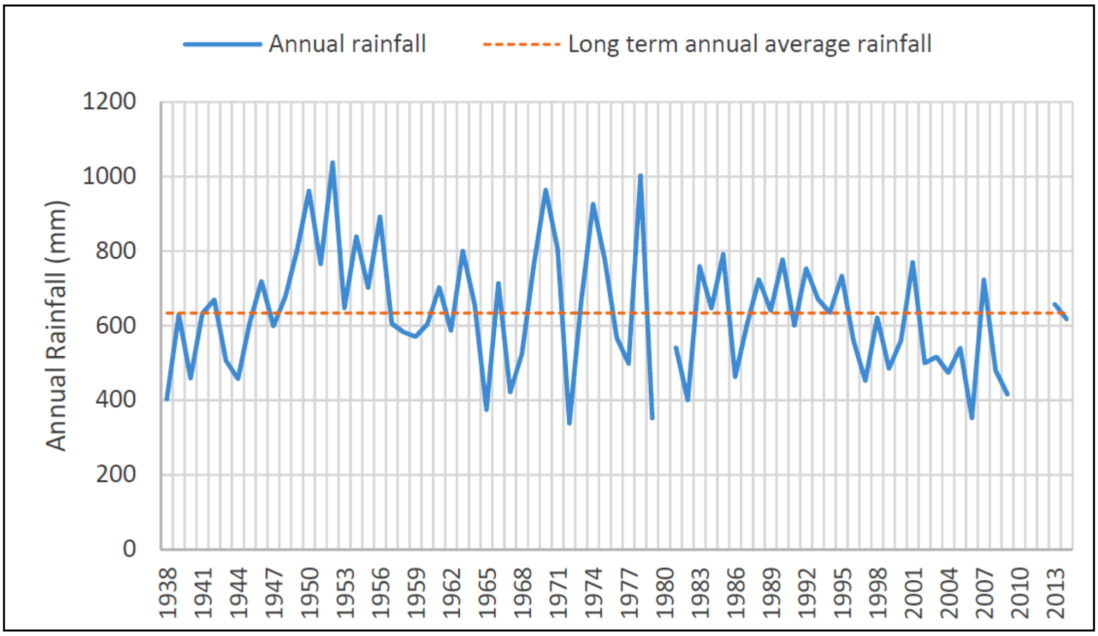


Figure 2. Long term annual rainfall data at Glenmaggie station (85034). ***Source:*** **Alluvium, 2015a**

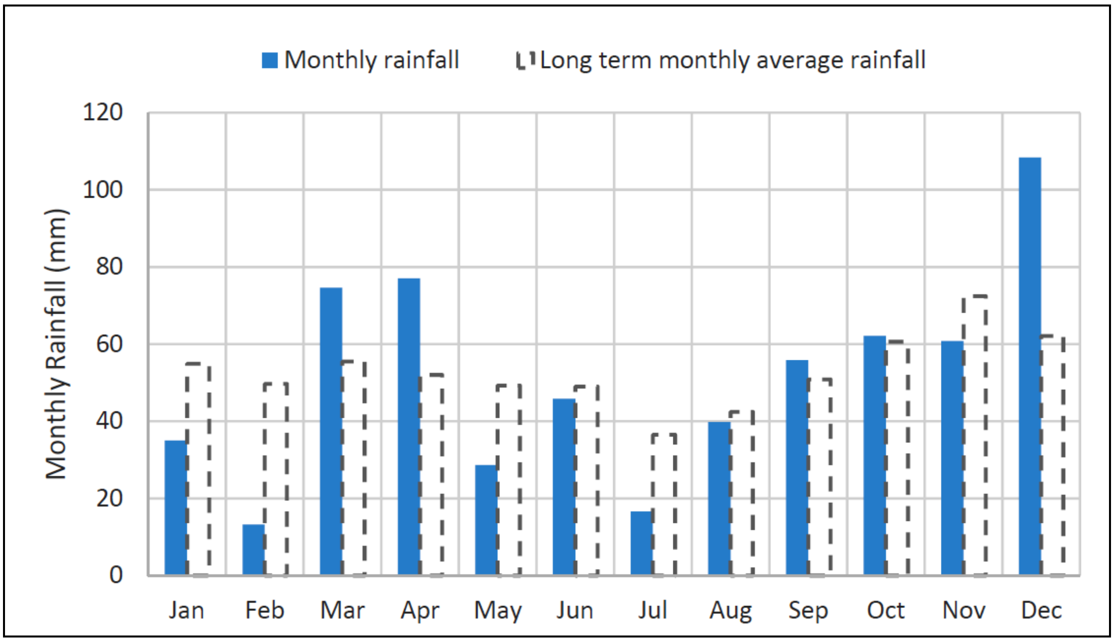


Figure 3. Long term average monitoring rainfall and monthly rainfall in 2014 at Glenmaggie station (85034). ***Source:*** **Alluvium, 2015a**

Climate change

Projected changes to rainfall and runoff under 1°C and 2°C global warming scenarios are reported as part of the South Eastern Australian Climate Initiative (Post et al., 2012) using outputs from 15 Global Climate Models (GCMs). These projections are reported for the larger Thomson catchment, which includes the Macalister. The models predict a median reduction in rainfall of five and nine percent for the 1°C and 2°C scenarios, respectively. Projected runoff reductions are more profound, ranging from 12 to 22 percent median reduction for the 1°C and 2°C scenarios, respectively.

2.2.2 Hydro-physical characteristics

In general, the lower Macalister River Is characterised by 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, 2015a; SKM, 2009).

Figure 4 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, 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).

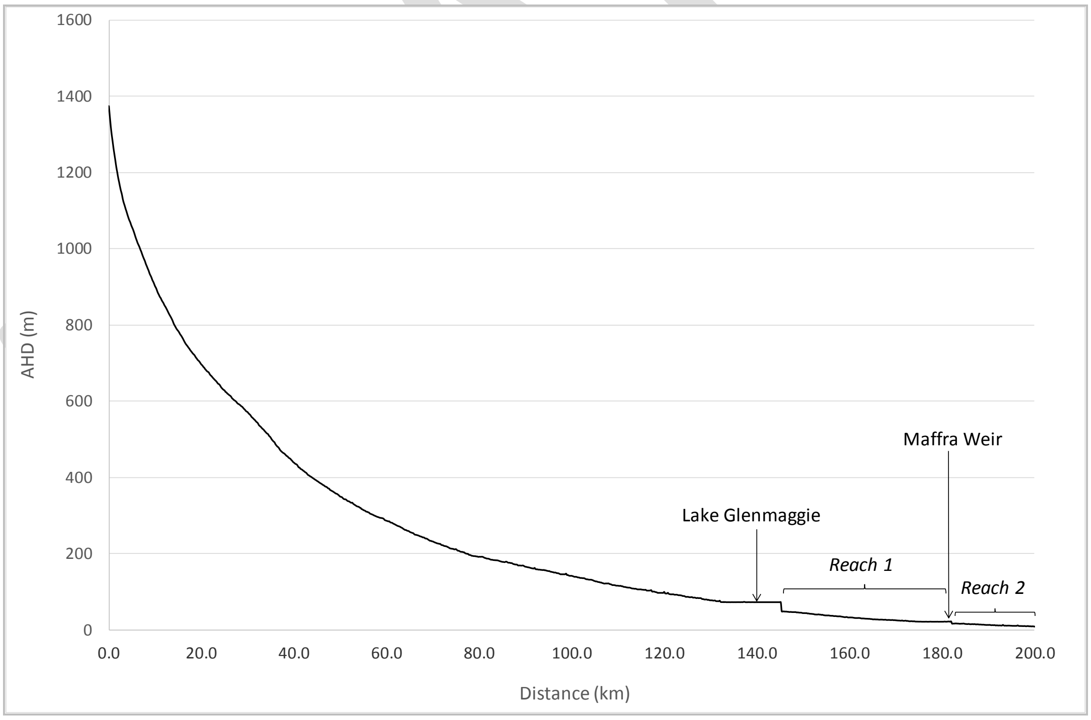


Figure 4. Long section of the entire Macalister River

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 a number of 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 5). 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 (SRW, 2014b). The storage is managed by Southern Rural Water.

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 (Alluvium, 2015a). 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, 2015a).

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 (CRCFE, 1999; Moar and 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 5), 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 5); 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, Undated).

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, over the past two decades 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 (Rod Johnston per comm., 14th October 2015).

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 Southern Rural Water (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 5). 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.

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 5). 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; CRCFE, 1999). 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., 14^{th} October 2015).

Figure 5. Site conceptualisation of reaches 1 and 2 of the Macalister River, highlighting the main physical characteristics along the river

2.3 Land status and management

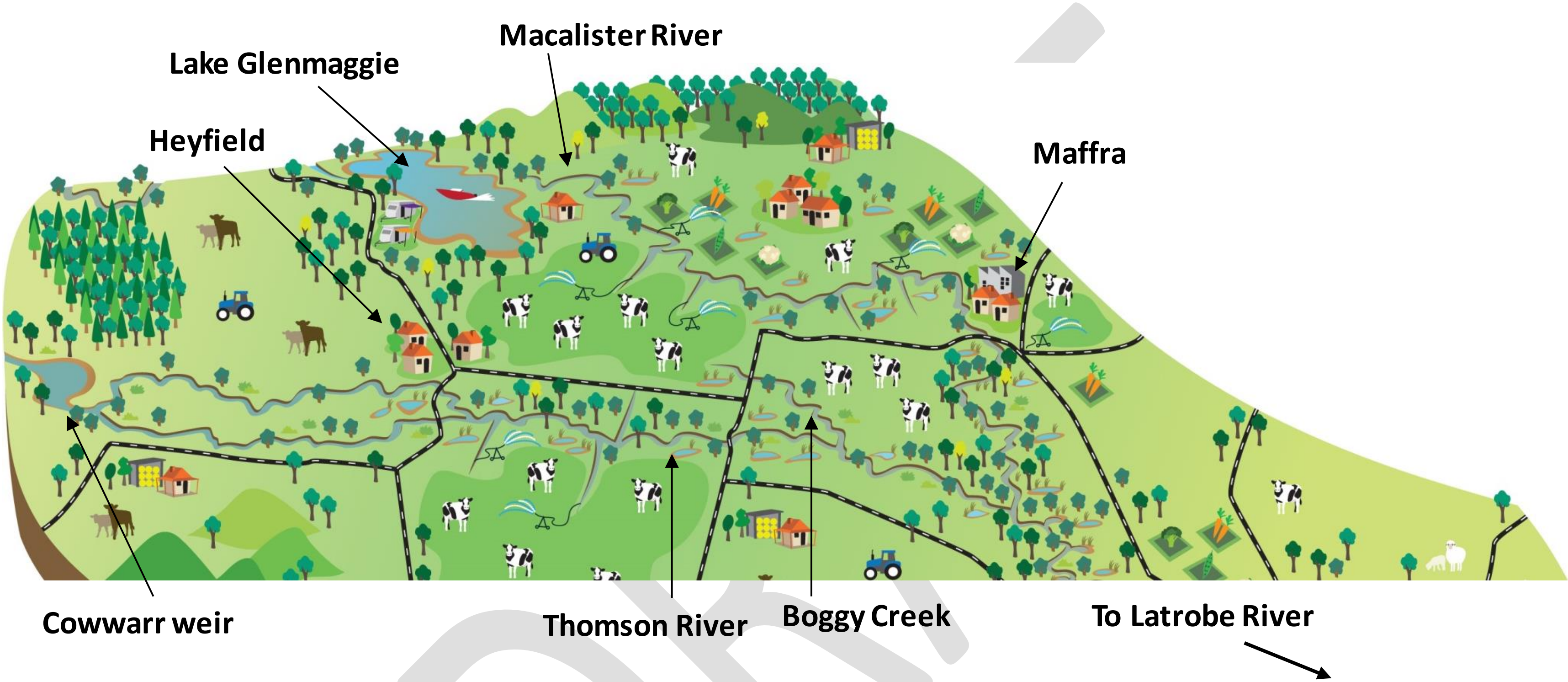


Figure 6. A conceptual model of the lower Thomson and Macalister River catchments, illustrating the various land uses. Note: diagram is not to scale and does not include all hydro-physical features or water resource infrastructure in the catchment. *Source:* WGCMA, 2014.

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 6). A small proportion of the catchment is also dedicated to urban and industrial land use, with Maffra being the largest township and location of a Murray Goulburn Cooperative plant that processes much of the milk produced in the region (SRW, 2015c).

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, have been funding projects within the irrigation district to increase water supply efficiency, improve on-farm productivity, achieve significant water savings, and reduce nutrient export to the Gippsland Lakes (WGCMA, 2008; DEWLP, 2015).

Nutrients are managed under the Macalister Land and Water Management Plan (MLWMP; WGCMA, 2008) 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) over the past two decades 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 and reptiles (BCRRMC, Undated).

2.4 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 and industry 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.

2.4.1 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. *Sources:* DEPI, 2013; SRW, 2015d.

Agency/group	Role in waterway/water dependent ecology management
Minister for Environment, Climate Change and 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 Environment, Land, Water and Planning (DELWP)**	• 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
***Waterway manager:* West Gippsland**	• identify the regional priorities for environmental water management in the Regional Waterway Strategy (WGCMA, 2014)

Agency/group	Role in waterway/water dependent ecology management
Catchment Management Authority	• 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

2.4.2 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. *Source:* WGCMA, 2014.

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 (WGCMA and VEWH, 2014)
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					
Lake Glenmaggie unregulated flows	25,000 – 620,000 ML/ year#	Limited ability to manage	1 & 2	Subject to spilling	Can provide 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 Macalister Seasonal Watering Proposal, developed on an annual basis. The *Macalister River Environmental Entitlement 2010* and the operating arrangements (WGCMA and 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 (refer to discussion below). 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. Thus, the planning and delivery of entitlement water is inherently dynamic, reflecting this staggered water availability.

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 and 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, before the 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. Unregulated 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 can meet SRW's storage fill outcomes and deliver specific ecological flow objectives.

Unregulated releases from Lake Glenmaggie may be of a substantial volume and magnitude (refer to Table 4). There is potential for these releases to deliver the water requirements to fulfil ecological flow objectives with a winter to spring focus. This was 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.

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.

2.5 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) West Gippsland Regional Waterway Strategy (WGCMA, 2014) Macalister Land and Water Management Plan (WGCMA, 2008) Macalister River Seasonal Watering Proposal 2015 – 16 (WGCMA, 2015) Seasonal Watering Plan 2015 – 16 (VEWH, 2015) 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 a–c) Baseflow estimation method pilot trial (GHD, 2013)
Monitoring reports	Refuge habitat identification and mapping in the Macalister River (SKM, 2009) VEFMAP macro-invertebrate monitoring (Crowther and Papas, 2006)[1] VEFMAP physical habitat monitoring (Moar and Tilleard, 2010)[1] VEFMAP vegetation monitoring (Water Technology, 2015)[1] VEFMAP fish monitoring (Amtstaetter et al., 2015)[1]

[1] There have been two, three and seven VEFMAP reports produced for the physical habitat, vegetation fish monitoring components, respectively. This table references the most recent of these reports.

3.0 Hydrology and water use

3.1 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, 2015a). 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, 2015a).

Three modelled streamflow scenarios developed using the Resource Allocation Model (REALM; Jacobs, 2015) have been used to illustrate the “natural” flow regime in the Macalister River (reaches 1 and 2), and the subsequent deviation from these patterns owing to flow regulation, water consumption and climate change. These scenarios are described in Table 6.

Table 6. The different flow scenarios used to understand the hydrology of the Macalister River. Note: REALM = Resource Allocation Model.

Flow scenario	Description
REALM Unimpacted (Reaches 1 & 2)	Represents streamflow in the absence of diversions from the river and flow regulating structures, but with historical land cover (Jacobs, 2015)
REALM Current (Reaches 1 & 2)	Represents regulated streamflow with current entitlement volumes, the 2004 level of demand and irrigator behaviour, and historical land cover. Current conditions assume no active use of the environmental entitlement. This entitlement is assumed to contribute to reservoir spills (Jacobs, 2015).
REALM Climate change (Reaches 1 & 2)	Consists of the same regulation and water demand as the “current” dataset but represents the ‘return to dry’ climate conditions experienced during the Millenium drought from 1997 – 2009 (Jacobs, 2015).

The average annual flow under each of the above scenarios is provided in Table 7. These figures indicate that current flows are 2% lower than the unimpacted scenario in reach 1, however there is a 38% reduction in reach 2. Under a climate change scenario, the average annual flow reduces by 34% and 50% in reaches 1 and 2, respectively (Jacobs, 2015).

Table 7. The average annual flow under the unimpacted, current and climate change flow scenarios for reaches 1 and 2 in the Macalister River. *Source:* Jacobs, 2015.

Metric	Unimpacted	Current	Climate Change
Average annual flow in reach 1 (GL/yr)	492	484	321
Average annual flow in reach 2 (GL/yr)	492	304	151

Figure 7 presents flow duration curves of each of the above flow time series for reaches 1 and 2. These curves illustrate the range of flow magnitudes the system experienced naturally (i.e. as per the unimpacted scenario), and the relative amount of time different magnitudes were likely to occur. This is contrasted with the current and climate change scenarios. The key areas of hydrologic change from the unimpacted scenario as indicated by Figure 7 include:

- Low flows (<1,000 ML/month) : increasing periods of low flows in both reaches, however more pronounced in reach 1;

- Low to medium flows (1,000 – 50,000 ML/month): marginal reduction in the frequency of these flows in reach 1, a substantial reduction in reach 2;
- Medium to high flows (50,000 – 100,000 ML/month): decreasing periods of these flows for both reaches; the frequency greatly reduces under the climate change scenario, particularly for reach 2; and
- Very high flows (>100,000 ML/month): little to no impact under the current scenario, but a marked reduction in the frequency of these flows under the climate change scenario.

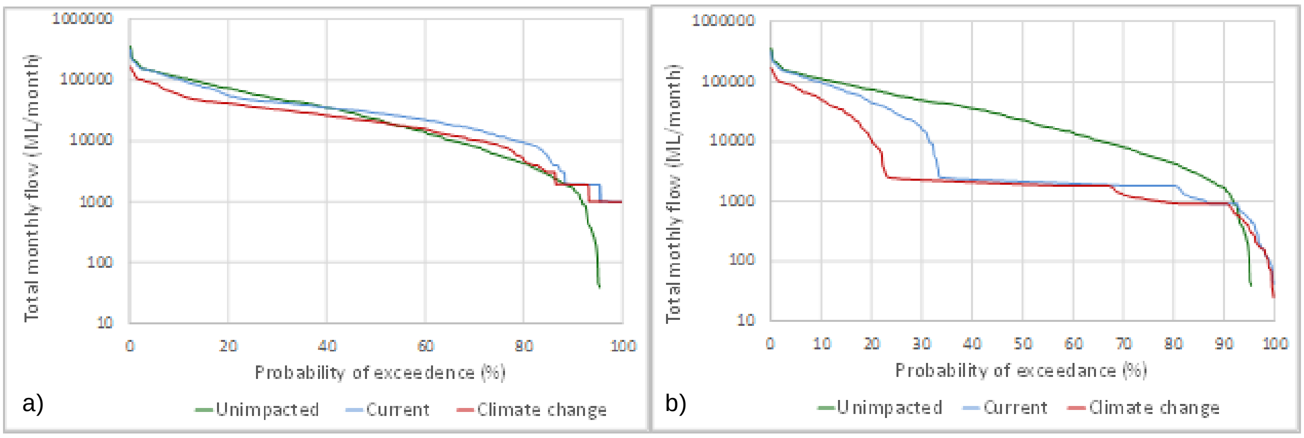


Figure 7. Flow duration curves for the Macalister River under unimpacted, current and climate change modelled flow scenarios; a) Reach 1 – downstream Lake Glenmaggie to Maffra Weir headwater; b) Reach 2: Maffra Weir tailwater to Thomson-Macalister confluence. ***Source:*** **Jacobs, 2015.**

Changes to flow seasonality are shown in Figures 8 and 9, which compares the current and unimpacted and the current and climate change scenarios, respectively. The apparent modifications to flow seasonality compared to the unimpacted scenario include:

- flow augmentation in reach 1 during the summer, reducing the seasonal distinction in streamflow magnitude and tending towards almost uniform flow distribution in this reach under a climate change scenario;
- reduced winter and spring streamflow in both reaches, being more profound in reach 2;
- reduction of summer streamflow in reach 2, especially significant with climate change; and
- significant decreases to winter and spring flows under the climate change scenario, by more than half for August to October.

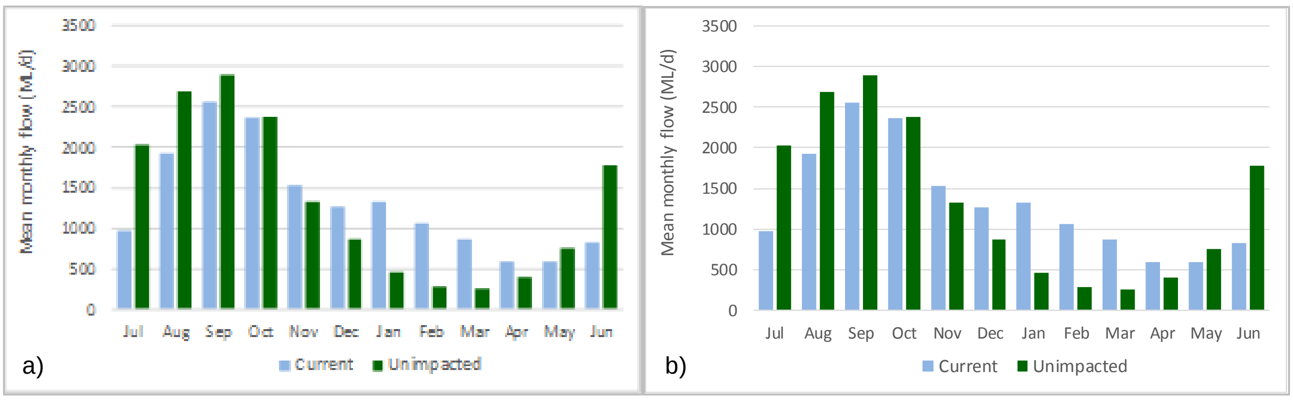


Figure 8. Mean monthly flows for the Macalister River under unimpacted and current modelled flow scenarios; a) Reach 1 – downstream Lake Glenmaggie to Maffra Weir headwater; b) Reach 2: Maffra Weir tailwater to Thomson-Macalister confluence. ***Source:*** **Jacobs, 2015.**

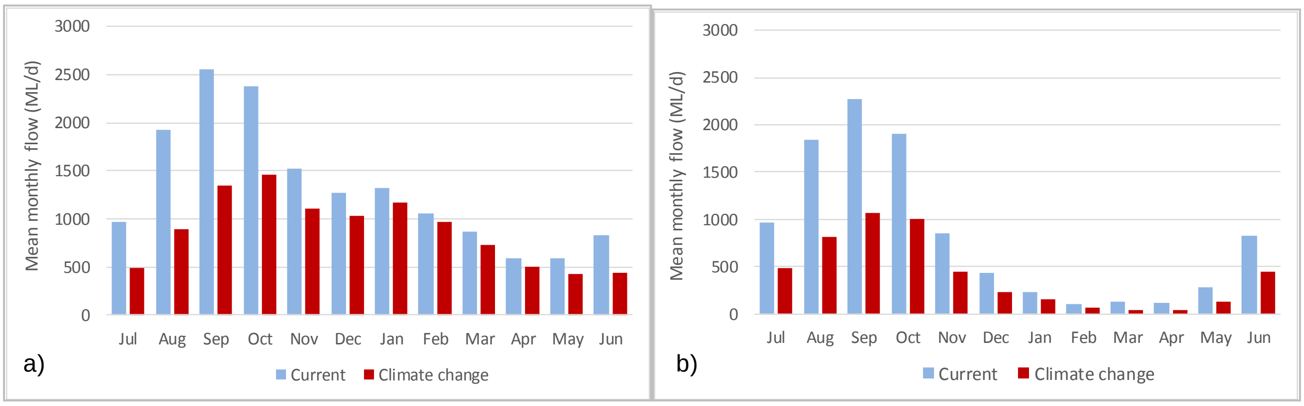


Figure 9. Mean monthly flows for the Macalister River under current and climate change modelled flow scenarios; a) Reach 1 – downstream Lake Glenmaggie to Maffra Weir headwater; b) Reach 2: Maffra Weir tailwater to Thomson-Macalister confluence. *Source:* Jacobs, 2015.

Whilst these flow scenarios are based on modelled data with a number of assumptions (refer to Jacobs, 2015), these analyses do provide some useful insights into the impact of water resource development on this river. The critical impacts appear to be the loss of seasonal streamflow patterns in reach 1 as a result of flow augmentation in the summer, the significant reduction of streamflow throughout the year in reach 2 from consumptive water diversions and the attenuation of medium to high monthly flows by Lake Glenmaggie and water use. Interestingly, very large flows still remain largely intact in both reaches owing to the high catchment area versus storage capacity ratio.

3.1.1 Streamflow monitoring

Streamflow in reaches 1 and 2 of the Macalister River is measured at three established stream gauging stations, shown in Table 8. Water levels in Lake Glenmaggie and Maffra Weir are also measured.

Table 8. 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 – 2015.
Macalister River at Maffra Weir tailwater	225242	Measured streamflow downstream of Maffra Weir. This dataset extends from 2011 – 2015.
Macalister River at Riverslea	225247	Measured streamflow just before the Thomson-Macalister confluence. This dataset extends from 2001 – 2015.

3.1.2 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, 2015a).

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, 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, 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).

3.2 Groundwater

Since European settlement there has been significant changes to the hydrology of the catchment due to deforestation, drainage of low lying water logged regions, surface water extraction, farms dams and the construction of Lake Glenmaggie. 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 10. Trends over time demonstrated a generally declining groundwater level since 1990 (Alluvium, 2015a). A decadal trend of lowering groundwater levels coincides with the drought period from 2001-2007 (Figure 10). This may be attributed to reduced recharge via river flows and rainfall (Alluvium, 2015a). 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.

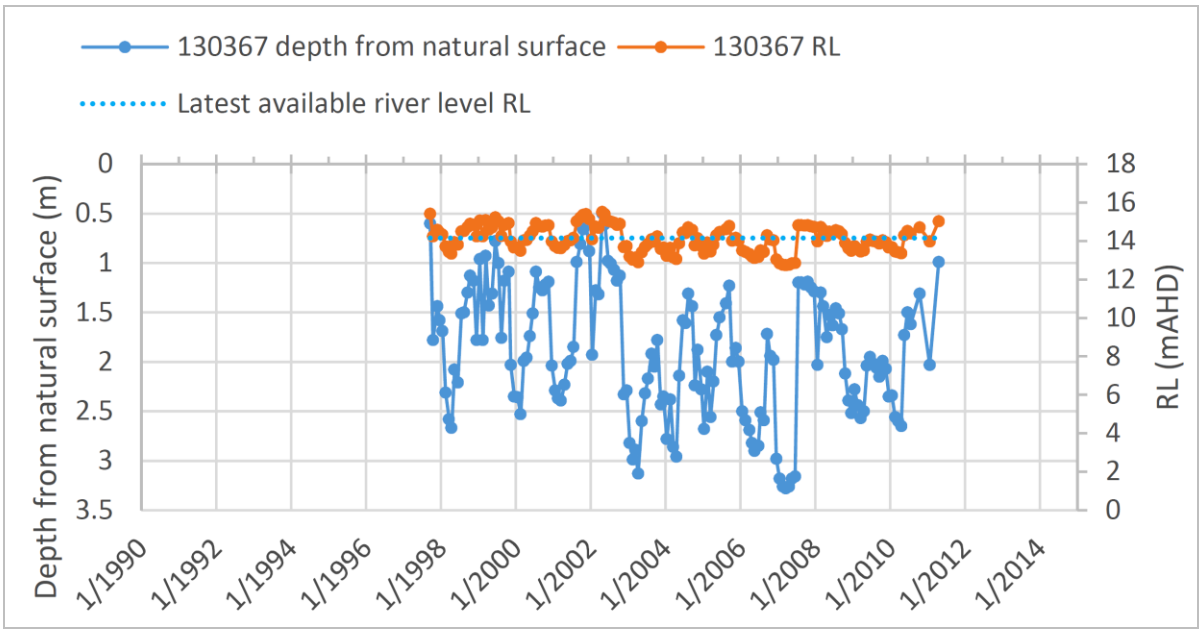


Figure 10. Groundwater hydrograph for station 130367.

3.2.1 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 are 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, 2015a). During dry years and low flow periods, the river is largely losing water to the groundwater system, 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 potential (Alluvium, 2015a).

3.3 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; SRW, 2015b). Management of the storage is described in Section 2.4.2 (Lake Glenmaggie unregulated flows).

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 (SRW, 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 current (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).

Over the last five years, water shares have increased due to savings realised from modernisation projects in the MID. At present there are 149,011 ML high reliability water shares and 71,110 ML low reliability water shares associated with the Macalister River (Gavin Prior, SRW, pers comm. 26th October 2015). These volumes exclude the environmental entitlement. Those who hold high reliability water shares 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 (refer to Section 2.4.2). 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 (SRW, 2015a) and management of these resources is described in the *Catchment Statement for Central Gippsland and Moe Groundwater Catchments* (SRW, 2014a).

3.4 Environmental watering

Environmental watering activities in the Macalister River (i.e. reaches 1 and 2) to date reflect 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).

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

- **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 its connectivity to downstream systems.

Unregulated flows have provided winter freshes (peaking at 1477 ML/d), spring baseflows (maintained at 140 ML/d) and summer freshes (peaking at 350 ML/d) for approximately six out of the last ten years. Bankfull flows (peaking at 10,000 ML/d) were also a flow recommendation, but are not actively provided through the entitlement due to the risks tp private and public property and the large volumetric demand of the event. However, this event tends to be provided via unregulated flows and has occurred three years out of the last ten.

4.0 Socio-economic values of the Macalister River

4.1 Social values

4.1.1 Recreational values

There are at least four reserves along the Macalister River that provide basic facilities allowing visitors to enjoy the river (see Section 2.3). Lake Glenmaggie and its surrounding recreational reserve is used for boating, swimming, recreational fishing and other watersports (SRW, 2014b). 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, 2015a). Bellbird Corner Riverside Reserve is also an important reserve for viewing native wildlife, and is frequented by avid bird watchers and wildlife photographers (BCRRMC, Undated).

4.1.2 Cultural heritage

The Gunaikurnai nation are the traditional owners for much of the Gippsland region. They are made up of five clans, with the Macalister catchment home to the Brayakaulung clan. Waterways and floodplains were a rich source of food, medicine and resources for indigenous peoples. Waterways were traversed using canoes made from river red gum bark or stringybark (GLaWAC, 2015). Anecdotal evidence indicates that in the early 1930s traditional owners used to camp at the Macalister River at Bellbird Corner Reserve. It is thought that the Gunaikurnai camped at many sections along the river including its confluence with Newry Creek (BCRRMC, Undated).

Ecosystems like the Macalister River, are still significant for the Gunaikurnai nation from the strong connections to country innate in their culture.

4.2 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, and the Lake also provides an important source of drinking water for several regional towns. 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 after processing in the Murray Goulburn Co-operative processing plant (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.

5.0 Ecological values of the Macalister River

The focus of this EWMP is on the preservation and restoration of the water dependent 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. A summary of the water-related threats is provided in Section 5.7.

5.1 Overall condition of the system

The health of the Macalister River was measured under the statewide condition monitoring program; the Index of Stream Condition (ISC; DEPI, 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 either 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 9.

Table 9. 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. *Source:* DEPI, 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 condition of aquatic life was scored poorly for both reaches and reach 2 was assessed as having poor water quality.

5.2 Fish

The presence, abundance and condition of fish in reaches 1 and 2 of the Macalister River have been monitored annually since 2005 under the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP). Eleven native freshwater fish species have been recorded in the lower Macalister River (see Appendix A for a full list; Amtstaetter et al., 2015). Estuary perch, predominantly inhabiting estuarine waters, have also occasionally been recorded in the lower Macalister River (Alluvium, 2015a).

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 et al., 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, 2015a). Similarly, the results of recent fish surveys indicate that populations of southern pygmy perch are currently small and limited in distribution (Amtstaetter and 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, threatened under the *Flora and Fauna Guarantee Act* 1988 and has a vulnerable conservation status in Victoria (DSE, 2013). Australian grayling has been recorded in fish surveys each year (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.

5.2.1 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 10 – 13 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 10. 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 11. 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 3 years (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 et al., 2006). Fish mature and spawn in fresh water and larvae drift downstream to the sea, with juveniles migrating back into fresh water (Fisheries Scientific Committee, 2015; Alluvium, 2015a)

Amphidromous species flow requirements	
Flow-ecology link 1: *Spawning*	Increases to river discharge in autumn are required to trigger downstream spawning migration of adult Australian grayling Adult Australian grayling undertake a downstream migration in April-May to lower freshwater reaches coinciding with increases to discharge (Koster et al., 2013; Amtstaetter et al., 2015). Spawning occurs in these lower freshwater river reaches (Amtstaetter et al., 2015). Eggs are non-adhesive and larvae hatch between 10 – 20 days. Eggs and larvae drift/disperse into marine waters (Bacher and O'Brien 1989; Crook *et al.* 2006, Koster *et al.* 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 and 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 et al., 2013).
Flow-ecology link 2: *Recruitment*	Increases to river discharge in spring are required to recruit juvenile Australian grayling back into freshwater reaches 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 *et al.* 2006, Koster *et al.* 2013). It is hypothesised that increases to freshwater discharge during spring and early summer (Sep–Dec) trigger this upstream migration.

Table 12. 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).
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, 2015a).
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 and Selosse, 1996). Gonad development, downstream migration for spawning and year class strength has been found to be correlated with high flow events (Heasman and Fielder, 2011; Growns and James, 2005).

Flow-ecology link 2: *Recruitment*	<u>Increases to river discharge in spring and summer are required to recruit juvenile Australian bass back into freshwater reaches</u> Australian bass post-larvae and juveniles migrate back into the estuarine and freshwater reaches, using macrophyte beds as a source of shelter (Heasman and Fielder, 2011).	
Other species in the Macalister system with these requirements	Tupong (*Pseudaphritis urvillii*) Lifespan of 3 – 5 years (TSN, Undated)	
	Long-finned eels *(Anguilla reinhardtii)* Lifespan up to 52 years (MDBA, Undated).	
	Short-finned eel *(Anguilla australis)* Lifespan of around 35 years (NFA, Undated b).	
	Common galaxias *(Galaxias maculatus)* Lifespan between 2–3 years (MDBA, Undated a)	

Table 13. 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, 2015a).
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, Undated c). 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).

5.3 Macro-invertebrates

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 (Alluvuim, 2015a).

5.3.1 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 14.

Table 14. 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 (Alluvium, 2015a).
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 (Alluvium, 2015a). Additionally, these flows prevent the accumulation of fine sediment in habitats during low flow periods (Alluvium, 2015a).
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 (Alluvium, 2015a).

5.4 Platypus and rakali

Platypuses (*Ornithorhynchus anatinus*) and Rakali/water rats (*Hydromys chrysogaster*) are native, semi-aquatic mammals (Alluvium, 2015a). 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.

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, 2015a). Platypus populations are likely to be taking longer to recover and may be considered vulnerable. However, these assumptions need to be tested.

5.4.1 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 15 details the key flow requirements for both species.

Table 15. Flow-ecology linkages for platypus and rakali. *Source:* Alluvium, 2015a.

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 allow for free movement of individuals, provide protection from predators and maintain invertebrate populations (Alluvium, 2015a). 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 (Alluvium, 2015a).
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 (Alluvium, 2015a).
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 (Alluvium, 2015a).

5.5 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, 2015a). A full list of water dependent fauna in the Macalister River is provided in Appendix B.

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, 2015a).

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, 2015a). Surveys of birds, turtles, reptiles and frogs have not been undertaken.

5.5.1 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 16.

Table 16. 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 (eg. black swan), large waders (eg. eastern great egret, royal spoonbill, nankeen night heron), dabblers (eg. small grebes), fishers (eg. azure kingfisher, white-bellied sea eagle) and the common long-necked turtle (Alluvium, 2015a).
Flow ecology link 2: *Protection of nests*	<u>Avoid bankfull flows during breeding season</u> A number of birds (eg. 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 (Alluvium, 2015a). 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 (Alluvium, 2015a).

5.6 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 off-stream billabongs and lagoons adjoining the river. The EVCs that have a significant conservation status are listed in Table 17.

Table 17. 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

A full list of the water dependent flora in the Macalister River is provided in Appendix C. 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, 2015a; SKM, 2003). Reach 1 contains small swards of emergent non-woody macrophytes (*Bolboschoenus*, *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, 2015a). Vegetation condition was rated as 'medium-high' in the upper parts of reach 1 (Figure 11) 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 11. Upper site in reach 1, Macalister River (immediately downstream of Lake Glenmaggie), looking across at the left bank in the 2014 vegetation assessment. *Source:* 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, 2015a). The canopy layer contained remnant Floodplain Riparian Woodland EVC dominated by river red gum (*Eucalyptus camaldulensis*), silver wattle and the understorey contains tree violet (*Melicytus dentatus*) (Figure 12; Water Technology, 2015). The understorey is also dominated by exotic species including 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 12. Reach 2 VEFMAP vegetation assessment site in the Macalister River (upstream of Forsythe's Lane bridge) in the 2014 survey. *Source:* Water Technology, 2015.

5.6.1 Flow-ecology linkages

The watering requirements for vegetation are described in Table 18. 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 18. Watering requirements for the different vegetation categories present in reaches 1 and 2 of the Macalister River. ***Adapted from:*** **Alluvium, 2015a.**

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.		

5.7 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, 2015a).
- **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, 2015a).
- **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, 2015a).
- **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, 2015a).

6.0 Management objectives

6.1 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."

6.2 Management objectives

The next section describes the template for future 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 13 illustrates how these terms are related and link to non-flow related factors.

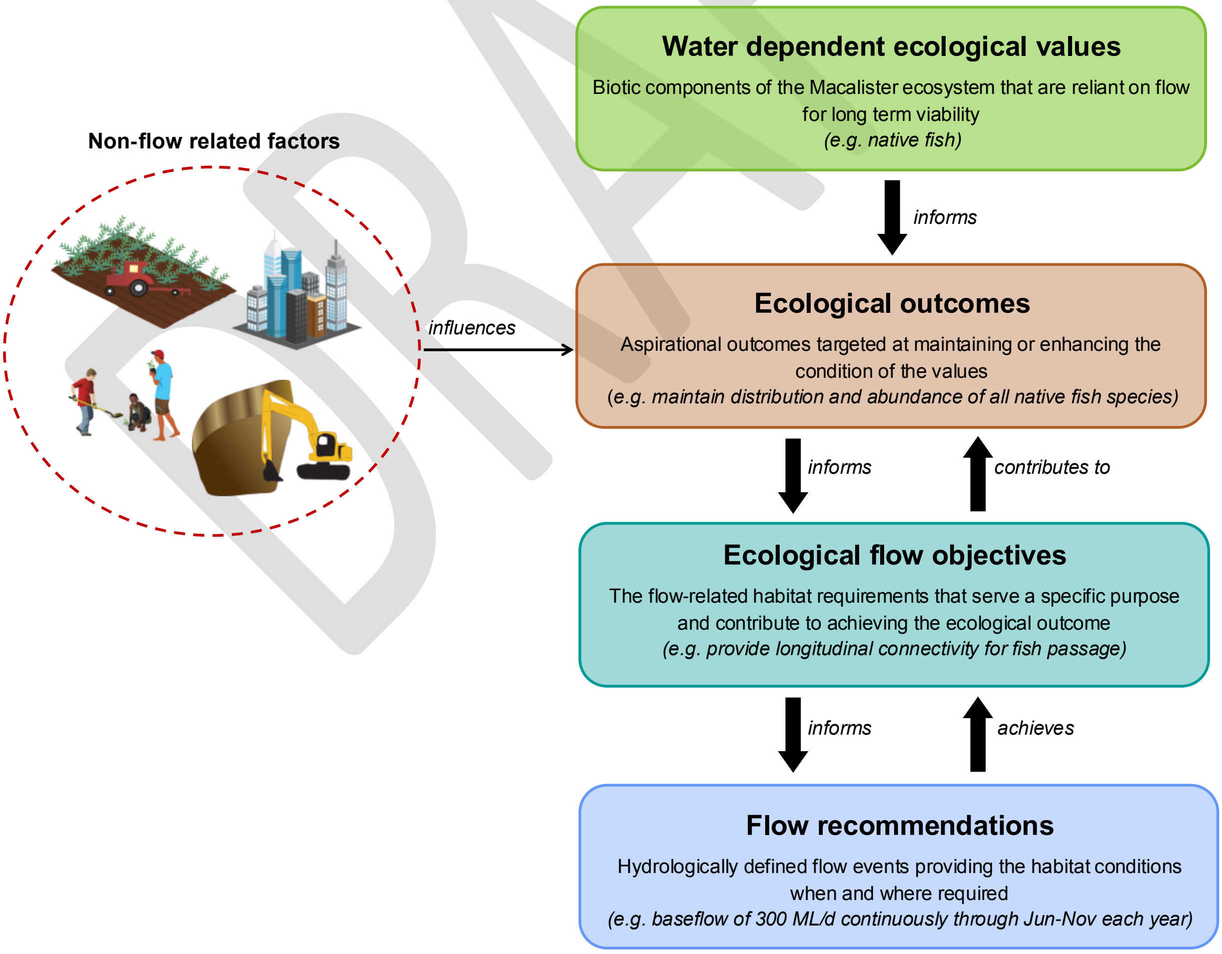


Figure 13. Linkages between values, outcomes, ecological flow objectives and flow recommendations.

6.2.1 Water dependent ecological values

The water dependent ecological values of reaches 1 and 2 of the Macalister River were 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 the biotic constituents of the Macalister River.

6.2.2 Ecological outcomes and ecological flow objectives

Ecological outcomes were developed for all values during the recent Macalister Eflows project (Alluvium, 2015a) 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 link (Section 5);
- 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 5. These objectives are measureable and achievable *entirely* through flow management. 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 other non-flow related factors that require other forms of management intervention (see Figure 13; discussed further in Section 11).

Table 19 (overleaf) lists all the ecological outcomes and corresponding ecological flow objectives identified during the Macalister Eflows project (Alluvium, 2015). Note that in some instances multiple objectives may be linked to a particular ecological outcome or vice versa.

Table 19. Ecological outcomes and the relevant ecological flow objectives identified for all water dependent ecological values in reaches 1 and 2 of the Macalister River.

Ecological outcome	Ecological flow objective
FISH	
Improve the distribution and abundance of Australian grayling	• Provide habitat through sufficient water depth in pools • Provide longitudinal connectivity for fish passage (min. depth 0.2 m)
Improve the distribution and abundance of all native fish species	
Improve spawning and recruitment opportunities for native migratory fish species	• Provide flows cues through increasing water depth to promote downstream migration and spawning for Australian grayling, tupong and Australian bass • Provide flows cues through increasing water depth to promote upstream migration 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)
MACROINVERTEBRATES	
Maintain the abundance and number of functional groups of macroinvertebrates	• Provide permanent wetted habitat through sufficient water depth in pools (1 m) • Provide flows with sufficient shear stress (>1.1 N/m^2)[#] to scour sediment and disturb biofilms for food sources • Inundate higher benches to move organic material into the channel to provide habitat • Flush pools to improve water quality • Increase wetted area to provide increased wetted habitat
PLATYPUS AND RAKALI	
Improve the abundance of platypus and rakali	• Provide longitudinal connectivity for local movement (min. depth 0.2m) and maintain refuge habitats • Avoid bankfull flows during breeding season to improve breeding opportunities* • Avoid extended high flow events to enable foraging*
BIRDS, TURTLES, FROGS	
Maintain the abundance of frog, turtle and waterbird communities	• Wet low lying areas on the floodplain to provide habitat and food sources
VEGETATION	
Re-instate submerged aquatic vegetation	• Provide flows with low water velocity and appropriate depth and to improve water clarity and enable establishment of in-stream vegetation • Inundate a greater area of stream channel (increasing water depth) to limit terrestrial vegetation encroachment
Improve native emergent (non-woody) vegetation	• Inundate a greater area of stream channel (increasing water depth) to limit terrestrial vegetation encroachment • Inundate low benches to provide water level variability and facilitate longitudinal dispersal of emergent vegetation
Improve fringing woody vegetation in the riparian zone	• Inundate mid-level benches to provide water level variability and submerge fringing vegetation • Inundate higher benches to provide water level variability and submerge woody vegetation • Inundate to top of bank to disturb and reset fringing vegetation

Ecological outcome	Ecological flow objective
PHYSICAL FORM	
Improve physical habitat	• 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 • 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.

6.2.3 Flow recommendations

Defining hydrologic parameters

Flow recommendations were developed for each of the ecological flow objectives (Table 19). 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 20.

Table 20. 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, 2015b.

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 14), from avoiding critical losses and protecting refuge habitat in drought & dry conditions to maximising reproductive and recruitment opportunities in average and wet years.

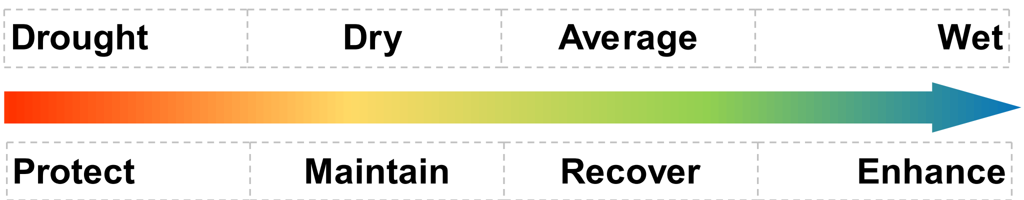


Figure 14. The changing aims of flow management under varying climatic conditions.

Flow recommendations for ecological flow objectives

Flow recommendations may cater for multiple ecological flow objectives (e.g. flushing waterholes for macro-invertebrates 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).

Table 21 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 (see Section 2.2.2), 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 implementing a flow recommendation, the magnitude and duration appropriate for the target reach will be chosen.

Table 21. Flow recommendations for the ecological flow objectives established for reach 1 (R1) and reach 2 (R2) of the Macalister River. Note: 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				
Physical form	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
Fish	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 R2 DRT 20* DRY 40 AVG 40 WET 60	DRT 1/yr DRY ≥1/yr AVG ≥1/yr WET ≥1/yr
Macro-invertebrates	Flush pools to improve water quality				
Macro-invertebrates	Increase wetted area to provide increased wetted habitat				
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	<u>Inundate mid-level benches</u> to provide <u>water level variability</u> and <u>submerge fringing vegetation</u>	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 <u>increasing water depth</u> to promote <u>upstream migration</u> 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 R2 700	Sep – Dec	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
Macro-invertebrates	Provide flows with <u>sufficient shear stress</u> (>1.1 N/m^2)# 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 sufficient shear stress (>1.1 N/m^2)# to flush fine sediment from interstices 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 thes e events and the high likelihood of flooding private land and damaging infrastructure, these events are not considered when pri oritising watering actions each year.

7.0 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.

7.1 Planning and prioritisation of watering events

7.1.1 The habitat assessment approach

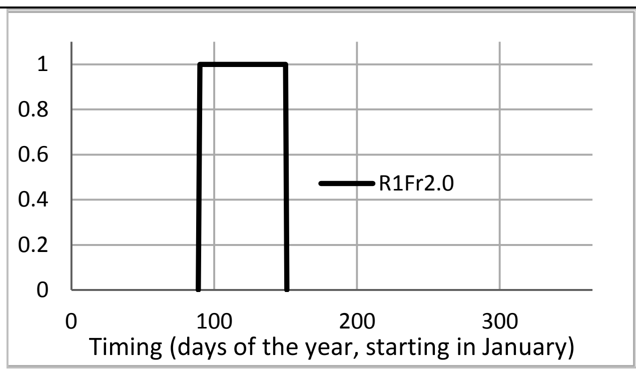
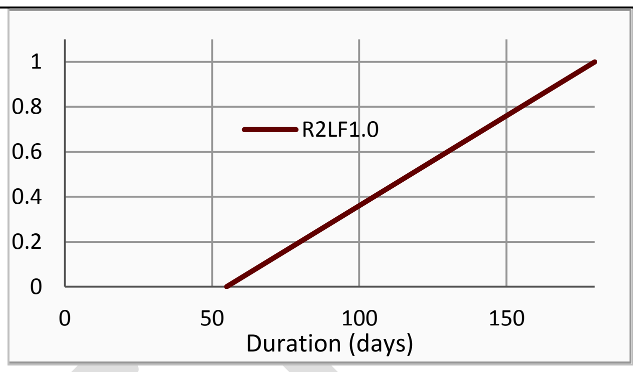
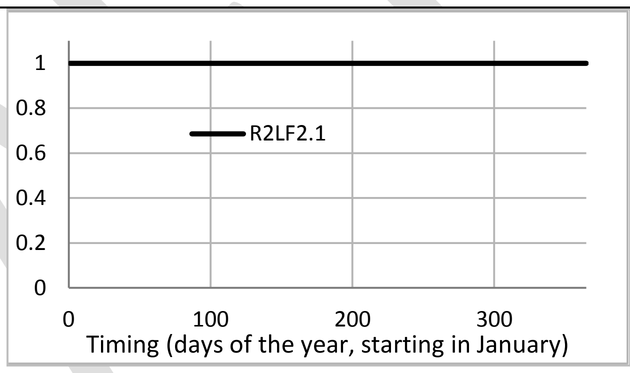
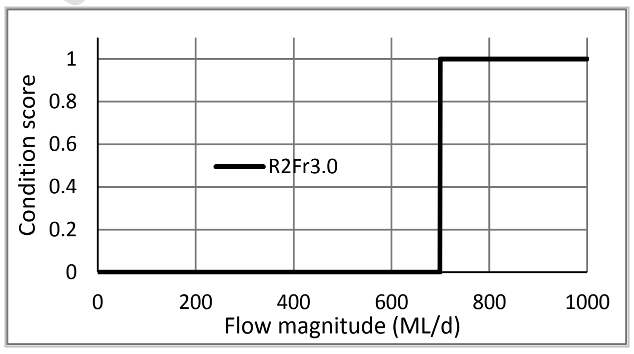
The hydrologic parameters that characterise a flow recommendation combine to provide a specific flow-based habitat required to meet an ecological flow objective. However, it is recognised that the relationship between the habitat condition and changes to the hydrologic parameter varies depending on the 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;
- 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 (for planning in 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 ecological flow objective (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 flow-ecology link. Three types of habitat condition responses were identified and are described in Table 22 (overleaf). Note that whilst most curves in Table 22 illustrate only one discrete response, a habitat preference curve may be made up of any combination of these responses.

Table 22. 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. paramete r does not offer any habitat benefit).

Response	Relevant example ecological flow objective	Habitat preference curve
<u>Binary:</u> 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 <u>increasing water depth</u> to promote <u>downstream migration and spawning</u> 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.
<u>Incremental:</u> habitat condition increases or decreases with a change in the hydrologic parameter.	Provide flows with low water velocity and appropriate depth and to <u>improve water clarity</u> and enable <u>establishment of in-stream vegetation</u>	 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.
<u>No response:</u> habitat condition does not change with the hydrologic parameter (up to a point or for the full range of the parameter).	a) Provide <u>longitudinal connectivity</u> for <u>local movement</u> (min. depth 0.2m) and <u>maintain refuge habitat</u> for platypus and rakali b) Provide flows cues through <u>increasing water depth</u> to promote <u>downstream migration and spawning</u> 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 habitat preference curves (Figure 15). This delivers a habitat provision time series for a specific ecological flow objective (Figure 16).

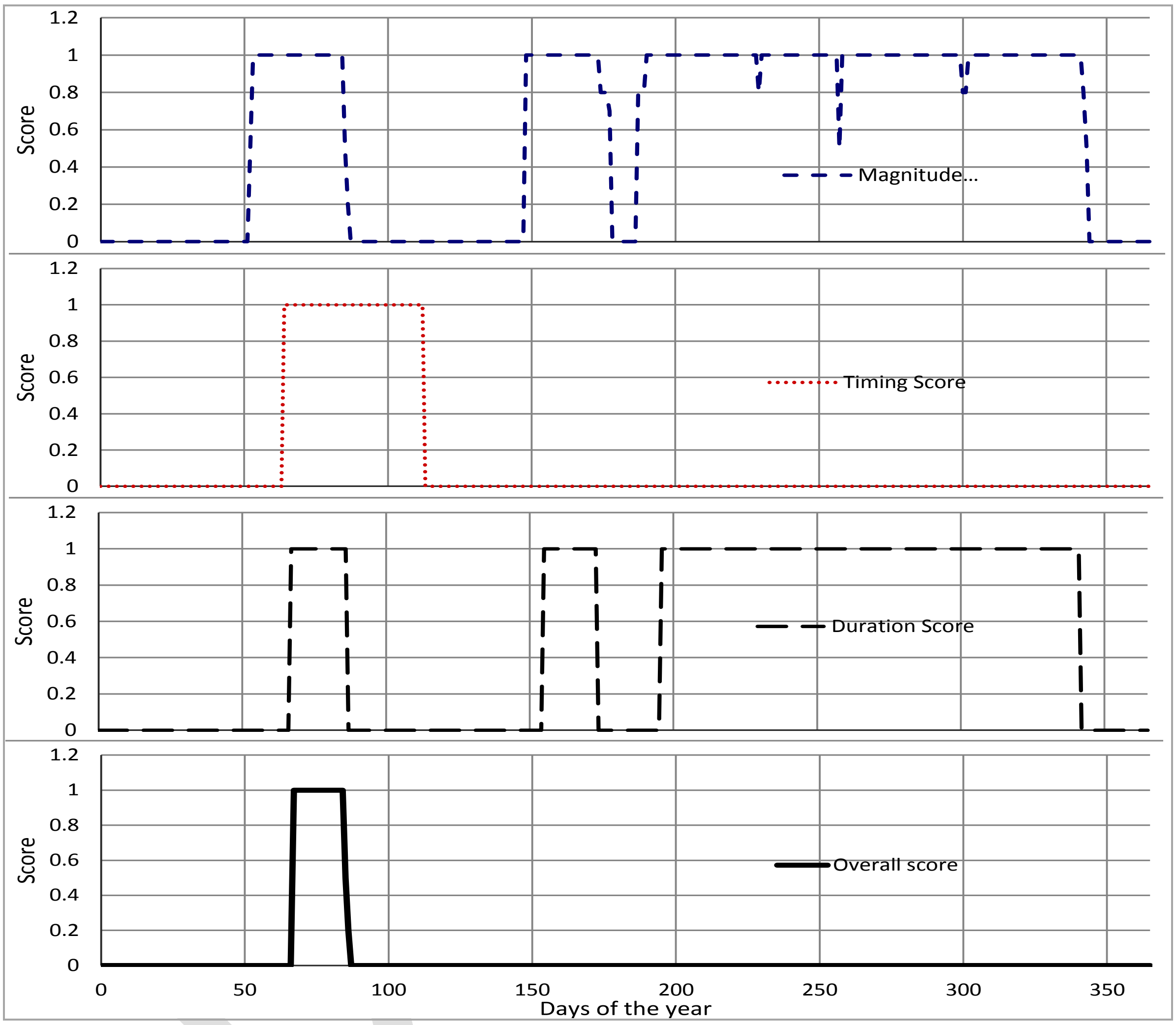


Figure 15. Habitat provision assessment: how daily flow time series and habitat preference curves are combined to quantify the extent of habitat provided for an ecological flow objective. ***Source:*** **Alluvium, 2015c.**

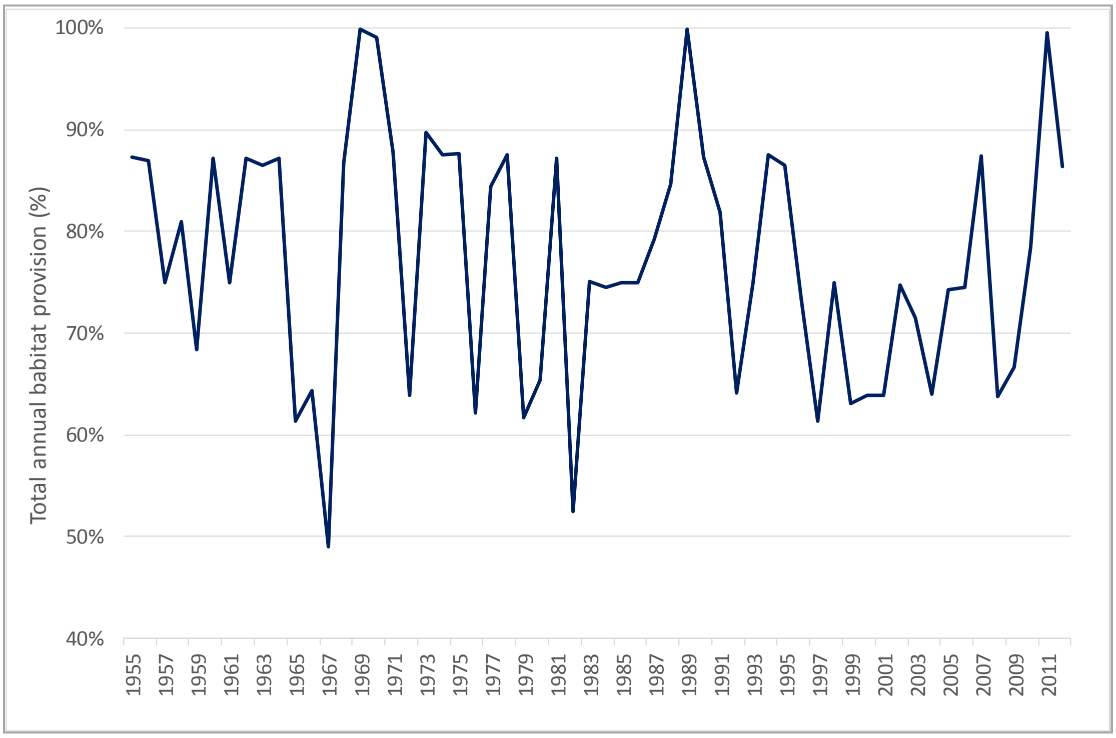


Figure 16. Habitat provision time series showing the change in flow-habitat conditions required for the upstream migration of juvenile catadrmous species (short-finned and long-finned eels). Note that these times series can be developed for any time step including daily and monthly.

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 5), 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).

7.2 Environmental water shortfalls

It is very likely that there will be a shortfall in the volume of environmental water needed to provide all of the revised environmental flow recommendations (Alluvium, 2015b) due to the greater number of flow recommendations compared with the previous flows study (SKM, 2003). This shortfall should be quantified, and options to recover some or all of this shortfall should be explored. Potential options could include:

- **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. Close collaboration between SRW and WGCMA would be required to (a) deliver a watering action and (b) meet SRW's storage filling curve objectives.
- **Trading water on a temporary basis:** including environmental water from other systems 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 water entitlement:** in order to permanently increase the environmental entitlement
- **Investment in water savings projects:** in return for a permanent increase in the environmental entitlement.

8.0 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 23 details the assessment matrix used and Table 24 provides an overview of the risks and contingency planning to manage these risks.

Table 23. 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 24. 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	Possible	Major	High	• There is little knowledge on the extent of groundwater reliance of

Risk description	Likelihood	Consequence	Risk rating	Mitigation Strategies
river itself, adjoining wetlands and riparian vegetation				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
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
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)

9.0 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 25.

Table 25. 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 proposal to investigate fish passage options at Maffra Weir has been submitted to DELWP for implementation in 2015-16	• 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

10.0 Demonstrating outcomes: monitoring

Monitoring activities in the Macalister system may be classified using the VEWH's (2015) monitoring classification system illustrated in Figure 17.

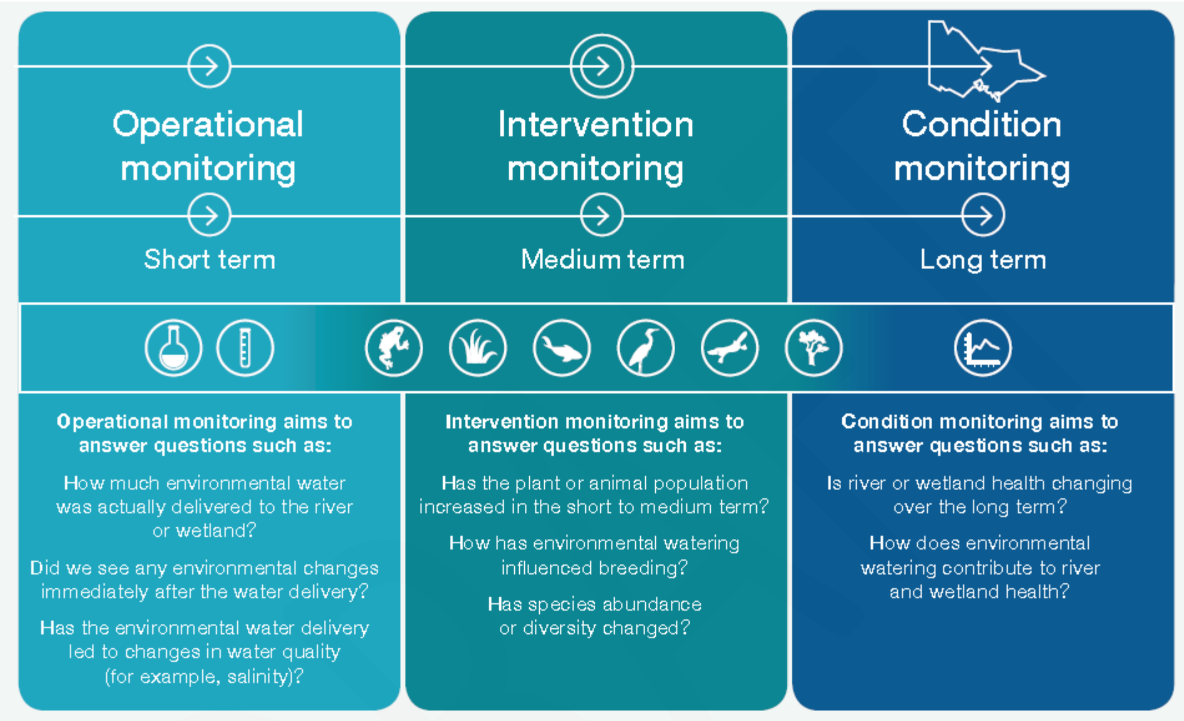


Figure 17. The different types of monitoring. *Source:* VEWH, 2015.

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

10.1 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) on a monthly basis. This data is also used to assess whether flow recommendations were inadvertently met through unregulated flows or consumptive water delivery.

10.2 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 (without in-stream vegetation): 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.

11.0 Recommendations

11.1 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 26 outlines the important knowledge gaps identified for this system that, if addressed, will allow for the adaptive management of this ecosystem. Alongside each knowledge gap are activities identified to address the gap, including monitoring, desktop analysis or investigative technical studies (Alluvium, 2015c).

Table 26. 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).	**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, tupong and Australian bass)	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 • Statistically analyse movement data with overlayed hydraulic and hydrologic information

Knowledge gap	Description	Activities to address knowledge gap
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
Catadromous fish species (e.g. common galaxias, Australian grayling, lamprey)	Limit understanding on the relationship between the upstream migration of these species and freshwater flow.	**Intervention monitoring** • Research looking at river flow and upstream migration using micro-structural and micro-chemical analyses of otoliths has recently commenced for various coastal Victorian streams • These monitoring outputs may be used to customise monitoring in the Macalister River, or at the very least, be extrapolated to flows in this system
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
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	**Condition monitoring** Macro-invertebrate surveys to capture what is present in the system and what has changed is required

Knowledge gap	Description	Activities to address knowledge gap
	and diversity of functional groups, since last survey in 2005 – 06.	
Abiotic		
Water quality	The relationship between environmental watering in the Macalister River and water quality is not 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 are only receive water during overbank flood events.	**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
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
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 (see Section 3.1).	**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.

11.2 Partnerships

Strong partnerships between agencies involved in flow management is critical to the long term health 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. Collaboration is particularly important between the waterway manager (WGCMA) 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
- Both agencies working out suitable timing to deliver environmental watering actions during irrigation season, so that both consumptive and environmental water demands may be met.

11.3 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[1] in the Macalister River

Table B. Water dependent fauna in the Macalister River (excluding fish).

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*

[1] Excluding fish

Group	Common name	Scientific name
	Pink-eared duck	*Malacorhynchus membranaceus*
	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

Table C. 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*
	Boraginaceae spp.
Daisy	*Brachyscome spp.*
	Bursaria spinosa
	Callistemon paludosus
	Callistemon rugulosus
	Callistemon sieberi
	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

Common name	Scientific name
	Einadia nutans subsp. nutans
	Einadia trigonos subsp. trigonos
	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
	Pittosporum undulatum
	Plantago debilis
	Plantago major

Common name	Scientific name
	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
	Stylidium spp.
	Stypandra glauca
	Themeda triandra
	Triglochin procera s.l.
	Typha domingensis
	Urtica incisa
	Vallisnera americana var. americana
	Veronica calycina
	Veronica plebeia
	Veronica spp.
	Viola hederacea sensu Entwisle (1996)
	Vittadinia sp.
	Wahlenbergia gracilis
	Wahlenbergia spp.
	Wahlenbergia stricta subsp.

Appendix D: Habitat preference curves[2]

Reach 1

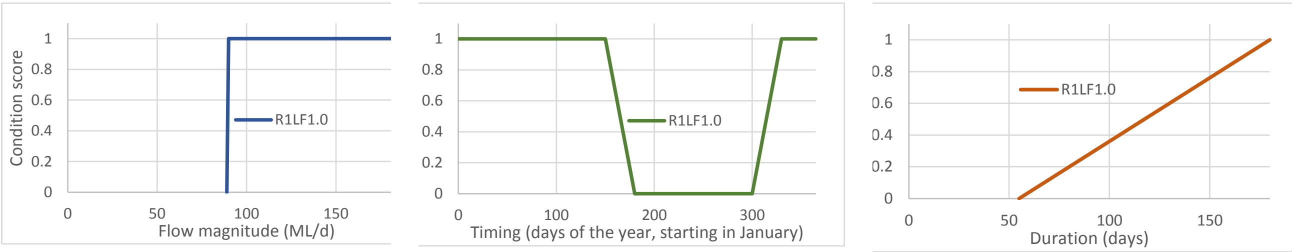

Figure A. Habitat preference curves for model R1L1.0 (low flow Dec – May for physical habitat and vegetation values)

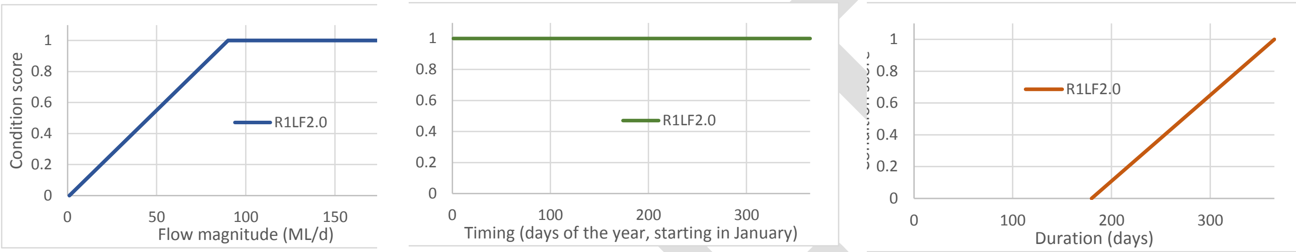

Figure B. Habitat preference curves for model R1L2.0 (Low flow required all year for habitat for fish, macroinvertebrate and platypus values

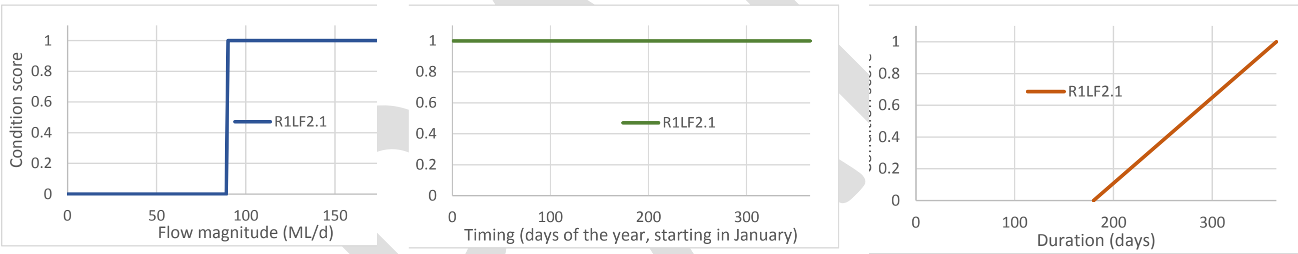

Figure C. Habitat preference curves for model R1L2.1 (low flow all year for local movement of fish, macroinvertebrate and platypus values)

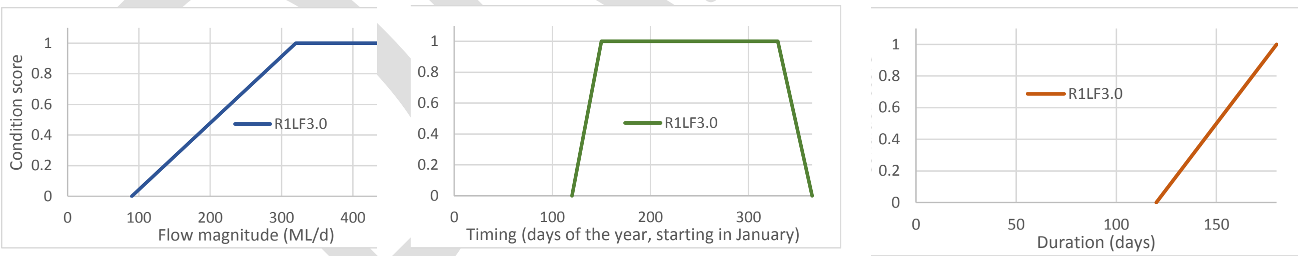

Figure D. Habitat preference curves for model R1LF3.0 (low flow Jun-Nov for vegetation values)

[2] Note: all habitat preference curves are sourced from Alluvium, 2015c.

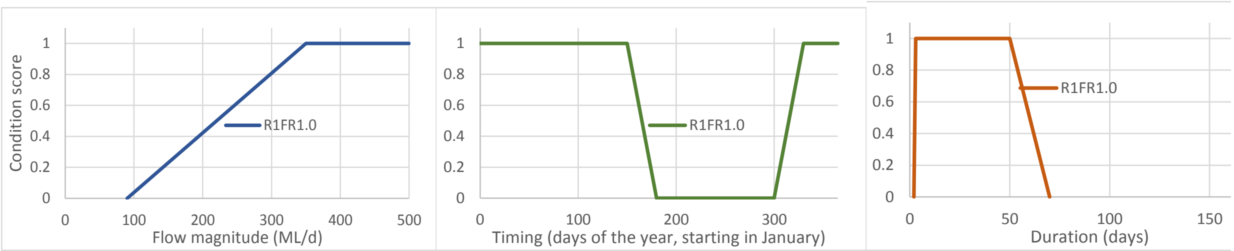

Figure E. Habitat preference curves for model R1FR1.0 (fresh Dec - May for water quality, macroinvertebrate and vegetation values)

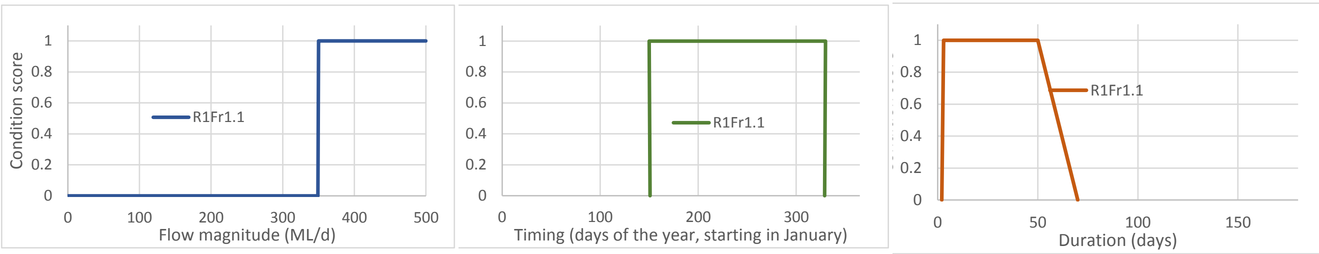

Figure F. Habitat preference curves for model R1FR1.1 (fresh Dec - May for migration of eels)

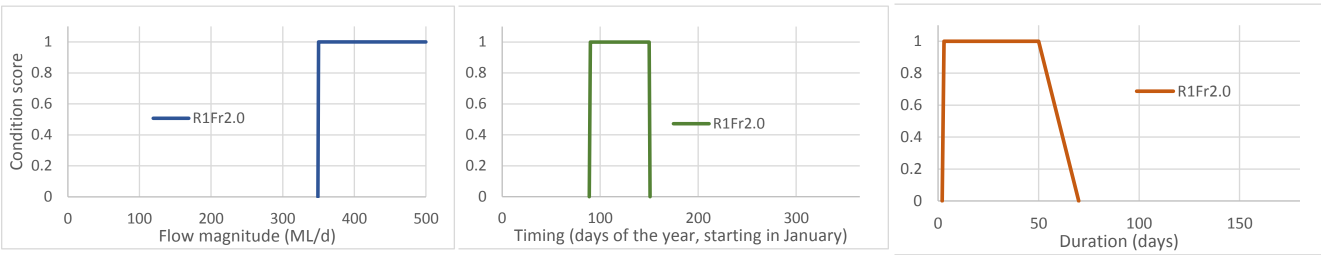

Figure G. Habitat preference curves for model R1FR2.0 (fresh April - May for grayling migration)

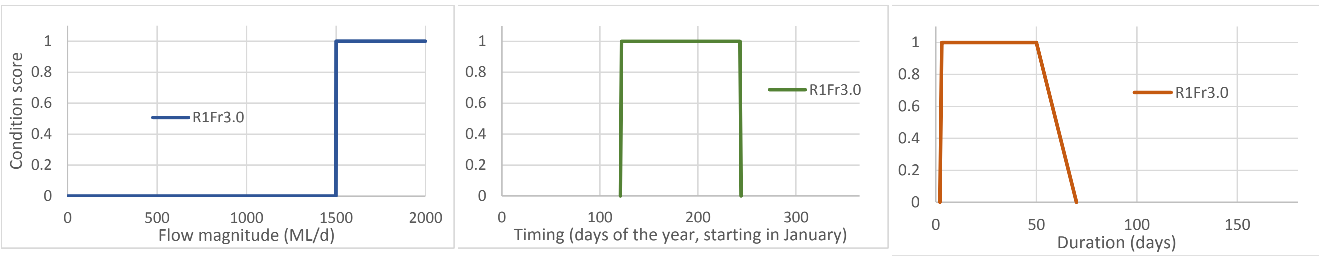

Figure H. Habitat preference curves for model R1FR3.0 (fresh May - Aug for tupong and bass migration)

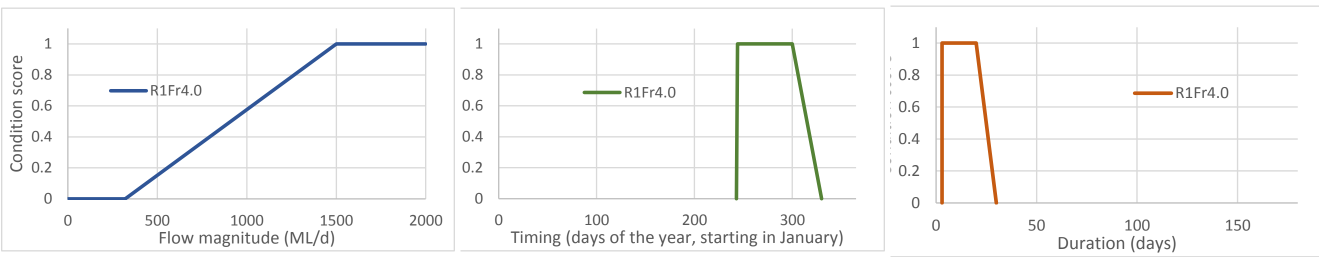

Figure I. Habitat preference curves for model R1FR4.0 (fresh Sep – Oct for vegetation values)

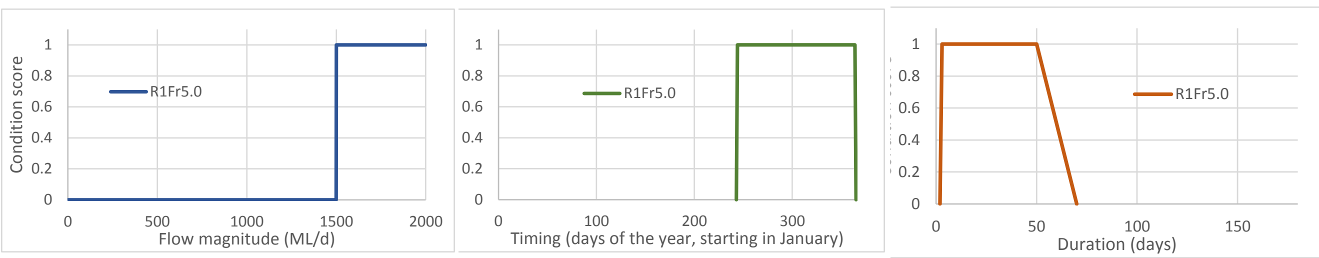

Figure J. Habitat preference curves for model R1FR5.0 (fresh Sep – Dec for fish recruitment)

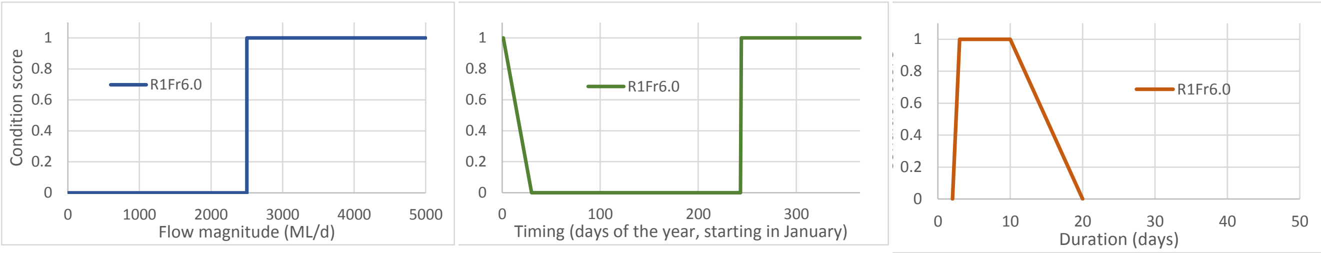

Figure K. Habitat preference curves for model R1FR6.0 (fresh Sep – Dec for vegetation and macroinvertebrate values)

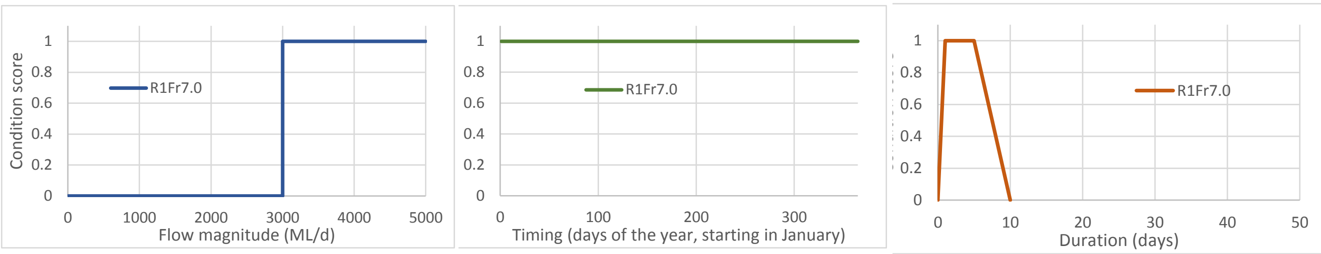

Figure L. Habitat preference curves for model R1FR7.0 (fresh anytime for geomorphology and macroinvertebrate values)

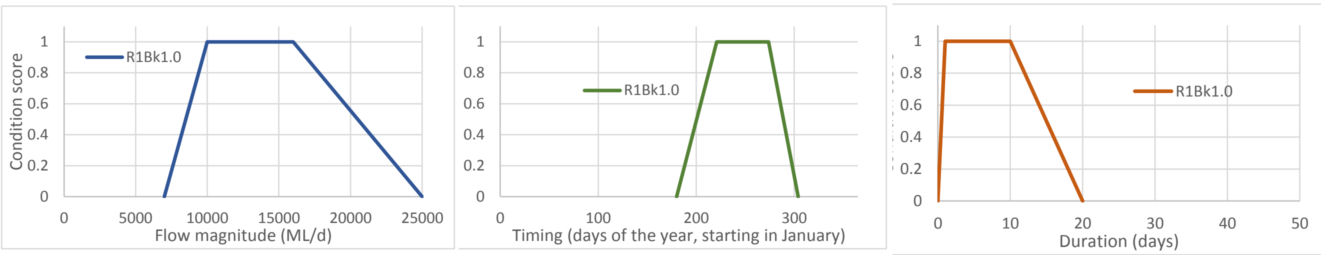

Figure M. Habitat preference curves for model R1BK1.0 (bankfull July - Oct for vegetation, geomorphology, frog, bird and turtle values)

Reach 2

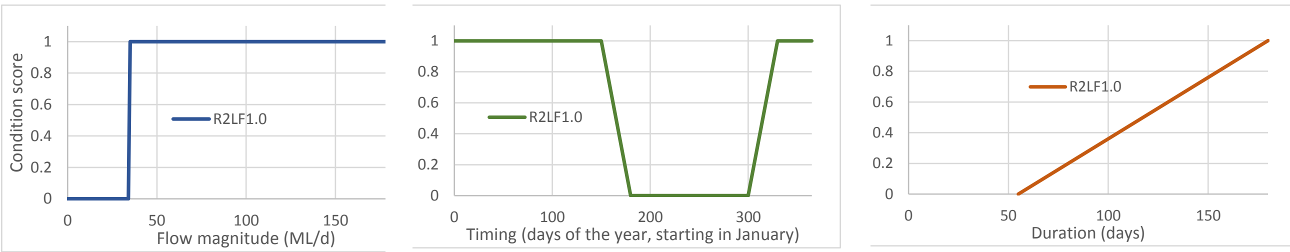

Figure N. Habitat preference curves for model R2L1.0 (low flow Dec – May for physical habitat and vegetation values)

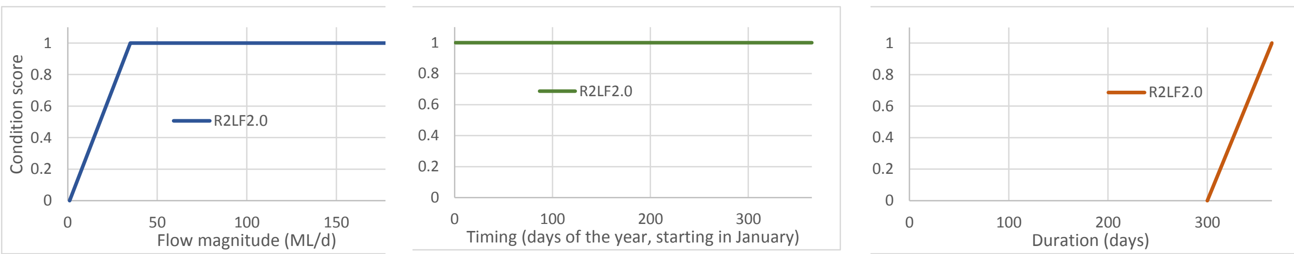

Figure O. Habitat preference curves for model R2L2.0 (Low flow required all year for habitat for fish, macroinvertebrate and platypus values

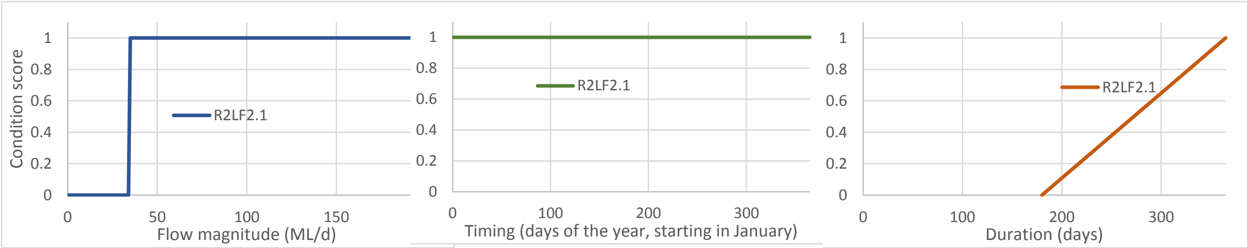

Figure P. Habitat preference curves for model R2L2.1 (low flow all year for local movement of fish, macroinvertebrate and platypus values)

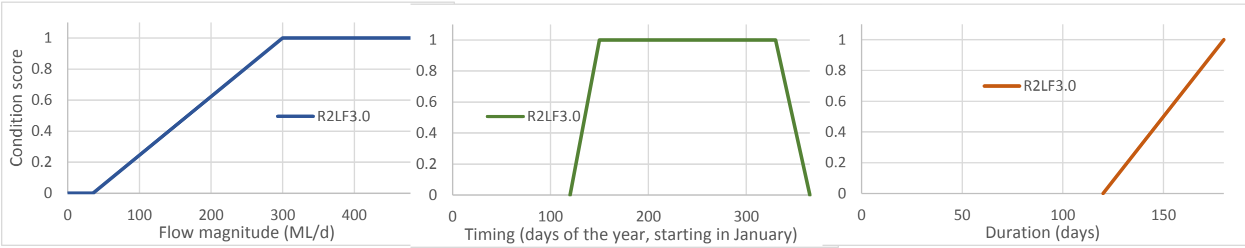

Figure Q. Habitat preference curves for model R2LF3.0 (low flow Jun-Nov for vegetation values)

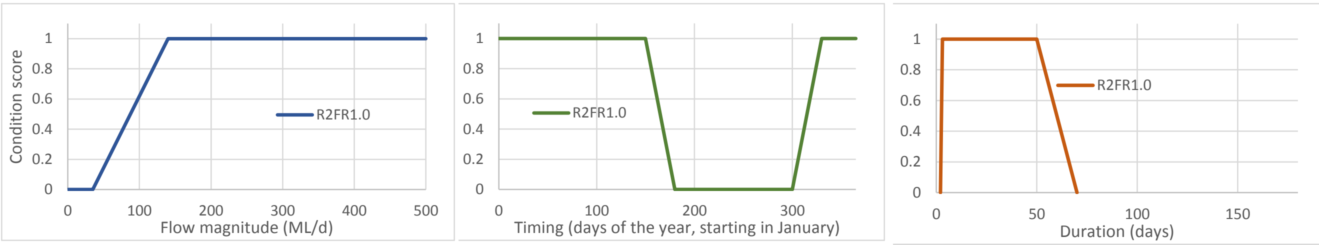

Figure R. Habitat preference curves for model R2FR1.0 (fresh Dec - May for water quality, macroinvertebrate and vegetation values)

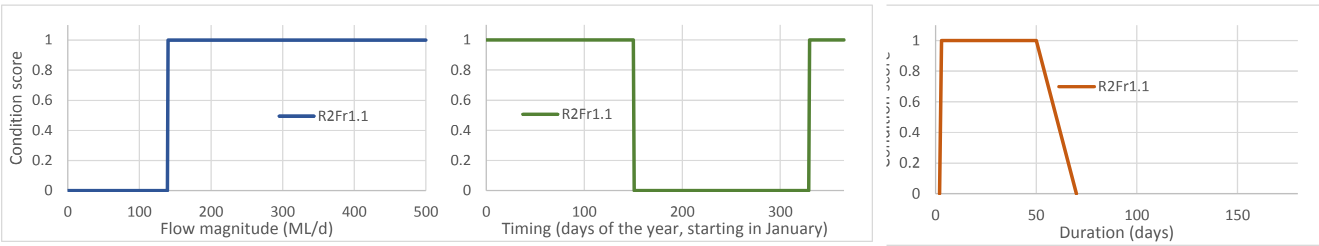

Figure S. Habitat preference curves for model R2FR1.1 (fresh Dec - May for migration of eels)

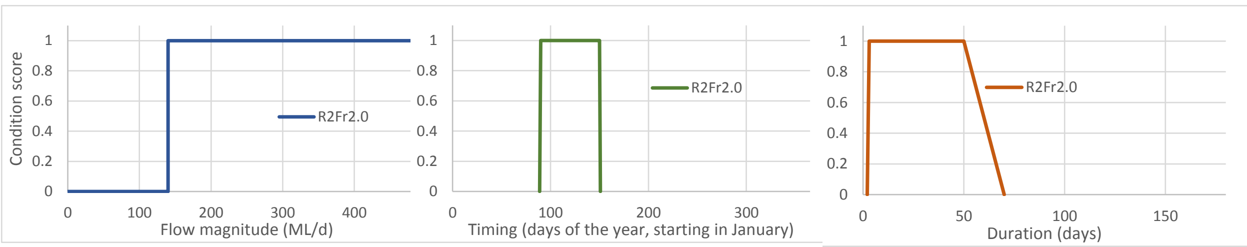

Figure T. Habitat preference curves for model R2FR2.0 (fresh April - May for grayling migration)

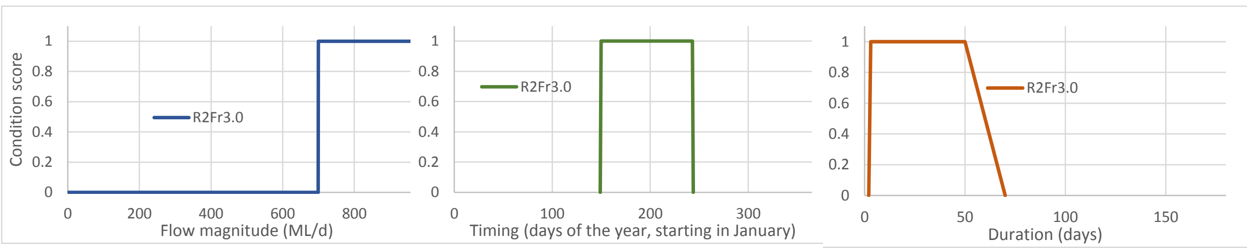

Figure U. Habitat preference curves for model R2FR3.0 (fresh May - Aug for tupong and bass migration)

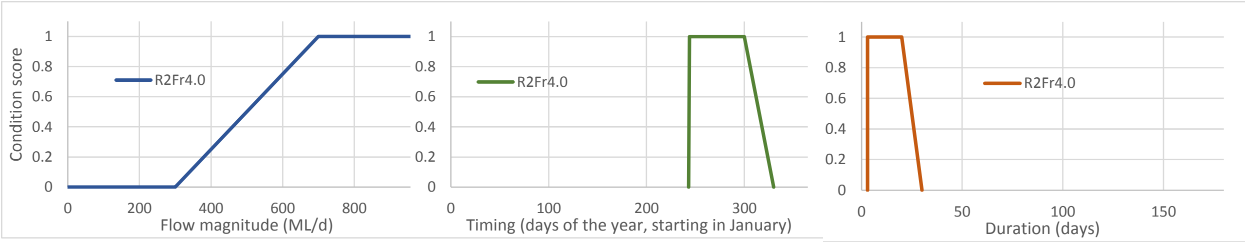

Figure V. Habitat preference curves for model R2FR4.0 (fresh Sep – Oct for vegetation values)

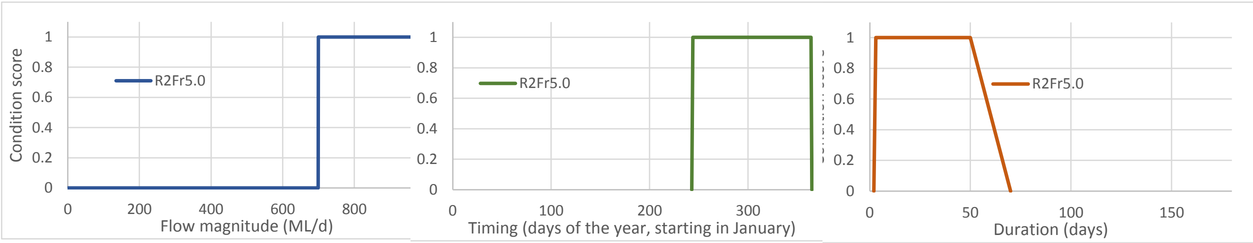

Figure W. Habitat preference curves for model R2FR5.0 (fresh Sep – Dec for fish recruitment)

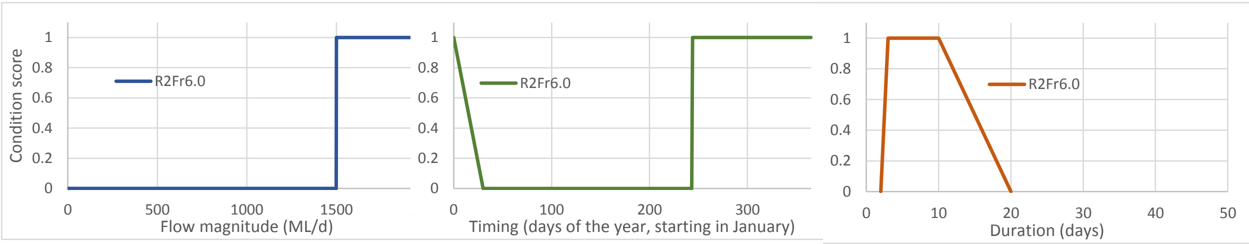

Figure X. Habitat preference curves for model R2FR6.0 (fresh Sep – Dec for vegetation and macroinvertebrate values)

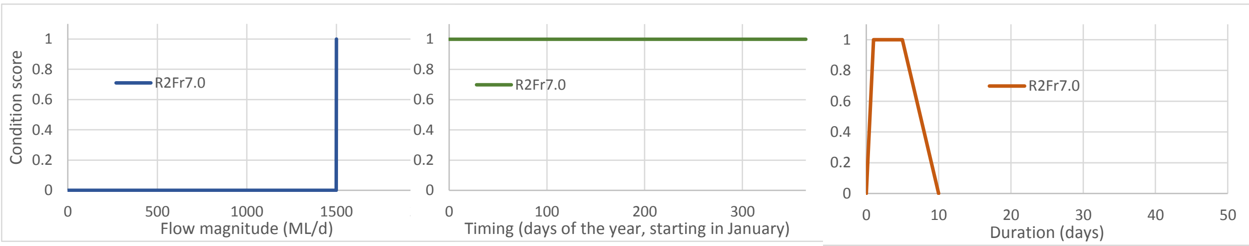

Figure Y. Habitat preference curves for model R2FR7.0 (fresh anytime for geomorphology and macroinvertebrate values)

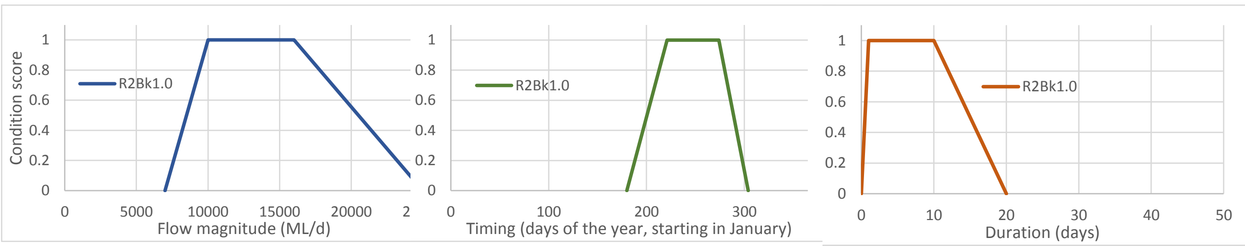

Figure Z. Habitat preference curves for model R2BK1.0 (bankfull July - Oct for vegetation, geomorphology, frog, bird and turtle values

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