Thomson River Environmental Flows and Management Review

Issues Paper

Report for West Gippsland CMA

June 2020

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Streamology and West Gippsland Catchment Management Authority would like to acknowledge and pay our respects to the Gunaikurnai as the Traditional Owners of the lands on which the project is based. We look forward to continuing to work collaboratively with the Gunaikurnai Land and Waters Aboriginal Corporation on achieving water for Traditional Owner cultural values and uses.

Contents

Glossary

Amphidromous	Species of fish that spawn in the freshwater reaches of rivers and the eggs and larvae drift downstream with the current into the estuary and, ultimately, the sea.
Anadromous	Species of fish that undertake upstream adult migrations from the sea into the freshwater reaches of rivers to spawn.
AWA	Aboriginal Waterway Assessment
ARI	Average Recurrence Interval: the likelihood of occurrence, expressed in terms of the long-term average number of years, between flood events as large as or larger than the design flood event.
Bankfull flows	These flows are of sufficient magnitude to reach bankfull condition with little flow spilling onto the floodplain. All benches are inundated creating further habitat for macroinvertebrates, plants and fish.
Baseflow	A continuous flow through the channel. The flow may be limited to a narrow area of the channel but will provide flow connectivity between habitats in the channel.
Catadromous	Species of fish that undertake downstream adult migrations out of the freshwater reaches of rivers to spawn in the estuary or sea.
CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
EC	Electrical Conductivity
EFTP	Environmental Flows Technical Panel. A multidisciplinary panel, usually of four to six people, who provide the core team undertaking a FLOWS investigation
Environmental flows	Flows that describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems
EVC	Ecological Vegetation Class
FLOWS	A method for determining environmental water requirements in Victoria
Fresh	A fresh is a small and short duration peak flow event. These are flows that exceed the baseflow and last for at least several days, often as a result of intensive, and sometimes localised, rainfall
GLaWAC	Gunaikurnai Land and Waters Aboriginal Corporation
ISC	Index of Stream Condition

Lidar	Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. Previously termed LiDAR.
LWD	Large Woody Debris
MID2030	The Macalister Irrigation District modernisation program
Non-diadromous	Species of fish that are generally restricted to freshwater reaches throughout their life history (although some species may occasionally stray into brackish or salty water).
Overbank flows	These flows are greater than bankfull and result in inundation of the adjacent floodplain habitats
PAG	Project Advisory Group
Passing flows	A volume of water that water corporations are obliged to provide out of a storage or past a diversion point before water can be taken for consumptive use
Rheophillic	Preferring or living in flowing water
SEPP	State Environment Protection Policy
SRW	Southern Rural Water
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environment Water Holder
Water for the Environment	Water that is allocated and managed specifically to improve the health of rivers, wetlands and floodplains
WGCMA	West Gippsland Catchment Management Authority
WSPAs	Water Supply Protection Areas

1. Introduction

The Thomson River flows from the slopes of the Baw Baw plateau in the Victorian Alps bioregion and discharges into the Latrobe River downstream of Sale in the Gippsland Plains bioregion. River flow is regulated by the Thomson Dam, which provides potable water for Melbourne, and the Cowwarr Weir, which provides water for the Macalister Irrigation District. Environmental water is managed via water holdings held in the Thomson Dam storage and in Lake Glenmaggie (on the Macalister River, to the east) for the reach downstream of the confluence with the Thomson River (Reach 6).

The river was originally referred to as the Carran Carran by Gunaikurnai peoples. It was given its English name in 1840. Gunaikurnai recognise the importance of the interconnectedness of the river, including land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing.

Prior to 2003, regulated flows for the environment in the Thomson River were essentially a base flow (~25 ML/d). Flow objectives were determined by an environmental flows assessment undertaken in 2003 by Earth Tech. This study identified six management reaches from immediately below the Thomson Dam to the confluence with the Latrobe River.

Since 2003 there has been significant system changes and increased knowledge of biotic and physical response in the Thomson River. There have also been two on-ground projects to improve fish passage through the river system, hence providing significantly improved connectivity. In conjunction with further advancements in the science of environmental flow management, a review and update of the 2003 objectives is warranted.

Streamology and Associates were commissioned to undertake the Thomson River Environmental Flows and Management Review by West Gippsland Catchment Management Authority (WGCMA) using the updated FLOWS 2 method. The aim of the project is to identify flow requirements that align with the vision for the Thomson River and draw upon the latest knowledge of waterway values and their flow dependencies. These flow requirements will be considered in the context of the management of water and water requirements for the Thomson River.

2. Project objectives

The overarching objectives for the Thomson River Environmental Flows and Management Review project are to:

- **Collate, review and update ecological information, objectives, stream condition (current and future trajectory) and conceptual models for the identified reaches of the Thomson River**
- Review and update the 2003 environmental flow recommendations (Earth Tech), including their expansion to cover hydrological scenarios including current demand, unimpacted (natural), climate change (modest and extreme) and impact of irrigation modernisation (modest and extreme)
- Calculate the environmental water shortfalls for required scenarios, and assess the risks of not addressing, and conversely the benefits of addressing, these shortfalls. The risks and

benefits should be presented qualitatively and be inclusive of environmental, social, cultural and economic values.

This Issues Paper addresses the first objective: updating the 2003 ecological and flow objectives for determination of recommendations. The Issues Paper is not designed to reproduce information already collected under previous investigations, but instead focusses on changes to the Thomson River system since 2003.

The second and third stage of the process covering objectives two and three are covered in the Recommendations Paper (Streamology 2020a) and Shortfalls and Risk Assessment Paper (Streamology 2020b).

3. Project Scope

Reach selection for the updated flows study involved reviewing the reaches used in the 2003 assessment for any new knowledge or changes to waterway characteristics that warranted modification of the reaches. Based on this review, the 2003 reach definitions were found to still be valid. Therefore, six reaches were investigated as part of the Project scope; two upstream of Cowwarr Weir and four downstream (refer to **Figure 1**). The Gippsland Lakes, including Sale Common and Lake Wellington, are not included in the project scope.

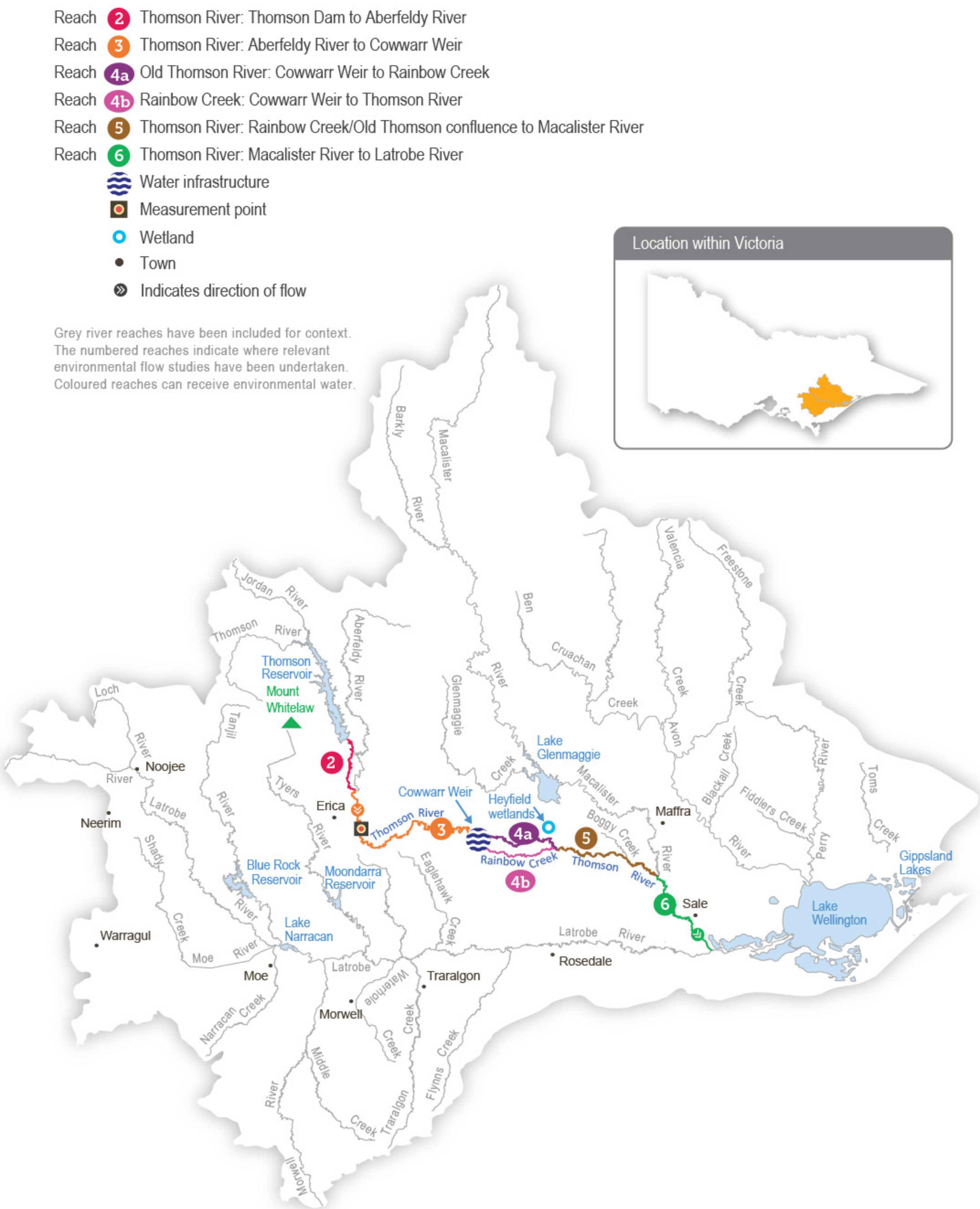


Figure 1: Thomson River Reaches (from VEWH, 2019)

4. **Project Governance**

4.1. **Environmental Flows Technical Panel (EFTP)**

The Thomson River Environmental Flows Technical Panel (EFTP) is comprised of:

- Dr Geoff Vietz (Geomorphology)
- Associate Professor David Crook (Fish Ecology)
- Professor Paul Boon (Vegetation Ecology)
- Steve Clarke (Hydrology, Hydraulic Modelling).

The objectives for each reach were developed by the EFTP members at a workshop held on Tuesday 19th November 2019 in Traralgon, Victoria.

4.2. **Steering Committee**

The purpose of the Steering Committee is to oversee project implementation, provide direction on the scope of work, and review and provide feedback for key milestones throughout the project. The Steering Committee represents stakeholders directly involved in the management of environmental water in the Thomson and includes representatives from DELWP, the WGCMA, Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) and Victorian Environmental Water Holder (VEWH). The Committee is a forum to provide advice and recommendations in preparation for, or directly after, workshops to ensure flow recommendations, objectives and key priorities are achievable.

4.3. **Project Advisory Group**

The purpose of the Project Advisory Group (PAG) is to ensure that the broader stakeholder groups of the Thomson system are adequately represented. This group provides a source of local knowledge and community expectations via participation and contribution through workshops. Stakeholders include representatives from GLaWAC, Southern Rural Water (SRW), Melbourne Water, Gippsland Water and community interest groups including VRFish, Waterwatch, Landcare and local irrigators / land holders.

5. **Vision for the Thomson River**

The EFTP vision for the Thomson River views the river as a living entity, a continuous system spanning three bioregions from the river's headwaters in the Victorian Alps, through the Southern Falls, to where the river discharges into the Gippsland Lakes and hence into the ocean, on the Gippsland Plain. The 'living river' vision focuses on connectedness and continuity, maintaining the system's character and ecological integrity, and an acknowledgement of human disturbance over the past 200 years. This includes construction of the Thomson Dam (1976 to 1983) and Cowwarr Weir (1957). These structures, particularly diversion of more than 60% of the mean annual flow to Melbourne, have significantly altered the river. Therefore, active management is required to protect and maintain the river's cultural and ecological values. Fundamentally, this involves caring for, and protecting, the life and culture of the river and its tributaries.

The living river vision described here recognises the Gunaikurnai people's beliefs that "the land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing" (Gunaikurnai Land and Waters Aboriginal Corporation, 2015, p8) are intertwined and unable to be separated. This belief has been the basis for successful management of the Thomson River landscape for countless generations before European colonisation and remains as relevant as ever.

The Thomson River is one of a network of coastal rivers across Gippsland and south-eastern Australia that sustains populations of nationally significant migratory native fish species, including the Australian Grayling, Tupong and Short- finned and Long-finned Eel. The vision for the Thomson River emphasises the importance of native fauna at this broader scale and at the catchment scale, where the Thomson River forms the backbone of a complex system of connected tributaries and wetlands. The vision of the Thomson River as a living river therefore includes the Aberfeldy River, a significant upstream tributary connecting the main Thomson River to the headwaters high in the catchment, introducing connectivity from the lakes and ocean to the headwater mountains. It also includes the tributaries of the Macalister and Latrobe Rivers.

Wetlands in the lower reaches are vital components of the living river. Maximising connectivity to maintain the structural and ecological complexity of the Thomson River, its streams, wetlands and the species which rely upon them, is a principal theme driving the vision for longitudinal and lateral connectivity (**Figure 2**).

> The vision for the Thomson River is:
>
> *A living river, from mountains to sea, that sustains social, cultural and ecological values, contributing to the health and prosperity of the Gippsland lakes and broader region*

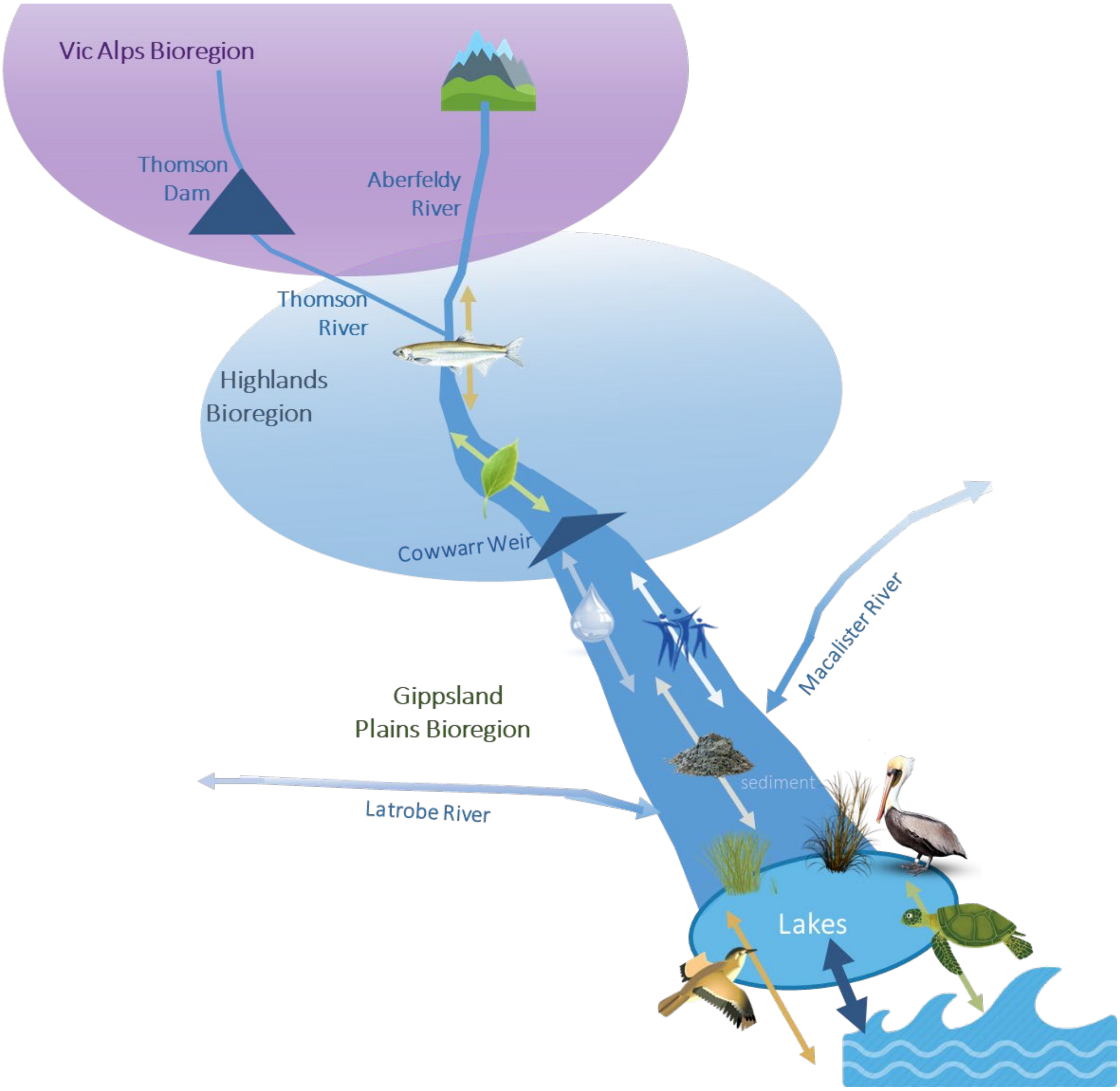


Figure 2: The Thomson River; a continuous system part of an interconnected network of rivers

6. **Carran Carran - the Thomson River**

The Thomson River, from where it starts in the Baw Baw ranges, to where it joins the Latrobe River near Sale, is across the Brayakaulung[1] clan's area of country, which includes from the Great Dividing Range to Lake Wellington. The Brayakaulung clan's name means "Bra" - Men, "Yak" – West. The Journey Boran, The Pelican, took across this area of country is vital to the Gunaikurnai creation story, knowing Boran checked his gree (canoe) in this area close to Sale (GLAWAC 2020).

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

Bundalaguah near the confluence of the Macalister and Thomson rivers was also the preferred site for a mission in the mid-1860s, before it was set up at Lake Tyers in 1863 after pressure from the white settlers saw Bundalaguah as a site quashed (GLAWAC 2020).

Today the majority of Carran Carran is inaccessible to the Gunakurnai, making it very difficult to read Country and assess the health of the River with a cultural lens. It is estimated about 80 per cent of the waterway is inaccessible due to being on privately held land. As a result, not much cultural heritage surveying has been undertaken, nor has it been possible to meet and yarn along the River. The ability to meet and yarn along the river would greatly increase the ability to define relationships between cultural practices and flows in the river. There is no doubt there are many culturally significant sites along the river, but these have not been well documented. To determine the watering needs from a cultural perspective, resourcing and access has to be provided to understand where cultural heritage sites are intact, and engage with Gunaikurnai Community on cultural values and uses (GLAWAC 2020).

GLAWAC view Country as connected, with the Latrobe, Thomson and Macalister rivers being integral to the lower Latrobe wetlands and the Gippsland Lakes. Carran Carran is an important feeder into the Lower Latrobe wetlands, which are very important - traditionally and today - although not within the scope of this Environmental Water Study (GLAWAC 2020).

[1] The Brayakaulung clan is one of the five clan groups of the Gunaikurnai.

7. General Changes in System

7.1. Advances in Environmental Water Management

7.1.1. The Victorian Environmental Water Holder

The VEWH was established in 2011 as an independent body responsible for managing Victoria's environmental water entitlements. The VEWH prepare a yearly seasonal watering plan to guide environmental watering decisions in Victoria, with the Thomson River covered in the Gippsland Region section. The yearly seasonal watering plan is informed by WGCMA's yearly seasonal watering proposal for the Thomson River System to present the proposed watering actions and priorities for the Thomson River, taking into consideration the seasonal conditions, best available ecological science and the long term environmental flow objectives for the River.

7.1.2. FLOWS Method

The FLOWS method, first developed in 2002, was updated in 2013 to incorporate current best practice and new approaches in science and modelling. The following changes are among the most notable:

- Additional opportunities for community engagement and consultation
- A requirement for more justification for the link between flow recommendations and ecological response based on the latest science
- Definition and protocols for hydraulic and hydrologic modelling.

7.1.3. Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP)

In 2005 the Victorian Government established the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP), a long-term monitoring program to evaluate the efficacy of environmental water delivery and to assess ecosystem responses. Monitoring of vegetation and fish commenced in 2007. Stage six of the program is currently underway (2016-2020) and aims to confirm fish and vegetation responses to environmental flow events. This program provides direct ecological response information for the Thomson River that is invaluable in defining environmental flow recommendations. The program, at this stage, does not include physical form (geomorphic) monitoring.

7.1.4. Flagship Waterways Project

The Flagship Waterways Project acknowledges that change as a result of management may not be observed over short time frames (such as five years within the Index of Stream Condition (ISC)). This is especially the case when looking at changes occurring over large reaches over the entire State. An alternative approach was sought to inform on management interventions, providing guidance on what works, how fast changes are expected to occur, and what targets to set. The Flagship Waterways approach is to take a single stream, or reaches of that stream, from each Catchment Management Authority that is being actively managed. WGCMA has selected the Thomson River between Cowwarr Weir and Macalister River confluence as its Flagship waterway. The project aims to complete two key objectives; a natural riparian corridor from the Gippsland Lakes to the Alps and address future avulsion risks of Rainbow Creek. As part of this process DELWP has recaptured Lidar and aerial imagery over these reaches in 2018 and 2019 so that the vegetation and geomorphology can be compared against the ISC3 imagery collected in 2009-2010.

These data, and the overall approach, supports the setting of targets with the Regional Waterway Strategies. For example, if the CMA intends to fence and revegetate 50 km of stream in a catchment what are they hoping to achieve from this investment? If the intent is to increase the condition of riparian vegetation, reduce bank erosion and produce overhangs that advantage native fish then the likely trajectory of these goals should be articulated and then the results should be monitored relative to these targets.

7.1.5. Environmental Water Entitlements and Sharing Arrangements

WGCMA is authorised to use water made available by the VEWH under the Bulk Entitlement (BE) *Thomson River - Environment* (Victorian State Government 2017a). The Water holder is entitled to a storage capacity of 18 GL. This is made up of the first 10 GL of inflow from the Thomson Basin and 3.9% of all inflow to the Thomson Reservoir.

Under the BE, passing flows are intended to meet both the environmental needs of the Thomson River and irrigation needs below Cowwarr Weir, and are specified as instantaneous flow at Beardmores gauging station, at the Narrows gaugings station and at Coopers Creek gauging station. The Aberfeldy River is a tributary of the Thomson River and joins the Thomson River downstream of the Beardmores and the Narrows passing flow compliance points, and upstream of the Coopers Creek passing flow compliance point, see **Figure 3**. This means that unregulated flows in the Aberfeldy River contribute to meeting the Coopers Creek passing flow target.

SRW, under the BE *Thomson Macalister - Southern Rural Water* (Victorian State Government 2018), must provide a passing flow in the Thomson River and Rainbow Creek between Cowwarr Weir and Wandocka (refer to Figure 1), either:

a) The lesser of 125 ML/day, and the natural flow; or

b) If the natural flow is less than 50 ML/day, 50 ML/day.

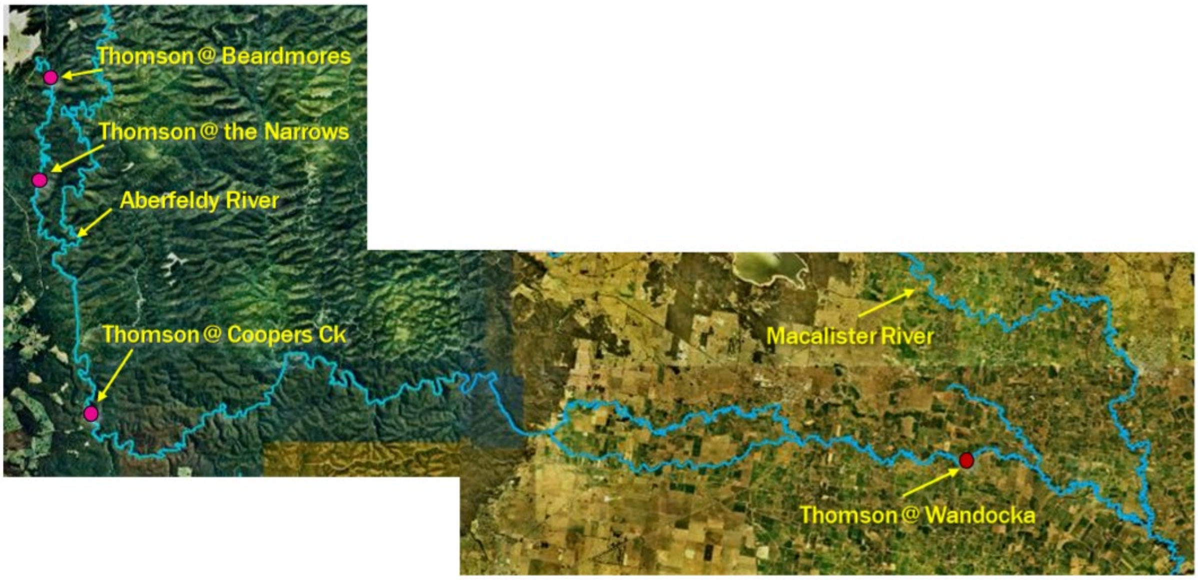


Figure 3: Location of passing flow compliance points along the Thomson River (VEWH 2017)

Under the Gippsland Water BE (*Thomson/Macalister Towns - Gippsland Water*) (Victorian State Government 2005), Gippsland Water can divert up to 6.5 ML/d at Thomson River @ Heyfield. This is to supply the town of Heyfield, by 2021 this system will be expanded to supply Coongulla, Glenmaggie and Glenmaggie Point as well. The Heyfield Water Treatment Plant is supplied by a pump on the Thomson River.

In 2017, an agreement between WGCMA, VEWH, SRW, Melbourne Water and Gippsland Water defined passing flow modifications. The existing passing flow targets were designed for both environmental and irrigation purposes meaning they are higher than the low flow ecological recommendations for the Thomson River. The working group therefore identified an opportunity to potentially accrue passing flows, by lowering the targets during winter, which can then be used to contribute to environmental watering events later in the year. Accrual of savings will be influenced by SRW's harvest right and is not guaranteed if passing flows are reduced; a risk-benefit assessment is made with the Passing Flows Working Group to determine whether to proceed. Passing flows may be reduced in either or both July and August depending on the conditions – a decision-making process and tools to support this process have been agreed and established by the Thomson passing flows working group in 2017. Water saved can be banked and used for environmental benefit.

Since the flow recommendations were first developed in 2003, environmental water has primarily been used to deliver Autumn and Spring Freshes for the purposes of creating spawning and recruitment opportunities for Australian grayling, Australian bass and tupong (VEWH 2020).

An Autumn Fresh was unable to be delivered in 2019 due to construction of the Horseshoe Bend Fishway. The 2020 Autumn Fresh released has been scheduled for April – June 2020 (and will be followed by delivery of a baseflow) to trigger downstream migration and spawning of Australian Grayling.

7.2. **Catchment Based Changes**

7.2.1. **Fire and Flood**

As at December 2019, the Thomson Catchment has experienced three major fires since the 2003 Flows Study:

1. **December 2006 - Great Divide Fire**
   Ignited by lightning strikes in the Victoria Alps, the Great divide fire burnt through 1.2 - 1.3 million hectares of which 90,000 ha was within the Thomson River catchment (Alluvium 2014).
2. **January 2013 - The Aberfedly-Donnellys Fire**
   This fire burnt through 60,000 ha of the Thomson catchment, and the majority of this area was previously burnt in the 2006 Great Divide Fire (Alluvium 2014).
3. **January 2019 - Thomson Dam Fire**
   A fire around the Thomson Dam was ignited by lightning[2].

In June of 2007, the Thomson River experienced widespread flooding in and around Sale, Maffra, Heyfield and Stratford, affecting access to the area and travel along the Princess Highway and South Gippsland Highway (State Emergency Service 2015). In Gippsland a total area of 56,600 hectares were inundated. The Thomson River upstream of Cowwarr Weir recorded a flow of 73,798 ML/d (1 in 25 year ARI) and the Thomson River at Wandocka gauge recorded a flow of 26,807 ML/d (1 in 4 year ARI). The Thomson River at Bundalaguah recorded a flow of 136,457 ML/d (1 in 28 year ARI) due to the Macalister River also being flooded.

In August of 2011, 85 mm of rain fell within 24 hours at the Thomson Dam and in the surrounding areas, resulting in widespread flooding of Gippsland farms and townships in low-lying areas along the river including Cowwarr, Riverslea and parts of Sale (Gray 2011).

During June of 2011, up to 200 mm of rain fell in eastern Victoria, with some areas receiving an entire month's rainfall in a single day (Australian Institute for Disaster Resilience 2012). This led to minor to moderate flooding within the Thomson River catchment (Levy 2012). Debris flows and large influxes of sediment was common during flood events following fire, with significant impacts throughout the Thomson River catchment (Alluvium 2014).

7.2.2. **Fishways**

Two new fishways have been constructed along the Thomson River since the last flow study in 2003. In 1996 a rock ramp fishway was installed at the broad crested weir on Reach 4a of the Thomson River to facilitate passage of migratory fish into the upper reaches of the Thomson River through the barrier of the Cowwarr Weir. The fishway was assessed by GHD in 2006 and found to be ineffective for small bodied fish such as the Australian Grayling and Common Galaxias but effective for large bodied species. In 2011 the fishway was upgraded to include a vertical slot fish ladder. Fish passage has not been provided at the upstream extent of Rainbow Creek at Cowwarr Weir.

In 2019 a fishway was constructed at the Horseshoe Bend tunnel, located in Reach 3 of the Thomson River. This fishway connects the middle reaches of the Thomson River near Coopers Creek to upstream reaches in the Victorian Alpine bioregion, thus unlocking an additional 22 km of waterway

[2] The extent of the 2019 fire cannot be established at time of writing.

to fish passage on the Thomson main stem, as well as access to an additional 64 km of the Aberfeldy River (WGCMA 2019a). The fishway has a minimum flow split of 60:40 between the tunnel and the fishway, respectively, to avoid compromising the heritage aspects of the diversion tunnel.

7.2.3. Irrigation Modernisation

SRW manages the Macalister Irrigation District (MID), the largest irrigation district in southern Victoria, by supplying high reliability water to dairy sector and cropping industries and vegetables. In response to growing demand for irrigation and a need to improve irrigation practices, a modernisation and expansion program known as MID2030 is currently being delivered. MID2030 includes a combination of pipelining, channel automation and regulator upgrades (SRW 2019), all actions that will affect the volume of water available for the environment through recharge and runoff. The MID2030 program also aims to reduce farm run-off and drain outfall, which reduces nutrients being transported into the Gippsland Lakes. Although these flows are often viewed as losses from irrigation regions, they are an important source of streamflow reused downstream.

7.2.4. River rehabilitation works

Since 2003, significant river rehabilitation works have been completed including WGCMA fencing, willow control and revegetation programs. **Table 1** contains a summary of works undertaken from 2003 - 2020.

Table 1: Summary of WGCMA river rehabilitation works carried out from 2003 - 2020

	Weed control works		Fencing work		Revegetation work	
River section	Total Area treated (Ha)	Length of river treated (km)	Total fence length (km)	Length of river treated (km)	Total area revegetated (Ha)	Length of river treated (km)
Aberfeldy to Cowwarr Weir (70km)	61.02	24.21	30.1	25.11	56.56	25.11
Stoney Creek to Rainbow Creek (11km)	6.01	2.52	5.17	4.27	6.02	2.82
Rainbow Ck to Macalister River (37km)	132.45	22.47	38.14	20.24	65.39	21.14
Macalister River to Park Street Sale (25km)	54.51	17.57	19.24	17.62	22.29	18.18
Sale to Latrobe River (4km)	7.42	0.8	1.85	0.8	1.11	0.8
TOTAL	261.41	67.57	94.5	68.04	151.37	68.05

8. New Knowledge

8.1. Fish

A conceptual model for fish, based on latest science and research, was developed by Wayne Koster and Frank Amtstaetter from the Arthur Rylah Institute and David Crook from Latrobe University (**Figure 4**) for the purpose of this 2020 Environmental Flows Study.

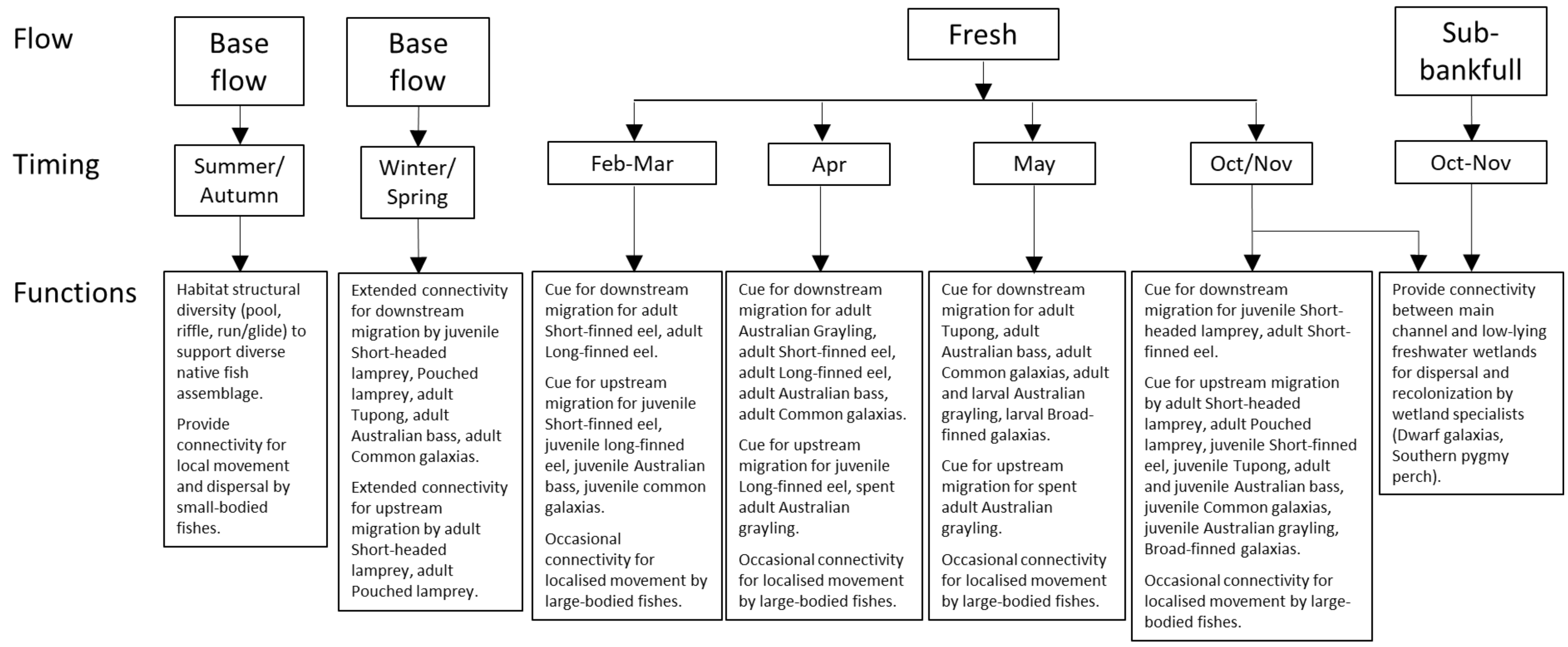


Figure 4: Fish conceptual model for the Thomson River (covering Reaches 2 – 6)

The Thomson River supports an ecologically diverse assemblage of native fishes, characterised by a high proportion of diadromous species: i.e., species that migrate between freshwater and the sea to complete their life history. Fifteen native freshwater fish species have been recorded from the Thomson River and associated wetlands (**Table 2**), including the Australian grayling (*Prototroctes maraena*) and Dwarf Galaxias (*Galaxiella pusilla*) which are both listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999. Native fish hold great significance for the Gunaikurnai Traditional Owners of the Thomson River (Brayakaulung country) and broader Gunaikurnai region (Brabralung, Brataualung, Tatungalung and Krauatungalung country), providing a food source and an important component of songlines and cultural practice for many thousands of years (GLAWAC 2015). Eels (Short-finned eel *Anguilla australis*, long-finned eel *Anguilla reinhardtii*) also support a significant commercial fishery in the Gippsland lakes and several species of native freshwater fish are targeted by recreational fishers, including Australian bass (*Macquaria novemaculeata*) and River blackfish (*Gadopsis marmoratus*).

In addition to the native fish fauna, six introduced fish species have established populations in the Thomson River, including Common carp (*Cyprinus carpio*), Brown trout (*Salmo trutta*), Rainbow trout (*Oncorhynchus mykiss*), Redfin perch (*Perca fluviatilis*), Gambusia (*Gambusia holbrooki*), Goldfish (*Carassius auratus*) and Oriental weatherloach (*Misgurnus anguillicaudatus*) (**Table 2**). Common carp support a commercial fishery in the Gippsland lakes and Brown trout and Rainbow trout are commonly targeted by recreational fishers in the upper Thomson catchment. While some introduced species in the Thomson River have social and economic value, they are likely to have ongoing detrimental effects on native fish and other aquatic fauna via competition, predation and adverse effects on water quality and ecosystem processes. We have not attempted to address the threats posed by introduced fishes in this report given the focus on environmental flow delivery to meet the requirements of native fishes; however, we emphasise the need for consideration of introduced species management as a complimentary measure across the region.

The status of fish assemblages in the Thomson River has been monitored intensively since 2005 as part of the DELWP established VEFMAP. The most recent phase of the program (VEFMAP Stage 6) provides information on fish species' status via annual population surveys and also includes specific 'intervention' or 'flow event' research activities to examine the benefits of environmental water at regional, catchment and state-wide scales (Amtstaetter et al. 2019). The research conducted under VEFMAP and associated programs has demonstrated a range of benefits to fish resulting from the provision of environmental flows (base flows and freshes) in the Thomson River, including stimulating downstream migration and spawning by adult Australian grayling and upstream dispersal and recruitment of Tupong and other species of diadromous fish (Amtstaetter et al. 2016; 2019). The findings of the VEFMAP reports, additional fish surveys and research projects, and associated reports and scientific publications have been considered in detail during the development of the updated flow objectives and recommendations for fish in the Thomson River.

Table 2: Native and introduced freshwater fishes recorded from the Thomson River. L = lower reaches, Longford to Cowwarr Weir; M = mid reaches, Cowwarr Weir to Horseshoe Bend; U = upper reaches, above Horseshoe Bend (from Koster and Crowther 2003). The '#' column refers to the total reported numbers of each species collected in the 2019 VEFMAP survey of the Thomson River (Amtstaetter et al. 2019). No value in this column means that the species was not collected by Amtstaetter et al. (2019). While these surveys did not aim to provide a comprehensive estimate of species abundance across the catchment, they provide a valuable snapshot of the status and distribution of fishes in the Thomson River.

Common name	Scientific name	Migratory type	Distribution	#
River blackfish	*Gadopsis marmoratus*	Non-diadromous	L/M/U	39
Dwarf galaxias	*Galaxiella pusilla*	Non-diadromous	L	-
Flatheaded gudgeon	*Philypnodon grandiceps*	Non-diadromous	L	6
Dwarf flatheaded gudgeon	*Philypnodon macrostomus*	Non-diadromous	L	-
Southern pygmy perch	*Nannoperca australis*	Non-diadromous	L/M/U	10
Australian smelt	*Retropinna semoni*	Non-diadromous	L/M/U	2268
Short-finned eel	*Anguilla australis*	Catadromous	L/M/U	100
Long-finned eel	*Anguilla reinhardtii*	Catadromous	L/M/U	29
Common galaxias	*Galaxias maculatus*	Catadromous	L/M	-
Australian bass	*Macquaria novemaculeata*	Catadromous	L	33
Tupong	*Pseudaphritis urvillii*	Catadromous	L/M/U	117
Poached lamprey	*Geotria australis*	Anadromous	L/M/U	-
Short-headed lamprey	*Mordacia mordax*	Anadromous	L/M/U	1
Australian grayling	*Prototroctes maraena*	Amphidromous	L/M/U	23
Broad-finned galaxias	*Galaxias brevipinnis*	Amphidromous	M	-
Brown trout*	*Salmo trutta*	Non-diadromous	L/M/U	50
Rainbow trout*	*Oncorhynchus mykiss*	Non-diadromous	M/U	-
Redfin perch*	*Perca fluviatilis*	Non-diadromous	L/M	12
Common carp*	*Cyprinus carpio*	Non-diadromous	L/M	37
Goldfish*	*Carassius auratus*	Non-diadromous	L/M	-
Gambusia*	*Gambusia holbrooki*	Non-diadromous	L/M	-
Weather loach*	*Misgurnus anguillicaudatus*	Non-diadromous	L	-

* Introduced species.

Native fish in the Thomson River can be broadly categorised according to their migratory characteristics, providing a useful basis for conceptualising and aggregating critical flow-related ecological requirements across the Thomson River fish assemblage.

Non-diadromous species are generally restricted to freshwater reaches throughout their life history (although some species may occasionally stray into brackish or salty water). Non-diadromous fish species recorded from the Thomson River catchment include River blackfish, Dwarf galaxias, Flatheaded gudgeon (*Philypnodon grandiceps)*, dwarf flatheaded gudgeon (*Philypnodon macrostomus)*, Southern pygmy perch (*Nannoperca australis*) and Australian smelt (*Retropinna semoni*) (**Table 2**). Recent otolith chemistry studies have shown that some populations of Australian smelt in coastal streams of eastern Victoria exhibit facultative diadromy, where only a proportion of the population is migratory. However, Australian smelt populations appear to be non-diadromous in the Thomson River (Hughes et al. 2014). Three species of recently described endemic galaxiids (Family Galaxiidae) are also present in the upper reaches of the Thomson/Macalister/Latrobe catchment. The Tapered galaxias (*Galaxias lanceolatus*) has been recorded only from the headwaters of Stoney Creek in the Thomson River catchment, the Shaw galaxias (*G. gunaikurnai*) has been recorded only from Shaw Creek in the upper Macalister catchment and the West Gippsland galaxias (*G. longifundus*) is only known from the headwaters of Rintoul Creek east branch, a tributary of the La Trobe River (Raadik 2014). None of these endemic galaxiids occur within the reaches considered in the current study and, given their non-migratory life-histories and restricted distributions in the upper catchment, the flow-related ecological requirements of these species are not considered further here.

Catadromous species undertake downstream adult migrations out of the freshwater reaches of rivers to spawn in the estuary or sea. The juveniles then migrate upstream back into freshwater, where they grow and mature into adults. The most famous examples of catadromous life history are the anguillid eels, of which two species occur in the Thomson River: Short-finned eel and long-finned eel. Whilst anguillid eels are considered catadromous, recent studies have shown that a proportion of juveniles never enter freshwater, but live and mature in saline estuary waters (Arai et al. 2004). Thus, eels can be considered facultatively catadromous. Other catadromous fishes found in the Thomson include Australian bass, Common galaxias (*Galaxias maculatus*) and Tupong (*Pseudaphritis urvillii*).

Anadromous species undertake upstream adult migrations from the sea into the freshwater reaches of rivers to spawn. The juveniles often spend some time (1-2 years) in freshwater, before migrating downstream to the sea where they continue to grow and mature. Anadromy is very uncommon among native fishes in south-eastern Australia, with only two species of parasitic lampreys exhibiting this life history strategy (Short-headed lamprey, *Mordacia mordax* and Pouched lamprey, *Geotria australis*). In the marine adult life stage, parasitic lampreys are thought to attach to large-bodied fishes and feed upon the flesh of their hosts (Cadwallader and Backhouse 1983). Both parasitic lamprey species have been recorded in the Thomson River: Pouched lamprey are rare in the system and the abundance of Short-headed lamprey appears variable over time. Surveys conducted from 2005 to 2009 (Koster and Crook 2006; Koster 2006; Koster and Dawson 2008; Koster et al. 2009) recorded relatively high numbers of Short-headed lamprey and a single Pouched lamprey, whereas the most recent VEFMAP surveys recorded only one Short-headed lamprey and no Pouched lampreys (Amtstaetter et al. 2019). The apparent recent decline in lamprey numbers in the Thomson River and nearby catchments possibly reflects a broader decline of these fishes across their distribution (Bice et al. 2019), although little is currently known of the drivers of recruitment in Australian lampreys.

Amphidromous species spawn in the freshwater reaches of rivers and the eggs and larvae drift downstream with the current into the estuary and, ultimately, the sea. After spending the early life stages (usually 4-6 months) in the marine environment, the juveniles migrate and disperse upstream into freshwater, where they grow and mature into adults. Amphidromy is a relatively common life history strategy in Australian fishes, and is especially prevalent in the galaxioid fishes (Family Galaxiidae: "galaxiids", Family Retropinnidae "southern smelts and graylings"). Amphidromous species found in the Thomson River are the Broad-finned galaxias (*Galaxias brevipinnis*) and Australian grayling. Broad-finned galaxias have highly flexible life histories and commonly form land-locked populations in lakes and headwater streams (Waters et al. 2002), whereas amphidromous migration between freshwater and the sea appears to be obligate in the Australian grayling (Crook et al. 2006).

8.1.1. **Recent Advances in Understanding the Flow-ecology of Native Fish**

There have been substantial advances in our knowledge of the flow-ecology of fishes that inhabit Victorian coastal streams since the 2003 Thomson River FLOWS study. Much of this advancement has resulted from increased monitoring effort and the application of techniques such as telemetry, otolith chemistry and genetic analyses for examining spatial behaviour and population structure. Information from telemetry, in particular, has provided critical information regarding the movements and habitat preferences of fish that can been used to develop conceptual models of species' flow requirements (e.g. Koster and Crook, **Figure 5**). By linking movement data to other aspects of biology - for example, by conducting larval surveys to identify spawning location and timing (Koster et al. 2013; Amtstaetter et al. 2016) - it is possible to obtain information relating to the timing, environmental triggers and purpose (e.g., spawning, dispersal) of migrations by different species and life stages.

Of particular relevance to the current study is our greatly increased understanding of the ecology of the nationally threatened Australian grayling. At the time of the 2003 FLOWS study, Australian grayling were thought to spawn in the adult habitat in the mid-upper reaches of streams based on analysis of survey data and observations of spent fish in the adult habitat (Berra 1983). However, research using acoustic telemetry and larval fish surveys in the Bunyip River (Koster et al. 2013) and Thomson River (Amtstaetter et al. 2016) demonstrated that adult Australian grayling undertake extensive downstream migrations to spawn in the lower freshwater reaches, followed by return migrations of spent fish to the adult habitat. These studies also demonstrated that migration and spawning were tightly linked to increases in river discharge ('freshes') during April and May and could be stimulated via the provision of environmental flow releases that mimic natural flow pulses.

The habitat requirements and fine-scale movements of Australian grayling were documented in a radio-tracking study conducted by Dawson and Koster (2018), which showed small-scale (10s to 100s of m) movements outside of the spawning season and a strong preference for habitats of intermediate depth and velocity ('glides' and 'runs'). Otolith chemistry analysis conducted by Crook et al. (2006) also confirmed that Australian grayling exhibit obligate diadromy, with all juveniles spending 4-8 months at sea before returning to freshwater in Spring and early Summer. Subsequent genetic analyses revealed negligible genetic structuring among Australian grayling populations in coastal Victorian rivers, suggesting that juveniles recruit to systems like the Thomson River from a common marine source (Schmidt et al. 2011).

The findings of Schmidt et al. (2011) are significant because they suggest that the Thomson River grayling population is a component of a larger metapopulation, rather than a discrete, self-sustaining population. Metapopulations occur when species occupy distinct patches of habitat that are geographically separated, but linked periodically via dispersal or migration. Patches of habitat within a metapopulation may act as sources (net givers to the metapopulation) or sinks (net takers from the metapopulation) depending on their habitat quality. A recent study of the New Zealand grayling (*Prototroctes oxyrhynchus*) concluded that human-induced changes to source-sink dynamics likely played a major role in the extinction of this species last century (Lee and Perry 2019). Ensuring that the flow regime of the Thomson River provides the conditions necessary for the river to function as a source - and thus contribute to the sustainability of the broader metapopulation - is an important consideration for the management of Australian grayling and other diadromous fishes.

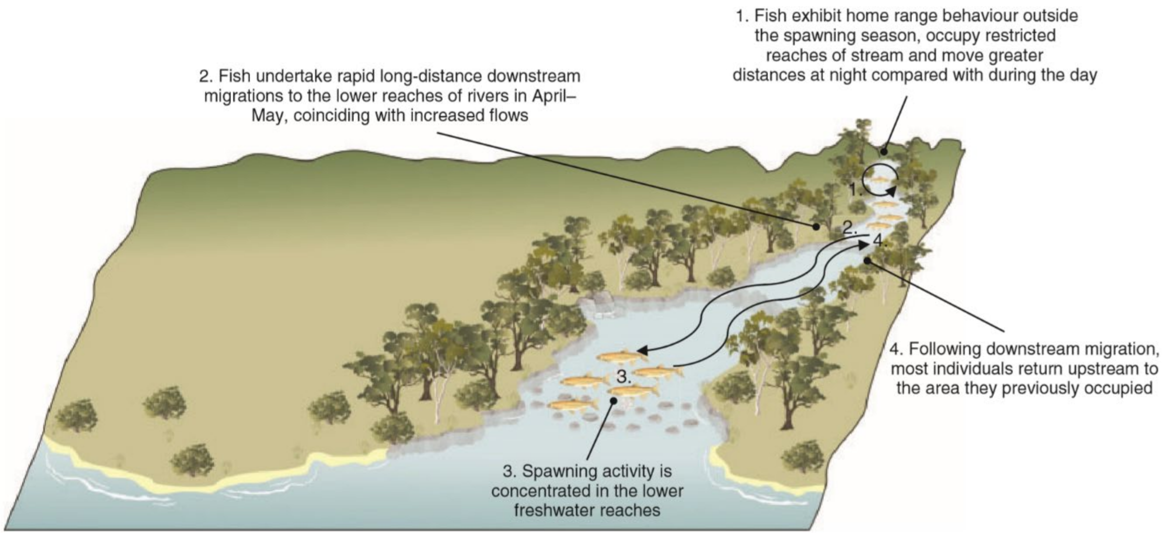


Figure 5: Conceptual model of movement behaviour relevant for determining the environmental flow requirements of Australian grayling (reproduced from Koster and Crook 2016)

In addition to the extensive research on Australian grayling in recent years, a tremendous amount of research effort has been devoted to other species of coastal freshwater fish that occur in the Thomson River. For example, acoustic tracking studies have documented the timing and role of river flows as cues for migration in tupong (Crook et al. 2006), short-finned eel (Crook et al. 2010), Australian bass (Brown 2011; Reinfelds et al. 2013; Harding et al. 2017) and Pouched lamprey (Bice et al. 2019). Radio-tracking was used to document the diel movements and habitat use of River blackfish (Koster and Crook 2008) and otolith chemistry analyses have been applied to study the migrations of Australian smelt (Crook et al. 2008; Hughes et al. 2014) and Tupong (Schmidt et al. 2013). Genetic analyses have been conducted to examine population structure in Australian bass (Nguyen and Ingram 2011), Australian smelt (Hughes et al. 2014), tupong (Schmidt et al. 2013), Southern pygmy perch (Cook et al. 2007) and dwarf galaxias (Coleman et al. 2013). Data from monitoring surveys of adults and early life stages of fish have also been used extensively in recent years to detect spawning responses of Australian grayling and Broad-finned galaxias to environmental flow delivery (Amtstaetter 2010; Amtstaetter et al. 2016; Koster et al. 2017), to examine trends in species abundance over time (Amtstaetter 2010), and to test hypotheses regarding the outcomes of changed river discharge on the recruitment of Australian smelt in the Thomson River (Webb et al. 2010).

8.1.2. Applying New Knowledge of Flow Ecology Relationships to Inform Environmental Flow Objectives

The recent increase in knowledge of the biology of fish species in coastal Victorian rivers provides the opportunity to consider fish assemblages more holistically than was possible in early FLOWS studies, which tended to focus on the requirements of a few, relatively well-studied species. Information from the sources cited above has been reviewed in detail, and utilised where appropriate, with the aim of developing recommendations for the Thomson River that address the flow requirements of the entire native fish assemblage.

Two broad considerations have been used to organise the conceptual basis for developing flow objectives for fish. The first of these is the provision of adequate habitat to support the native fish assemblage. This approach recognises that fish have diverse habitat requirements, not only among species but also among different life history stages. Whilst the specific habitat requirements of most species and life stages have not been studied in detail, the need for diverse habitat structure to support diverse fish assemblages is well established both in the Australian (e.g. Harris and Silveira 1999) and international fish ecology literature (e.g. Gorman and Karr 1978). The objectives for fish habitat, therefore, include reference to three broadly recognised mesohabitat types relevant to fishes in coastal streams of south-eastern Australia: *riffles* - shallow, fast flowing habitat with a broken water surface; *runs/glides* - habitat of intermediate depth and flow velocity with a wavy water surface; *pools* – deep, slow flowing habitat with a smooth water surface (see Jowett 1993). Where quantitative data on the habitat requirements of species and/or life stages is available, this information has been used as a basis for setting specific criteria relating to habitat depth and velocity.

The second broad consideration for developing flow objectives for fish is their movement / migration requirements. In this context, 'movement' refers to localised movement among habitats, whereas the term 'migration' is limited to larger-scale, directed movements associated with specific life history stages. As outlined above, fishes of the Thomson River display a range of migratory strategies. Details of the migratory requirements of diadromous species, including timing and flow-related cues, have been summarised in **Table 3** and a migration calendar has been developed from this information (**Table 4**). These summaries of the migratory requirements of diadromous fish are used to guide the development of optimal flow objectives for fish in the Thomson River.

Table 3: Summary of movement requirements of diadromous fishes in the Thomson River

Species	Migratory type	Life stage	Direction	Peak timing	Flow related cues	Reference(s)
Short-headed Lamprey	Anadromous	Macrophthalmia	Downstream	Jul-Nov	Downstream migration associated with increased discharge	Potter 1970
		Adult	Upstream	Jun-Dec	No current evidence of strong relationship with flow	McDowall 1980; Potter 1970; Sloane 1984a
Pouched Lamprey	Anadromous	Macrophthalmia	Downstream	Jul-Sep	Downstream migration possibly associated with increased discharge	Potter et al. 1970
		Adult	Upstream	Jun-Nov	No current evidence of strong relationship with flow	Bice et al 2019; Sloane 1984b
Short-finned eel	Catadromous	Glass eel/elver	Upstream	Oct-Jan	Upstream migration associated with low stream flows	Sloane 1984b
		Adult	Downstream	Nov-Apr	Downstream migration associated with increased discharge	Crook et al. 2014
Long-finned eel	Catadromous	Glass eel/elver	Upstream	Feb-Apr	Upstream migration possibly associated with low stream flows	Sloane 1984b
		Adult	Downstream	Mar-May	Downstream migration associated with increased discharge	Boubée and Williams 2006
Tupong	Catadromous	Juvenile	Upstream	Oct-Jan	Increased flows may attract juveniles into rivers as they return from the sea, as reported for Common galaxias. Summer/early autumn freshes may stimulate upstream movement	Amtstaetter et al. 2019
		Adult	Downstream	May-Aug	Downstream migration associated with increased discharge	Crook et al. 2010
Australian bass	Catadromous	Juvenile	Upstream	Aug-Nov	No current evidence of strong relationship with flow	Cadwallader and Backhouse 1983
		Adult	Downstream	Apr-Sep	Downstream movement associated with flow pulses, especially in early (Apr) and late (Aug-Sep) season. Mid-season (May-Jul) migration may occur under baseflow.	Reinfelds et al. 2013

Species	Migratory type	Life stage	Direction	Peak timing	Flow related cues	Reference(s)
		Adult	Upstream	Sep-Nov	Upstream migration occurs both on baseflows and during flow pulses. Migration is faster during flow pulses.	Reinfelds et al. 2013
Common galaxias	Marginally catadromous	Larvae	Downstream	Apr-Sep	Not directly flow related - larvae hatch when eggs inundated on spring high tides at top of estuary.	Barbee et al. 2011, Koster 2009
		Juvenile	Upstream	Sep-Mar	Rises in river level attract juveniles into rivers as they return from the sea. Recent study found no strong evidence of relationship between number of upstream migrants and river flow.	Benzie 1968; Koster 2009; Amtstaetter et al. 2019
		Adult	Downstream	May-Aug	Adults migrate to spawn in upper estuary during high river flows and spring tides	Barbee et al. 2011
Australian grayling	Amphidromous	Larvae	Downstream	Apr-May	Eggs rely on river flow to drift into saline estuary waters	Koster et al. 2013; Amtstaetter et al. 2016
		Juvenile	Upstream	Sep-Dec	Increased flows may attract juveniles into rivers as they return from the sea, as reported for Common galaxias. Upstream migration associated with elevated discharge over preceding 7 days.	Koster et al. (unpubl. data)
		Adult	Downstream	Apr-May	Increases in river discharge cue spawning migration to lower freshwater reaches.	Koster et al. 2013; Amtstaetter et al. 2016
Broad-finned galaxias	Amphidromous	Larvae	Downstream	May-Jun	Spawning corresponded to an environmental high flow fresh released in mid- to late May in the Thomson River and a large, short duration natural flow event in late May.	Amtstaetter et al. 2010
		Juvenile	Upstream	Oct-Jan	Increased flows may attract juveniles into rivers as they return from the sea, as reported for Common galaxias. However, a recent study found no strong evidence of relationship between number of upstream migrants and river flow.	Amtstaetter et al. 2019

Species	Migratory type	Life stage	Direction	Peak timing	Flow related cues	Reference(s)
Australian smelt	Facultative diadromous	Larvae	Downstream	Nov-Feb	No current evidence of strong relationship with flow	Crook et al. 2008
		Juvenile	Upstream	Dec-Mar	No current evidence of strong relationship with flow	Crook et al. 2008

Table 4: Migration calendar for diadromous fishes in the Thomson River. Green panels represent upstream migration timing, orange panels represent downstream migration timing.

	Direction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Short-headed Lamprey	US						green	green	green	green	green	green	green
	DS							orange	orange	orange	orange	orange	
Pouched Lamprey	US						green	green	green	green	green	green	
	DS							orange	orange	orange			
Short-finned eel	US	green	green	green								green	green
	DS	orange	orange	orange	orange							orange	orange
Long-finned eel	US		green	green	green								
	DS			orange	orange								
Tupong	US	green									green	green	green
	DS					orange	orange	orange	orange				
Australian bass	US								green	green	green	green	
	DS				orange	orange	orange	orange	orange	orange			
Common galaxias	US	green	green	green							green	green	green
	DS				orange	orange	orange	orange	orange	orange			
Australian grayling	US					orange				green	green	green	green
	DS				orange	orange							
Broad-finned galaxias	US	green									green	green	green
	DS					orange	orange						

8.2. **Vegetation**

A conceptual model for water-dependent vegetation was developed by Chris Jones from the Arthur Rylah Institute (**Figure 6**) for the purpose of this 2020 Environmental Flows Study.

The model highlights the ecological roles played by baseflows, periodic freshes and high flows (such as bankfull and overbank flows) in maintaining water-dependent instream, fringing and riparian vegetation associated with the Thomson River. It focusses on flow responses of vascular plants and does not consider non-vascular macrophytes (e.g. mosses) nor algae (e.g. phytoplankton, periphyton etc). The model shows how year-round baseflows create the aquatic environments required for obligate aquatic instream plants and maintain the wet soils required for fringing and riparian vegetation. Freshes play a number of specific ecological functions:

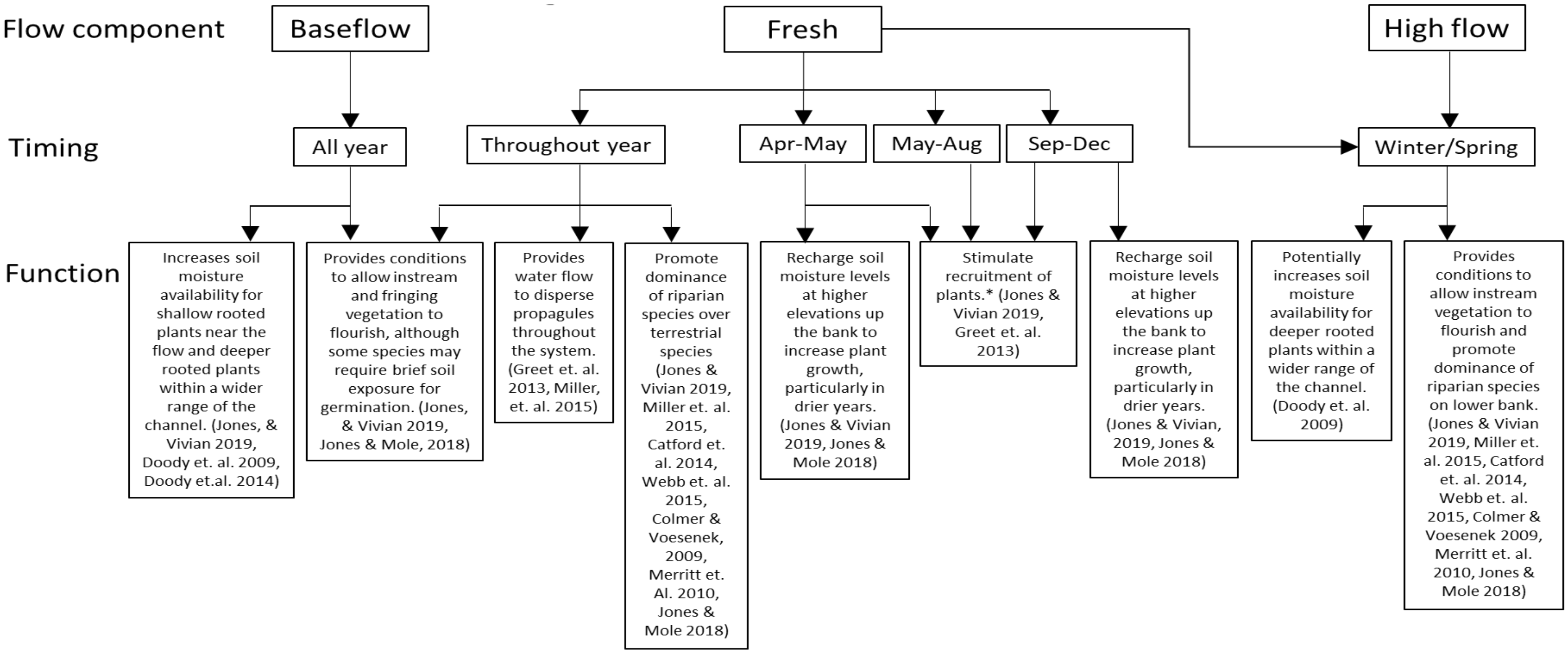
1. Disperse plant propagules (e.g. seeds and plant fragments in the case of clonal species),
2. Prevent the colonisation of the stream bed and fringing areas by terrestrial taxa that are intolerant of prolonged inundation,
3. Recharge soil moisture at higher elevations along the bank, and
4. Stimulate the recruitment of fringing and riparian species.

Higher flows, including bankfull events, further encourage the dominance by riparian species and water deep-rooted plants. They are also important for recharging floodplain wetlands.

Three major advances in our understanding of water-dependent vegetation have occurred since the first FLOWS study of the Thomson River in 2003:

- More inclusive, coherent and transparent approaches to dealing with the diversity of vegetation types that have to be considered in environmental flows studies.
- Improved knowledge of the extent and condition of vegetation associated with the Thomson River specifically:
    - Modelled distributions of contemporary (2005) and pre-European (1750) vegetation, from the NatureKit website, using the State-endorsed vegetation typology, Ecological Vegetation Classes (EVCs): see https://www.environment.vic.gov.au/biodiversity/naturekit
    - Results from the 3rd (2010) Index of Stream Condition assessment
    - Detailed information on the vegetation (aquatic and riparian) associated with the Thomson River, collected as part of the VEFMAP program, with the most recent assessment being 2014−2015.
- Improved information on the hydrological requirements of water-dependent vegetation and the responses of vegetation to environmental flows, sometimes in the form of ecological response curves for specific plant species.

These three advances are discussed sequentially in the following sections.



The Thomson River has few direct objectives or aims for riparian vegetation responses to modifications to the water regime using water for the environment, as identified in the WGCMA Flagship Waterways project logic for the Thomson River. However, there are a range of functions and processes relating to vegetation that can be used to benefit waterway health, in addition to the critical alternative actions such as livestock management, revegetation and weed control.

* - Different species recruit at different times of the year but predominantly in autumn and spring. (1)

Figure 6: Vegetation conceptual model for the Thomson River

8.2.1. Approaches to Dealing with the Diversity of Water-dependent Vegetation

Unlike some biological groups considered in FLOWS studies, such as platypus (one species only) or fish (a single taxonomic Class, Osteichthyes), the vegetation component covers an exceptionally diverse range of organisms, including cyanobacteria (blue-green algae), eukayrotic algae, non-vascular plants such as mosses and liverworts, and a suite of vascular plants including ferns, gymnosperms (e.g. conifers) and angiosperms (flowering plants). For example, there are over 3,500 species of vascular plants recorded for Victoria, of which about three-quarters are native and the remaining one-quarter introduced (Australian National Herbarium 2019). In the Thomson River system, 290 species of water-dependent vascular plants were identified in the latest (2014−2015) VEFMAP assessments (Water Technology 2015). In contrast, only 17 fish species were recorded (11 native and 6 exotic) in fish surveys of the Thomson River system in 2015−2016 (Armstaetter et al. 2016). This comparison is not intended to underestimate the great social and ecological value of platypus and native fish, merely to demonstrate the floristic diversity of plants in the study area and the implications this has for developing vegetation values and related flow objectives.

Moreover, vascular plants are only one type of water-dependent vegetation that has to be considered in FLOWS studies. Different types of plants occupy a wide range of habitats in aquatic systems, including solely in the water column (e.g. algae such as phytoplankton), on submerged surfaces (e.g. microbial biofilms), as floating, submerged or emergent aquatic non-woody plants, including ferns, as well as non-woody types such as grasses, herbs and forbes, and woody types such as trees and shrubs growing in the riparian zone, on floodplains or in wetlands such as billabongs. (Note: the term 'water-dependent vegetation' refers to plants that require the physical presence of free water for some stage of their life cycle. Of course, all plants are water dependent to some degree, but only 'water-dependent vegetation' requires free water directly for the survival of adults − e.g. obligate submerged plants such as Eelgrass *Vallisneria americana* − or for successful plant recruitment − e.g. River Red Gum *Eucalyptus camaldulensis*. The possibility that stream flows are ecologically significant also for nearby terrestrial vegetation communities is discussed later, in **Section 8.2.3.**)

A criticism of almost all of the earlier FLOWS-type studies is the poor handling of this wide diversity of water-dependent vegetation from both the taxonomic and the habitat-diversity perspectives. In hindsight it is clear that the approaches used in most earlier studies to sort different types of vegetation and to generate vegetation values and related flow objectives were often not comprehensive, consistent or transparent. They also often ignored non-vascular plants such as algae and microbial biofilms, the latter being of great significance to food-web structure and nutrient spiralling in mountain streams such as the upper reaches of the Thomson River.

Since 2003, many different approaches have been tried in attempts to devise a system that acknowledges the taxonomic and habitat diversity of water-dependent vegetation:

- Floristics, based on the water requirements of individual species (e.g. River Red Gum *Eucalyptus camaldulensis* or Common Reed *Phragmites australis*) − e.g. Roberts and Marston (2011) and Rogers and Ralph (2011)
- Functional groups, based on synthetic aggregations of plant species that have similar life histories and responses to water regime (e.g. obligate submerged taxa versus amphibious

plants versus terrestrial plants) − e.g. Brock and Casanova (1997, 2000) and Casanova (2011)

- Surrogate species, in which the collective inundation requirements of a limited number of species can act as surrogates for a broader range of plant taxa − e.g. Rogers *et al*. 2012
- EVC water requirements, in which the 'preferred' hydrological regime of broad vegetation groups (such as Ecological Vegetation Classes, or EVCs) underpin flow recommendations for vegetation − e.g. Frood 2012.

The approach adopted in this revision of the environmental-flow requirements of vegetation in the Thomson River system uses elements of each of these approaches, and is based primarily on the habitat position of different functional groups (e.g. biofilms on submerged surfaces, submerged vascular plants, fringing emergent vascular plants, vascular plants − mainly trees and shrubs − in the riparian zone, floodplain and wetland vegetation etc).

8.2.2. New Information on Vegetation Associated with the Thomson River System

It is arguably the case that vegetation is among the most poorly monitored of the biota in State-wide monitoring programs that focus on the effectiveness of environmental flows. For this reason, many knowledge gaps remain when attempting to devise environmental flows to maintain or improve water-dependent vegetation (e.g. see Webb et al. 2012). Even so, since 2003 three sets of information on the floristics and ecological condition of water-dependent vegetation in the Thomson River system are particularly valuable:

- Modelled distributions of contemporary (2005) and pre-European (1750) EVCs from the NatureKit website, https://www.environment.vic.gov.au/biodiversity/naturekit
- The 3rd assessment (2010) for the Index of Stream Condition (ISC) (DSE 2010)
- Various monitoring reports on vegetation responses to environmental flows in the Thomson and Macalister River systems undertaken in the VEFMAP program (e.g. Practical Ecology 2009; Water Technology 2012; 2015).

The most relevant component of the 2010 ISC assessments is the Streamside Zone sub-index. **Table 5** shows the scores recorded for various reaches of the Thomson River during this assessment. Findings of the VEFMAP analyses are discussed in Tables 12−17 for each river reach in turn.

Table 5: Scores of the streamside zone sub-index of the Index of Stream Condition (DSE 2010)

FLOWS Reach number in present study	ISC site number	Streamside Zone score (out of 10)	Overall ISC score and rating (out of 50)
2	5	9	43 – Excellent
3	4	8	44 – Excellent
4a	3	5	34 – Moderate
4b	17	4	36 – Good
5	2	6	32 – Moderate
6	1	7	31 – Moderate

8.2.3. New Information on Hydrological Requirements and Ecological Responses of Water-dependent Vegetation

Since 2003, a number of collations of the hydrological requirements of water-dependent vegetation has been prepared, the most exhaustive of which are Roberts and Marston (2011) and Rogers and Ralph (2011). These collations, however, are still very restrictive from two perspectives:

- They provide water requirements for only a small number of plant species, mostly the visually obvious rushes, reeds, shrubs and trees. Roberts and Marston (2011), for example, provides detailed information for only 19 taxa of vascular plants: six trees, one shrub, four grasses, six sedges or rushes, and two herbs. Compare this coverage with the 290 species of water-dependent vascular plants that were identified in the latest (2014–2015) VEFMAP assessments (Water Technology 2015).
- They collate information that, overwhelmingly, has been drawn from the Murray-Darling Basin (Boon 2012). It is by no means clear how well this information can be extrapolated to other parts of Australia, especially to regions south of the Great Divide which are mostly cooler and wetter than systems in the Murray-Darling Basin and have lower evaporative losses (i.e. arguably experience less water stress that vegetation in semi-arid or arid-zone regions to the north).

In a review article published in 2012, Webb et al. (2012) argued that few hypotheses regarding the putative responses of vegetation to environmental watering have been tested empirically, and major knowledge gaps remain that can be filled only by targeted research. Some of those gaps have been progressively filled with more recent research and monitoring, and in particular the role of flow variability in maintaining the floristic diversity of fringing and riparian vegetation along streams of south-eastern Australia is now well established (e.g. Greet et al. 2011a, b, 2012; Webb et al. 2013; Lawson et al. 2015).

One subject that has arisen in recent FLOWS projects is the role that a flowing headwater stream may play in controlling local microclimates and thus the type and condition of nearby terrestrial vegetation. Analysis of the hydrological requirements of vegetation in FLOWS studies has traditionally focussed on directly water-dependent vegetation (see Section 8.2.1 above), but in some cases, especially in wetter regions of the State, the ecological implications for more fully terrestrial vegetation might have to be considered as well.

Modelled distributions of contemporary (2005 EVCs) vegetation, available on the NatureKit website, indicate that EVC 18 Riparian Forest, EVC 29 Damp Forest, EVC 39 Montane Wet Forest and EVC 56 Floodplain Riparian Woodland line parts of the upper reaches of the Thomson River (and EVC 32 Cool Temperate Rainforest occurs along similar headwater streams to the east). All are vegetation communities that require moist or well-watered conditions and low relative humidity: they are described in the Regional Benchmarks for Vegetation Quality Assessment variously as requiring "permanently moist conditions" (EVC 18), containing "moisture-dependent ferns" (EVC 29) or occur in "moist, sheltered wet sites" that "remain saturated for long periods" (EVC 39): see https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks.

The question to be addressed then is "Would these moisture-requiring types of riparian and terrestrial vegetation continue to occur in the catchment if flows in the upper Thomson River were to cease or were to be reduced markedly?" The answer is 'Highly unlikely', since the waterway almost certainly helps maintain the cool, moist conditions required for these EVCs. The presence of water in-stream creates a localised gully/valley microclimate with lower temperature and relative humidity in nearby riparian and terrestrial areas. The plant taxa in these terrestrial EVCs may not be directly water-dependent, but they do require the cool, moist climatic conditions generated by the presence of a nearby permanent, well-flowing stream.

This topic of the ecological influence of stream flow on terrestrial vegetation communities is only recently being considered in FLOWS studies, and then of course only in the wetter parts of Victoria (such as Gippsland) that support such well-watered vegetation types. The mechanism and the flows required to maintain the stream-vegetation relationship are poorly understood. The converse relationship − how riparian and fringing vegetation alters stream temperature − is well understood (e.g. see Davis et al. 2019, Dugdale et al. 2018, Johnson & Wilby 2015, Moore et al. 2005). In contrast, the relationship posited here − that stream flow alters the gully/valley microclimate and thus nearby terrestrial vegetation in a complex two-way inter-relationship − has been rarely if ever investigated. The only report we could find on the subject (after an extensive search of the published literature using the bibliographic search tool Web of Science) was that of Ryan and McAlpine (2005), who mentioned the existence of such 'reciprocal feedbacks' in their review of riparian revegetation activities in south-eastern Australia. Davis et al. (2019) also concluded that some forests in the western USA could lose their capacity to buffer local climate extremes as they became drier and more water-stressed, but the inter-relationships were not explored further. The topic remains a significant knowledge gap.

8.3. Macroinvertebrates

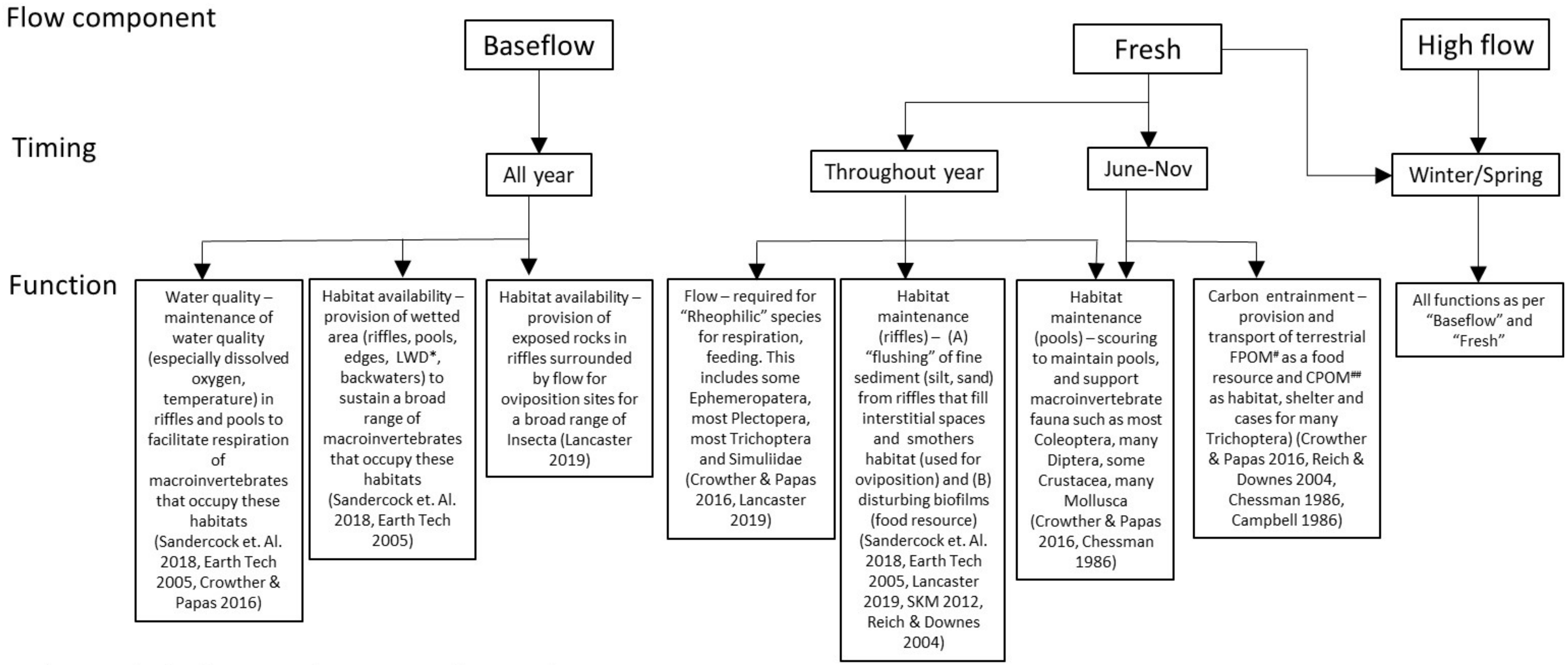
A conceptual model for macroinvertebrates, based on latest science and research, was developed by Phil Papas from the Arthur Rylah Institute, refer to **Figure 7**.

Macroinvertebrate assemblages are used as a biological indictor on the health of a waterway and are a vital part of the food chain for aquatic ecosystems as they form the basis of the diet of most native fish as well as platypus. Macroinvertebrate fauna found at a particular site are highly affected by catchment conditions such as water quality, flow, detritus, woody debris and water clarity.

Since the 2003 Environmental Flows Study, few macroinvertebrate sampling programs have been undertaken. From 2005 - 2006, a sampling program was undertaken in 12 reaches and edge and riffle habitats along the Thomson River. Notable findings included:

- Most sites in the upper forested area of the Thomson catchment passed the State Environment Protection Policy (SEPP) biological objectives.
- The site closest to the Thomson Dam, Reach 2, failed to meet a number of SEPP objectives, most likely due to the impact of flow regulation.
- Of the sites sampled downstream of the Cowwarr Weir, only the edge habitat along Reach 4a and the riffle habitat along Reach 4b passed the SEPP biological objectives in both years of the assessment. All other sites downstream of the Cowwarr Weir failed to meet the objectives for at least one indicator and failed the assessment.
- There was a clear difference in composition of taxa identified in the upper catchment when compared to the lower catchment in edge habitats. Taxa that inhabit clear, cool water and those commonly associated with woody debris were found in the upper catchment, whereas taxa found in the lower sites were those that can tolerate sedimentation, warmer water temperatures, reduced water quality and altered riparian habitat.
- Riffle samples showed a gradient of macroinvertebrate assemblages from the upper catchment to the lower catchment, most likely a result of reducing water quality downstream and a reduction in habitat complexity.

A more diverse macroinvertebrate community in the upper reaches of the Thomson river reflect the improved habitat condition when compared to lowland sites which supports a more diverse community.



* Large Woody Debris, # Coarse Particulate Organic Matter, ## Fine Particulate Organic Matter

Figure 7: Macroinvertebrate conceptual model for the Thomson River

The ISC third report analysed data collected over a six-year period from 2004 to 2010. From this assessment, the macroinvertebrate assemblages followed a similar pattern to that found in 2005-2006 sampling program; macroinvertebrate assemblages were most diverse in the upper forested reaches (Reach 2 and Reach 3) and reduced downstream (refer to **Table 6**). However, Reach 4b rated higher for aquatic life than any other reach along the length of the River (9 out of 10). Whilst an assessment of the accuracy of data collection cannot be made, given the presence of a variety of habitats along this reach, and the rock / cobble / gravel nature of the stream bed, there is no reason that the macroinvertebrate fauna should not contain species that are typical of reference streams.

Table 6: ISC3 results for aquatic life (Macroinvertebrates)

<table>
<tr><th>EFlow Reach Number</th><th>ISC3 Reach</th><th>Aquatic life score (out of 10)</th></tr>
<tr><td>2</td><td>25_005</td><td>7</td></tr>
<tr><td>3</td><td rowspan="2">25_004</td><td rowspan="2">7</td></tr>
<tr><td rowspan="2">4a</td></tr>
<tr><td>25_003</td><td>6</td></tr>
<tr><td>4b</td><td>25_017</td><td>9</td></tr>
<tr><td>5</td><td>25_002</td><td>4</td></tr>
<tr><td rowspan="2">6</td><td>25_001</td><td>4</td></tr>
<tr><td>25_201</td><td>4</td></tr>
</table>

8.4. **Geomorphology**

8.4.1. **Recent Advances in Understanding the Geomorphology of the Thomson River**

The fluvial geomorphology of the Thomson River system was most extensively reviewed in 1990 by Erskine et al. Whilst their assessment covered the fluvial geomorphology from the dam wall, through the reaches and tributaries to the Gippsland Lakes, it had a particular focus on the evolution of the Rainbow Creek avulsion (Reach 4). The background to this understanding was conducted by Brizga (1988) and Brizga and Finlayson (1990). The focus for geomorphology has since been on Reach 4 downstream of Cowwarr Weir due to the likelihood and consequence of avulsion in this reach.

More recently, a review was undertaken by Vietz (2011), in a report to Alluvium (Zavadil, Moar and Vietz 2011). What we know is that of the three phases of avulsion (initiation, development and aggradation) that Reach 4a is in the phase of aggradation. This means Reach 4a will infill as is currently occurring, see **Figure 8**. At the same time Reach 4b is degrading, through bed and bank erosion.

Figure 8. Thomson River downstream of Cowwarr Weir (Reach 4a) aggrading with sediments infilling the bed (photo Geoff Vietz, November 2019).

The flow split downstream of Cowwarr Weir moderates this evolution, with the current operational flow split – 2:1 in favour of Reach 4a. This is, however, only possible during low to medium flows in the Thomson River, with larger flows greater than 1,200 ML/d the flow split will end up tending toward 1:1 or 2:1 in favour of Rainbow Creek (Vietz 2011).

The limited capacity of the Thomson River downstream of Cowwarr weir (Reach 4a), and the potential to control flows to Rainbow Creek (Reach 4b) will result in continuation of the current geomorphic trajectory: 4a aggrading and 'closing down' and 4b eroding.

Most importantly for this reach and the environmental flow study, the EFTP is providing recommendations based on maintaining the Thomson River Reach 4a as the preferred flow path, despite the current trajectory of change. This means that the panel is defining geomorphically-focused flows that, within the operational constraints, may reduce the risk of complete capture of flow by Rainbow Creek, i.e. outflanking of Cowwarr Weir. This approach is based on the WGCMA (2019b) vision that: *The Thomson and Rainbow system is managed to reduce the risk of avulsion and improve waterway health with benefits for agriculture, the community and the Gippsland Lakes*.

The EFTP recognise that there is a likelihood of avulsion in the medium to long-term. Several paths have been identified through recent modelling conducted by Water Technology (2019) and as assessed by Ian Rutherfurd (**Figure 9**). As stated by WGCMA (2019b): "*This is not merely possible; it is inevitable, at some future time as the system evolves. It is understood that development of such an avulsion event is most likely under a moderate (1:5 to 1:20) flood event and that the probability of an avulsion in the next 100 years, under a non-intervention scenario is very close to 100%".* The report goes further to highlight that predictions (**Figure 9**), and interventions based on those predictions, do not provide certainty of maintaining the status quo. Therefore, the EFTP is managing Reach 4a and 4b under consideration of maintaining current conditions, but also identifying recommendations that may assist with the preparation of the channels to support altered conditions in the case of significant channel change through this reach. Recommendations therefore consider sediment scouring flows through Reach 4a, and complementary actions such as delivery of sediment to Reach 4b. Both of these aspects require monitoring and further consideration. The maximum channel capacity was not directly investigated in the recent flood and avulsion study by Water Technology, **Figure 10**.

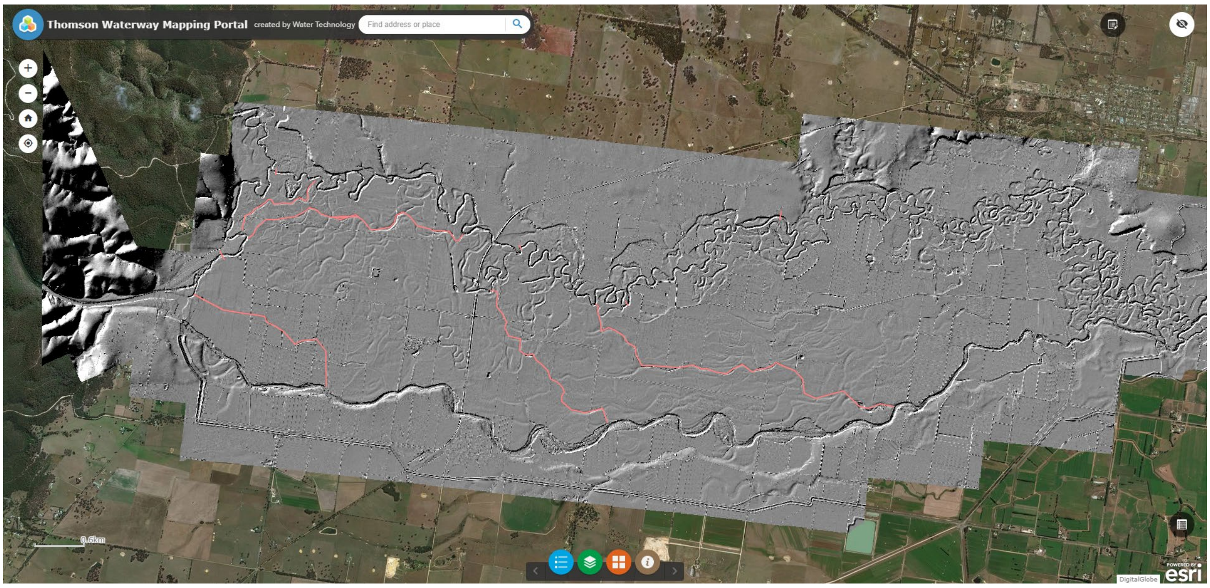


Figure 9. Potential avulsion flow paths as per WGCMA 2019b

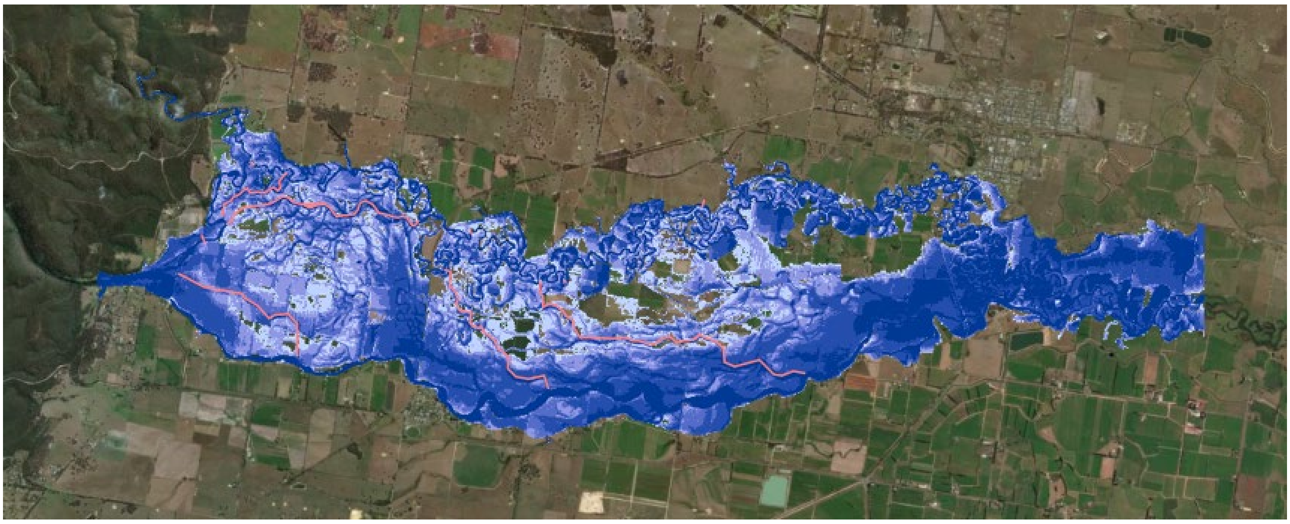


Figure 10. Flow paths for the 1% AEP flood event in the Thomson River downstream of Cowwarr Weir (Water Technology 2019)

From a geomorphic perspective we know that it is not just flow that modifies the condition of waterways. Sediment inputs play a major role. In the phase of development of the avulsion downstream of Cowwarr weir sediment plays a major role. We are also aware of a large volume of sediment being trapped within Cowwarr Weir (50,000 m^3 excavated in 2007 since construction of the weir in 1957 (Vietz 2011)).

If the goal to is to maintain the status quo then a goal would be to maintain the parent channel (4a) whilst directing as much of the bedload down the daughter channel (4b) as possible. The conceptual models (Figure 10, Figure 11 and Figure 12) are designed around keeping Reach 4b as a conduit for sediment and not aggrading the channel significantly. This is consistent with the Thomson River - Rainbow Creek Waterway Management Plan (WGCMA 2019b). The challenge with this intention is the scouring of sediment from Cowwarr Weir. The pondage exhibits very low velocities, even at high discharges. Therefore some consideration must be given to opportunities to pass sediments from the pondage, such as through the undershot gates, or by mechanical means. Once in Rainbow Creek sediments will eventually migrate down the channel given the inevitable flood events into the channel.

Will Rainbow Creek eventually develop a morphology similar to the old Thomson River? (Reach 4a) Within management timeframes the answer is no: a sinuous, narrow sand bed channel will not develop within decades or even centuries. Based on surveys from 1957 and 1990 Brizga and Finlayson (1990) concluded that Rainbow Creek showed no tendency to develop morphology similar to the old Thomson River.

Channel change following fire and flood (Alluvium 2009) is of some concern for Reach 3. VEFMAP survey was undertaken in 2006 and 2009. This has not been resurveyed, with the physical form component discontinued. The magnitude of change includes:

- The loss of benches (some loss of up to 2 m)
- Formation of new benches (at the channel margins)
- Significant scour (commonly a low-flow channel, of up to 1.5 m channel change)
- Bank collapse
- Sediment accumulation (all cross-sections)

Cross sectional comparison was last undertaken in 2009 (comparing 2003 and 2009 cross sections). Over the last decade considerable geomorphic adjustment may have been likely. We suggest that resurvey, by an experienced waterway surveyor, should be undertaken for the 2009 monumented cross sections. This would allow an assessment of the recovery of the channel. For the hydraulic assessment and environmental flow recommendations for Reach 3 the panel utilised the available HEC RAS models, which were the 2003 models (pre fire and flood) and the coarse-level 2011 models.

Channel change is not the only geomorphic consideration. The Thomson River is laterally confined upstream in Reaches 2 and 3. This means there is limited floodplain and high amounts of exposed bedrock combined with coarse riverbed material. The high flows are required to make sure that sediment does not build up in pools in the system.

Deposition in Reach 4a should be discouraged, whereas deposition in Reach 4b may reduce the potential for avulsion. A caveat to this is that if Reach 4b (Rainbow Creek) closed down to the extent that terrestrial woody species colonised the channel bed then bank erosion may be likely in a flood event. There is a balance between maintaining Reach 4a whilst preparing Reach 4b for the inevitable flood event. Ideally this would currently be minor degradation (bed erosion) in Reach 4a, and minor aggradation (bed deposition) in Reach 4b. Ultimately, maintaining movement of sediment through both Reach 4a is most important to prevent build up in pools (and loss of pool habitat). This is less critical in Reach 4b as it is not being viewed as a conduit for fish passage.

Conceptual models for waterway geomorphology were developed as a draft for discussion. These are as follows, **Figure 11**, **Figure 12** and **Figure 13**.

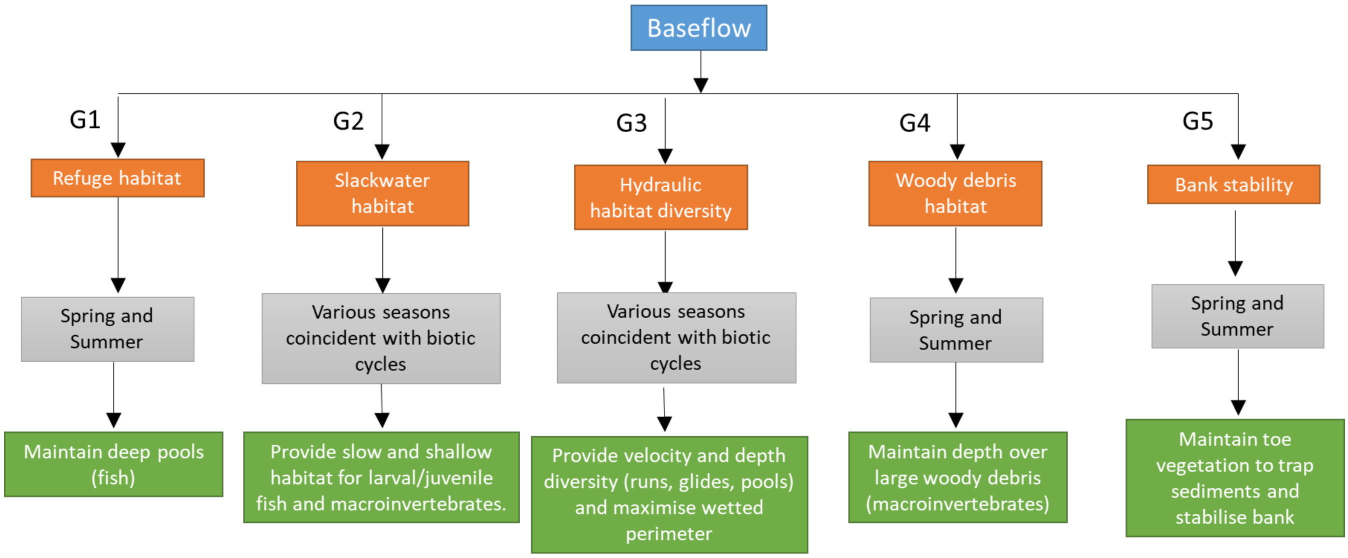


Figure 11: Geomorphology conceptual model – Baseflow

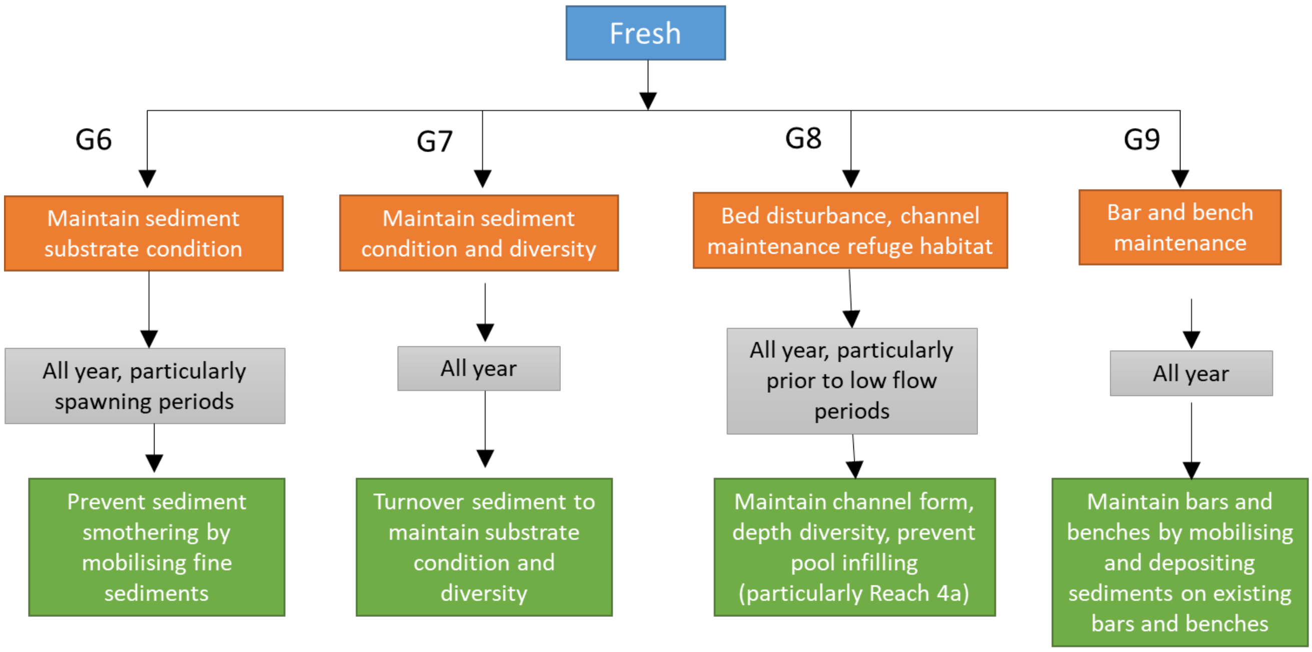


Figure 12: Geomorphology conceptual model – Freshes

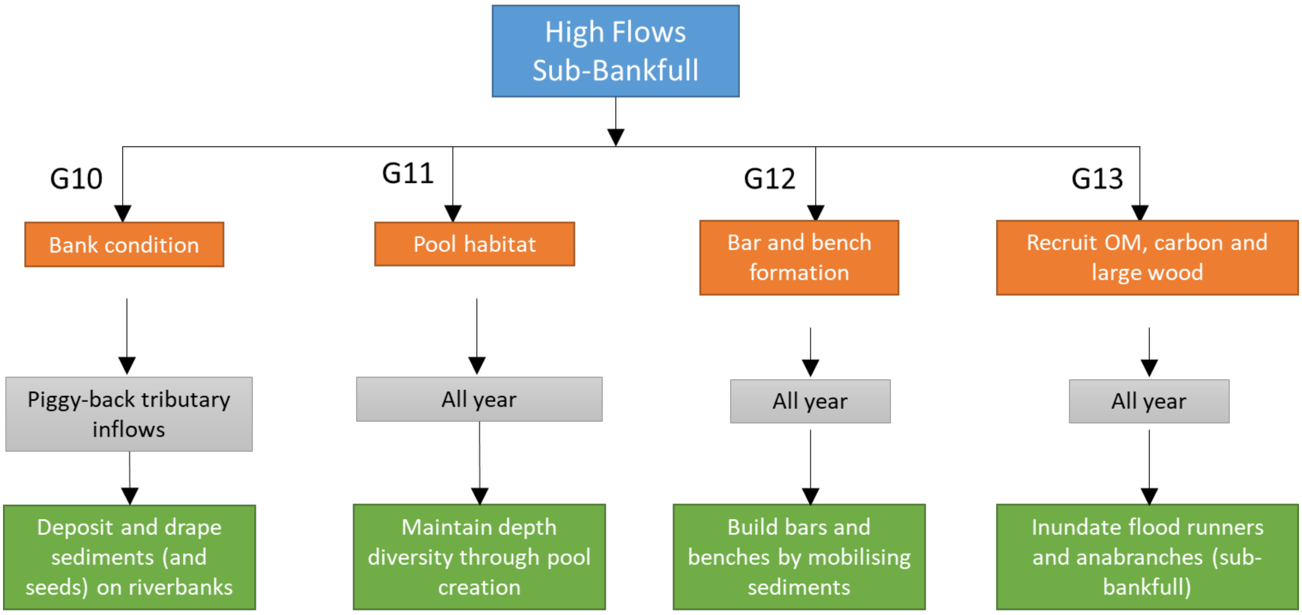


Figure 13: Geomorphology conceptual model – High flows

It is not expected that environmental flows will be sent down so that they are overbank, however, naturally occurring overbank flows may trigger other avulsions from the parent channel (4a). This is increasingly likely to happen as the reach aggrades and becomes ever more elevated relative to the surrounding floodplain. However, in the downstream Reaches 5 and 6 overbank flows should be encouraged to connect the floodplain storages (such as floodrunners and wetlands) to store sediment.

The maintenance of instream structures such as benches in the lower reaches should be encouraged by using freshes. It is also important to maintain the overall character of the stream by allowing erosion and deposition to continue in these reaches by delivering high flows.

8.4.2. Application of New Knowledge to Managing the Thomson River

New knowledge in environmental flows and geomorphic response includes:

- The role of flow regulation in river bank erosion, deposition and management (e.g. Vietz et al. 2017)
- The maintenance of in-channel benches through environmental flow provisions (e.g. Vietz et al. 2012)
- Recognition of the role of river channel migration, and dynamism, for ecosystem and ecological health in rivers (e.g. Cheetham et al. 2018)
- The role of channel morphology and ecohydraulics in the provision of fish habitat (e.g. Vietz et al. 2013; Windecker and Vietz 2014)
- The role of ecohydraulics in the provision of fish migration (e.g. Webb et al. 2018)

- The 'Flagship' project has included the mid Thomson River as a focus for assessing channel change. Current developments are able to highlight differences between 2010 and 2018 using Lidar (refer to **Table 7** and **Table 8**). The planned Digital Elevation Models of difference were not yet available during the time of this study.

Table 7: Erosion and Deposition in the Area Between the Bed Toe and Bankfull for the Reach 4a

Process	Area (m^2)	% Area	Volume (m^3)	% Volume	Average depth of change (m)	Average depth of change per annum
Erosion	76,689	80	-53,243	78	-0.69	-0.09
Error	391,936	Not included	-45,445	Not included		
Deposition	19,349	20	14,832	22	0.77	0.09
Total Including error	487,974	Net Change incl error	-83,856			
Total excluding error	96,038	Net Change excluding error	-38,411			

Table 8: Erosion and Deposition in the Area Between the Bed Toe and Bankfull for Reach 4b

Process	Area (m^2)	% Area	Volume (m^3)	% Volume	Average depth of change (m)	Average depth of change per annum
Erosion	45,236	57	-35,008	56	-0.77	-0.10
Error	632,377	Not included	-1,989	Not included		
Deposition	33,625	43	27,003	44	0.80	0.10
Total incl error	711,238	Net Change incl error	-9,994			
Total excluding error	78,861	Net Change excluding error	-8,005			

The influence of channel change on the recommendations will also be considered new knowledge for application. This includes consideration of how channel change has impacted on current recommendations, **Table 9**. This study, however, did not identify the required changes in flow based on channel change.

Table 9: Flow Recommendation Possible Modifications due to Channel Change by Fire and Flood, for Reach 3 (Alluvium 2009)

Reach 3 Thomson River: Aberfeldy confluence to Cowwarr Weir

Compliance at Coopers Creek Gauge

Recommendation number	Evaluation*	Volume ML/d	Notes on attainment of evaluation criteria at Walhalla site**	Confidence level that flow recommendation achieves objectives?
A	Minimum depth (0.4m) over shallowest allowing fish passage and bed sediment scouring	Low flow freshes >230 ML/d	2006: Depth of riffles 0.44m 2009: Depth over riffles: 0.52m, 0.36m	High Moderate
B	Minimum depth (0.4m) over shallowest allowing permanent fish passage	High flow > 230 ML/d (or natural)	2006: Depth of riffles 0.44m 2009: Depth over riffles: 0.52m, 0.36m	High Moderate
C	Inundate benches and litter recruitment	High flow freshes >800 ML/d	2006: Majority of benches and in-channel features inundated. 2009: Majority of benches and in-channel features inundated.	High
D	Maintain disturbance processes and ensure riparian vegetation diversity/structure	Semi-bankfull flow >2000 ML/d	2006: Near bankfull attained for majority of cross-sections. 2009: Near bankfull attained for majority of cross-sections.	High

* Low flow not reviewed as 'optimal area of habitat' and is not readily quantifiable without expert panel

** General assessments only, based on depth of water over main features along the reach

8.5. **Hydrology**

8.5.1. **Surface Water Hydrology**

Mean annual rainfall in the Victorian Alps Bioregion around Erica reaches 1,000 mm, with a mean annual of 500 mm in the south of the Gippsland Plans bioregion near Sale.

The Thomson Dam is a dominant cause of hydrologic changes to the system, which is located upstream of Reach 2. The Thomson Dam has a capacity of 1,068 billion litres and supplies water to Melbourne. Releases from the Dam to the Thomson River are regulated through the Thomson Hydro Station and/or via two release valves located downstream of the Dam. The design capacity of the Thomson Hydro Station is 480 ML/d at full supply capacity and the combined design capacity of the release valves is 2,300 ML/d.

Major inflows to the Thomson River are the Aberfeldy River and Macalister River with smaller tributaries; Coopers Creek, Deep Creek and Stony Creek. Outflows from the system occur in Lake Wellington and Lake Victoria (not covered under this Study - Reaches 7 and 8) with some minor outflows into the wetlands in the Sale area.

Cowwarr Weir, built in 1957 to divert water for irrigation, domestic and stock use in the Macalister Irrigation District, also alters natural hydrologic regimes, regulating the water that travels down the Thomson Reach 4a and Rainbow Creek Reach 4b and intercepting sediments. Passing flows are split two thirds down Reach 4a and one third down Reach 4b to avoid impacts to irrigators located on Rainbow Creek.

Reach 4a and 4b supports 144 diverters with a total licensed allocation of 35,479 ML/year.

Stream gauging along the Thomson River is undertaken at a number of locations, outlined in **Table 10.**

Table 10: Summary of available stream gauging information for the Thomson River

Gauge	Reach	Location	Period of Record*	Catchment Area (km²)*	Annual Average Discharge (ML / d) 2003 - 2019**
D/S Thomson Dam (225112)	2	Immediately D/S Dam @ Beardmore	• Water Discharge 1983-2019 • Water Level 1983-2019	487	221
Narrows (225210)	2	~10km downstream Thomson Dam	• Water Discharge 1953-2004 • Water Level 1953-2004 • Spot water quality 1990 - 2019	518	448
Coopers Creek (225208)	3	Immediately upstream of Coopers Creek	• Water Discharge 1955-2019 • Water Level 1972-2019 • Spot water quality 1976 - 1990	906	688
Cowwarr Weir (225231)	3	Thomson River Upstream Cowwarr Weir	• Water Discharge 1976-2019 • Water Level 1976-2019 • Spot water quality 2002 - 2019	1,080	525
Thomson River at Heyfield (225200)	4a	Thomson River @ Heyfield	• Water Discharge 1992-2018 • Water Level 1992-2018 • Spot water quality 2005 - 2012	1,238	241
Rainbow Ck at Heyfield (225236)	4b	Rainbow Creek @ Heyfield	• Water Discharge 1992-2019 • Water Level 1992-2019 • Spot water quality 2005 - 2012	-	235
Downstream Rainbow Ck (225243)	5	Thomson River Downstream Rainbow Confluence	• Water Course Discharge – N/A • Water Level 1996-2019	-	-
Wandocka (225212)	5	Upstream Boggy Creek	• Water Discharge 1963-2019 • Spot water quality 1976 - 2012	1,417	515
Bundalaguah (225232)	6	Downstream Thomson and Macalister Rivers Confluence	• Water Discharge 1976-2016 • Water Level 1976-2019 • Spot water quality 2002 - 2019	3,538	1,087

* Earth Tech 2003

**Data sourced from Water Data Online, http://www.bom.gov.au/waterdata/

The impacts of regulation on natural flow patterns are well documented within the Thomson River system, with a reduction in flows in winter and higher flows in summer (seasonal reversal). **Figure 14** to **Figure 25** demonstrate the differences in river flow unimpacted hydrology (pre-regulation) in comparison to the current hydrology.

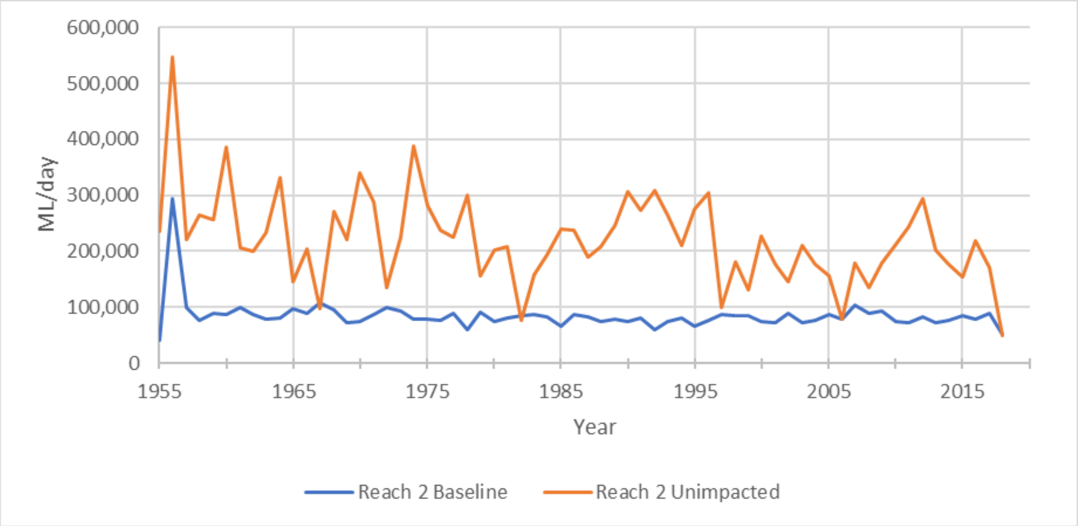


Figure 14: Reach 2 mean annual flow

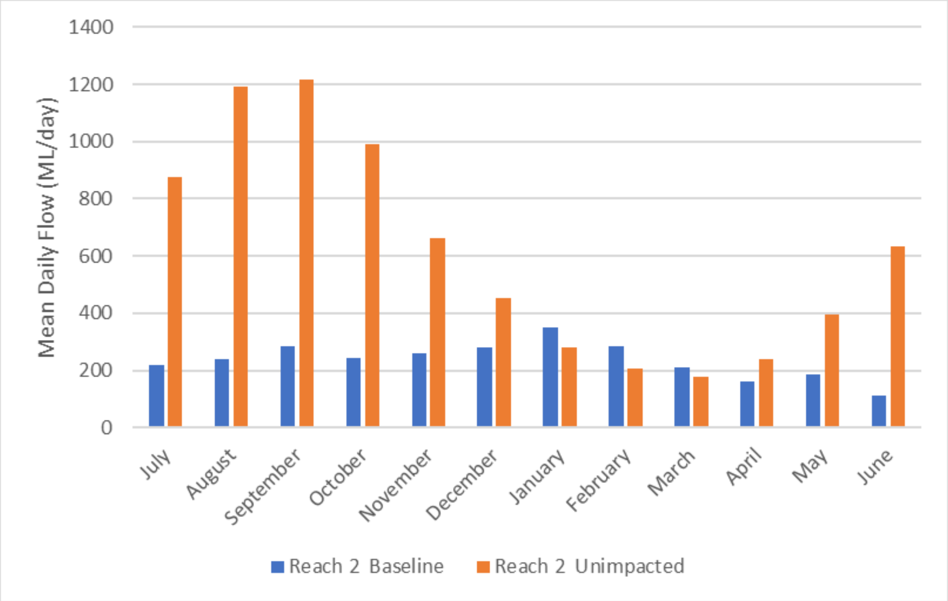


Figure 15: Reach 2 mean daily flows

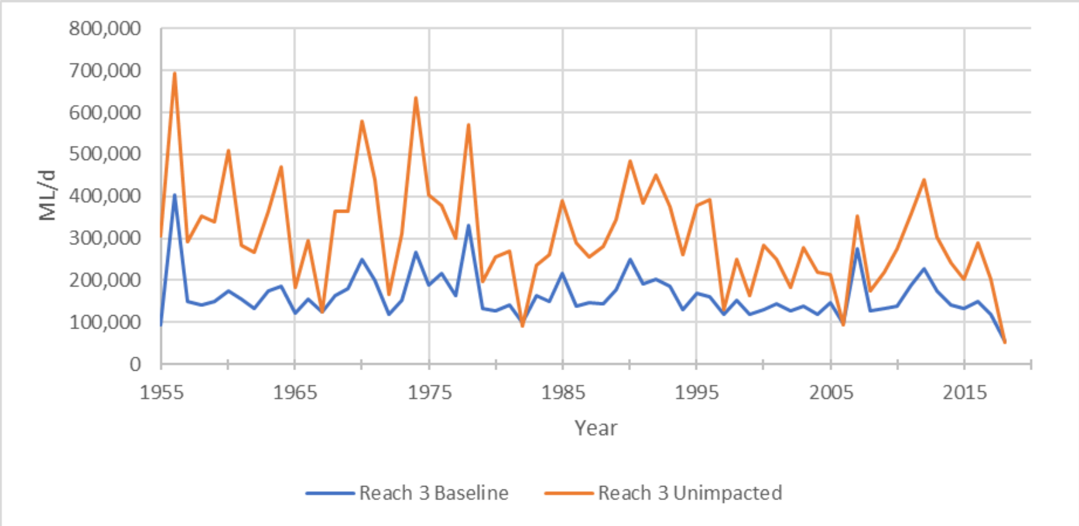


Figure 16: Reach 3 mean annual flow

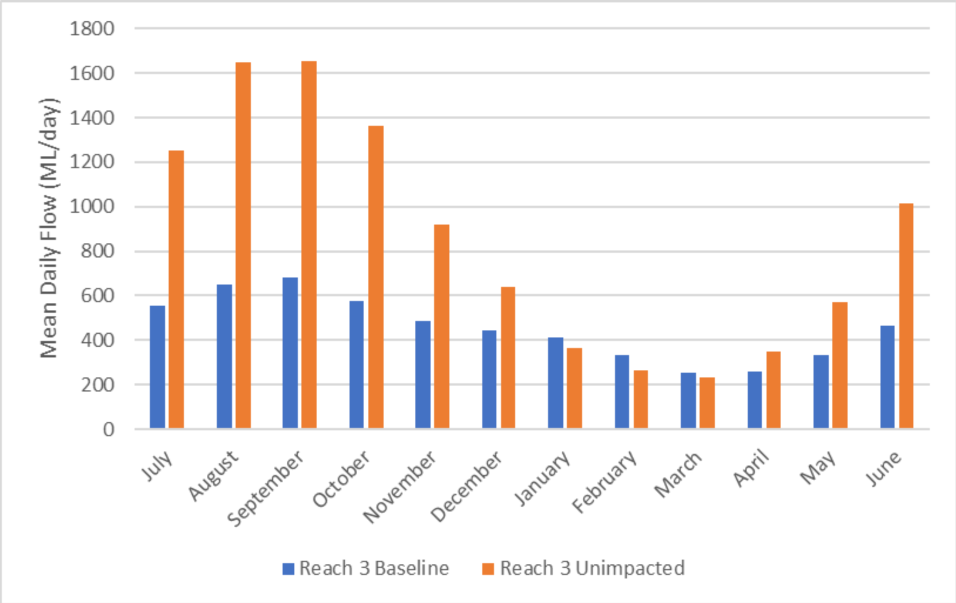


Figure 17: Reach 3 mean daily flows

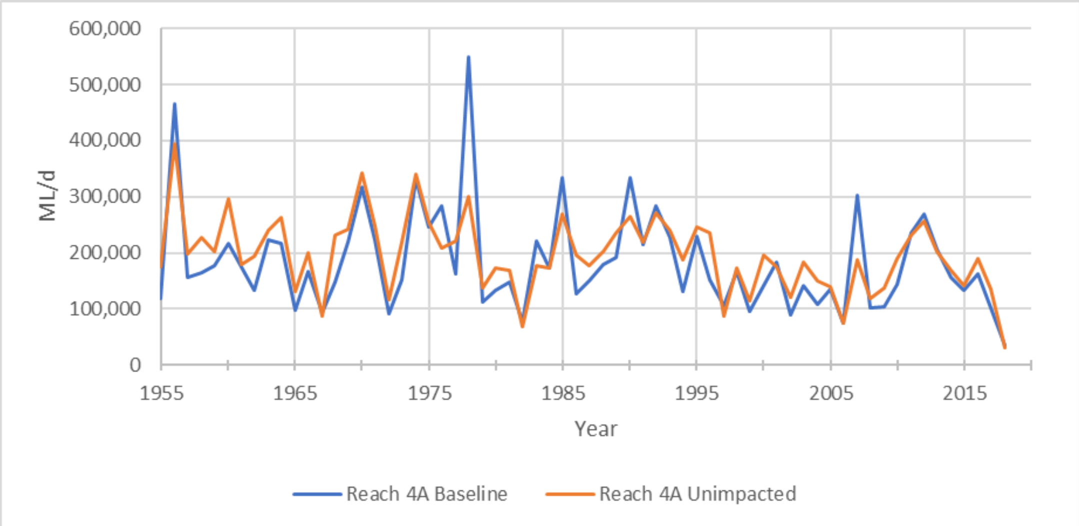


Figure 18: Reach 4a mean annual flow

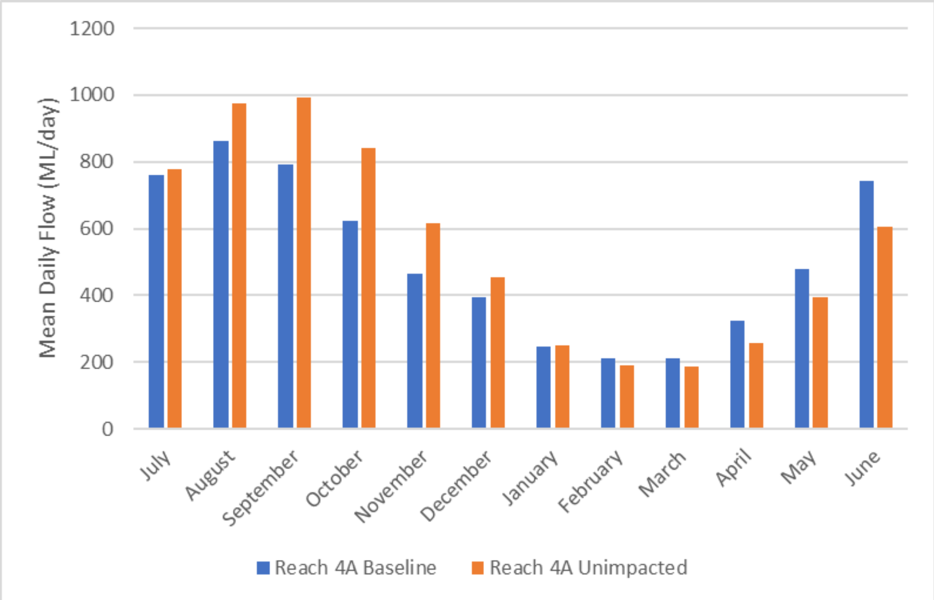


Figure 19: Reach 4a mean daily flows

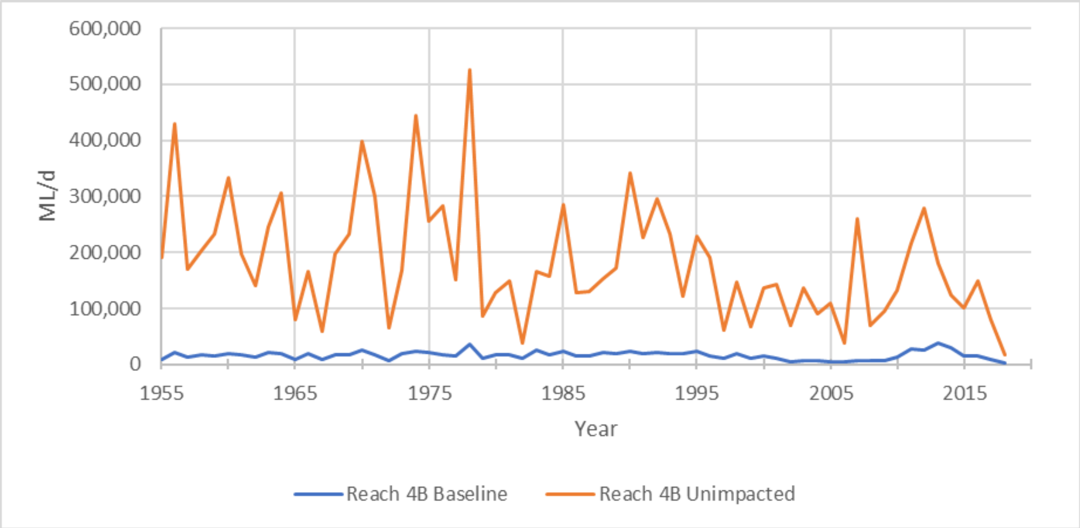


Figure 20: Reach 4b mean annual flow

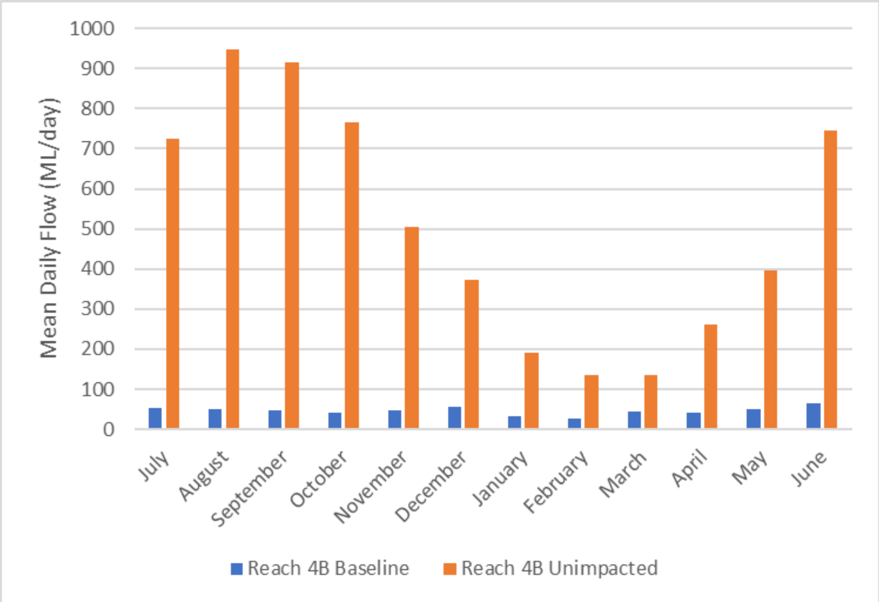


Figure 21: Reach 4b mean daily flows

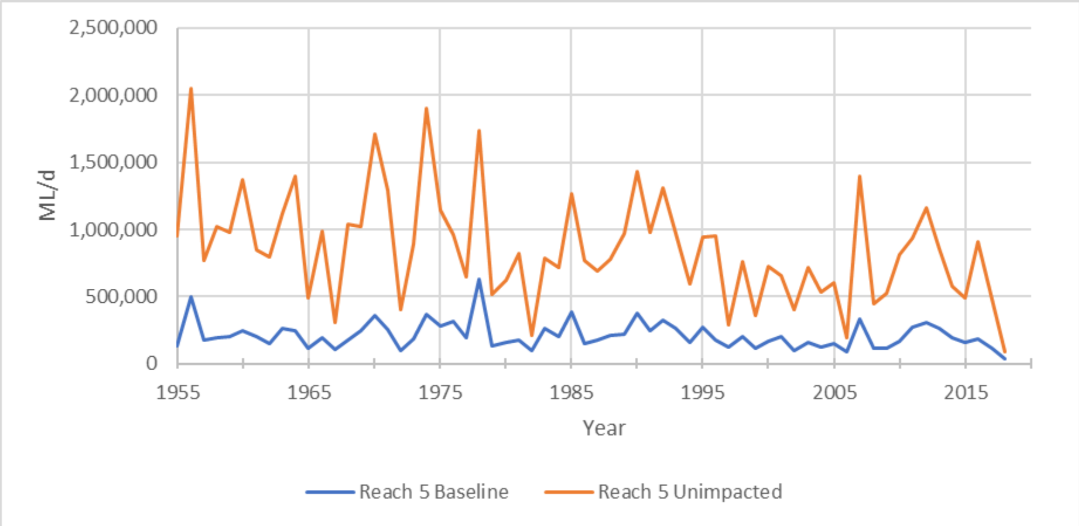


Figure 22: Reach 5 mean annual flow

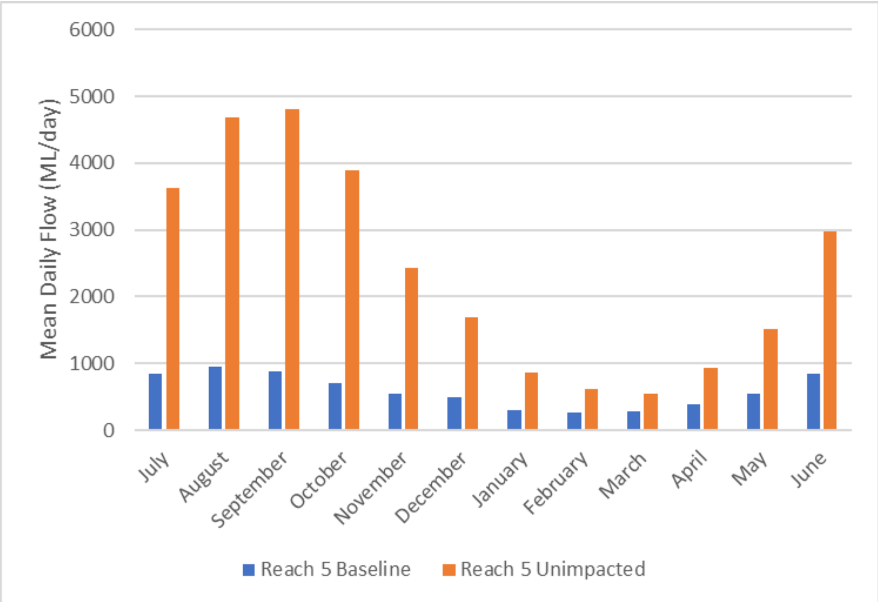


Figure 23: Reach 5 mean daily flows

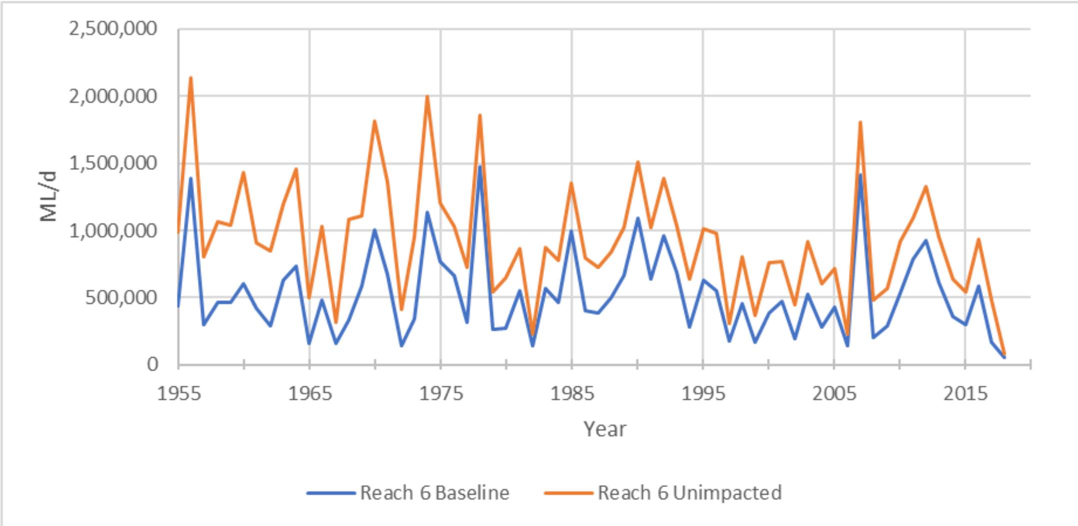


Figure 24: Reach 6 mean annual flow

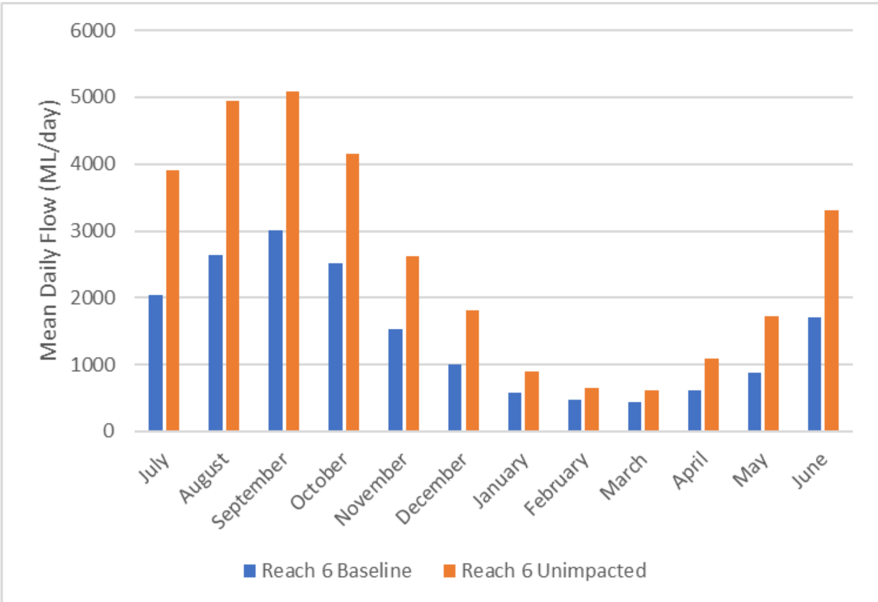


Figure 25: Reach 6 mean daily flows

Table 11 lists the percentage reduction in monthly flow after dam construction (post regulation) per reach of the Thomson River.

Table 11: Reduction in monthly flow after dam construction per reach

Reach	Reduction in monthly flow after dam construction
Reach 2 - Thomson Dam Wall to Aberfeldy River Junction	61%
Reach 3 - Aberfeldy River Junction to Cowwarr Weir	47%
Reach 4a - Thomson River, Cowwarr Weir to Rainbow Creek Confluence	7%
Reach 4b - Rainbow Creek, Cowwarr Weir to Thomson River Confluence	91%
Reach 5 - 4a / 4b confluence to Macalister River Confluence	75%
Reach 6 - Macalister River Confluence to the Latrobe River	43%

8.5.2. Water Quality

Water quality in the Thomson River in upstream reaches remains in good condition with reduced water quality in reaches downstream of the confluence with the Macalister River.

The ISC third report analysed data collected over a six-year period from 2004 to 2010 including an assessment of water quality. Results from the Thomson basin included one reach in reference condition (Reach 18 on the Aberfeldy River - not within the Study area) and another six reaches in near reference condition (Reaches 2, 3, 4b and 5), refer to **Table 12**.

Table 12: ISC3 scores for water quality

EFlow Reach Number	ISC3 Reach	Water Quality (out of 10)
2	25_005	9
3	25_004	9
4a		
	25_003	8
4b	25_017	9
5	25_002	9
6	25_001	6
	25_201	6

Currently, spot water quality data (EC, turbidity, pH, DO) and laboratory analysed data (Total Suspended Solids, Total NO_2 and NO_3, Kjeldahl Nitrogen, Total Phosphorus and Filterable Reactive Phosphorus) is collected at three sites:

- Thomson River @ The Narrows - 225210 (1990 - 2019)
- Thomson River u/s Cowwarr Weir - 225231 (2002 - 2019)
- Thomson River @ Bundalaguah - 225232 (2002 - 2019).

Table 13 shows the median water quality results at each of the three sites where monitoring is conducted. Turbidity, Electrical Conductivity and Total Suspended Solid (TSS) values increase with downstream extent. This reflects the catchment land use, with much of the upper catchment forested. The downstream reaches are generally lower in quality from landuse impacts such as runoff from industry, stock access as well as seven main drains from the Macalister Irrigation District entering the Thomson River.

Table 13: Median water quality parameters at three sites along the Thomson River

	Median pH	Median Turbidity (NTU)	Median Electrical Conductivity (uS/cm)	Median Dissolved Oxygen (ppm)	Median Total P (mg/l)	Median FRP (mg/l)	Median Total NO2 + NO3 (mg/l)	Median Kjeldahl N (mg/l)	Median TSS (mg/l)
Thomson River @ The Narrows - 225210	7	2.3	52	10.1	0.006	0.003	0.14	0.11	2
Thomson River u/s Cowwarr Weir - 225231	7.2	2.7	70	9.8	0.008	0.003	0.11	0.12	2
Thomson River @ Bundalaguah - 225232	7	16.5	113	9	0.088	0.01	0.086	0.285	16

8.5.3. Groundwater

Three aquifers are located within the Thomson River footprint; the Quaternary alluvial aquifer along the valleys, the Boisdale Formation aquifer which dominates the Gippsland Plains extending south and east past Heyfield and the Palaeozoic basement aquifer, a shallow aquifer of fractured sandstone and mudstone in the highlands area of the Basin.

There are two Water Supply Protection Areas (WSPAs) relating to the Thomson River catchment, areas declared in the Water Act to protect groundwater resources with rules relating to equitable management and long term resource sustainability. The Denison WSPA abuts the Thomson River and has a groundwater cap of 18,502 ML/yr; and the Sale WSPA covers the lower reaches of the Thomson River and has a groundwater cap of 21,212 ML/yr (SRW 2016). Groundwater use in this area is mainly for the MID and these groundwater resources have low salinity (SRW 2011).

A 2015 Study by GHD found that the Thomson River is largely dependent on regional groundwater discharge to streams, except possibly in the reach between Cowwarr Weir and Heyfield. The observed groundwater level and surface water level data at the Rainbow Creek gauge indicate consistent losing conditions, which is probably due to artificial maintenance of high stream water levels (above the watertable) via regulation at Cowwarr Weir (GHD 2015). Downstream of Heyfield, the Thomson River exhibits mainly gaining baseflow conditions.

8.6. **Vertebrate Fauna**

8.6.1. **Platypus**

A conceptual model for Platypus was taken from Jacobs et. al. 2016 (**Figure 26**).

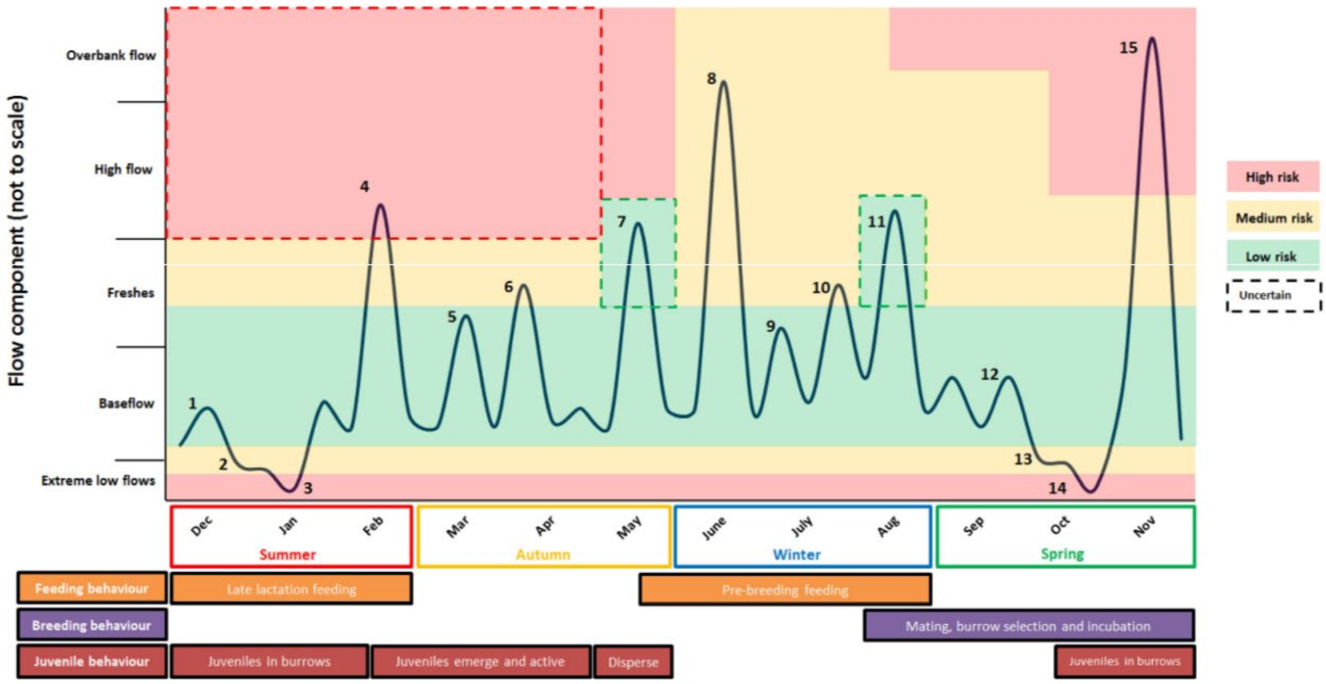


Figure 26: Platypus conceptual model

Platypus (*Ornithorhynchus anatinus*) are a top-order predator found in freshwater habitats along the east and southeast coast of mainland Australia and Tasmania and are listed as "Near Threatened" both in Australia and internationally (as described in the IUCN Red List since 2016).

There have not been any targeted investigations in to the platypus populations in the Thomson River, nor are there any Thomson River sightings recorded on the Australian Platypus Monitoring Network (https://www.platypusnetwork.org.au/findings), nor the Cesar PlatypusSPOT site (http://platypusspot.org/view-sightings). Anecdotal evidence suggests that there have been some platypus sightings along the Thomson River in the last 10 years.

In general, platypus populations have declined since European settlement through habitat destruction, degradation, changed hydrological regimes and predation. Platypus populations in river systems across Victoria where long term monitoring is conducted have also reported a population decline or extinction over the past 10 years, mainly attributable to extended drought conditions (Serena and Williams 2004, Williams 2010, Griffiths and Weeks 2011, 2013). It can be assumed that populations of platypus on the Thomson River have also experienced a similar decline in population.

The reliability and volume of water flow is important for platypus as outlined in **Figure 26**. Flow can affect platypus:

- Diet and foraging: Ideal environments for foraging include between 1 - 5 metres of depth, the presence of instream cobbles, gravel, pebbles, coarse particular organic matter, large woody debris, overhanging vegetation and notched banks (Grant 2004b, Serena et al. 2001, Ellem et al. 1998 and Coleman 2004).
- Adult movements: Localised movement within river reaches.
- Shelter burrow use: High flows can flood shelter burrows.
- Direct mortality risk from predation during low river levels.
- Reproductive success, particularly during mating season (early August to late October in southern Victoria) (De-La-Warr and Serena 1999; Easton et al. 2008). Platypus dig specific nesting burrows, which are deeper than shelter burrows, where females lay eggs and rear their young. There is a risk of flooding nesting burrows and drowning young during high flows.
- Juvenile dispersal, a key factor to maintain genetic diversity in populations. Predation of juveniles is frequent with successful dispersion dependent on juveniles ability to avoid predators as well as find enough food (Jacobs et al 2016).

8.6.2. **Rakali**

The Australian Water-rat or Rakali, *Hydromys chrysogaster*, is a native rodent, feeding predominantly on aquatic animals including fish, crustaceans, shellfish, small birds, eggs, mammals, frogs and reptiles. Rakali can also feed opportunistically on terrestrial prey. The water-rat is considered to be nationally secure and has an international conservation ranking of "Least Concern".

Rakali occupy burrows located in creek and river banks, or shelter in large hollow logs lying near the water. Radio-tracking studies undertaken by Australian Platypus Conservancy staff have shown that platypus and water-rats will use the same burrow, though probably not at the same time (Australian Platypus Conservancy 2020).

A 2018 study found that in south-eastern Victoria, the largest proportion of Water-rat sightings was associated with the Thomson River basin (28%), followed by the Mitchell River basin (23%) and Latrobe River basin (18%). In the Thomson River system, sightings were recorded in the Thomson, Macalister and Avon Rivers as well as the Aberfeldy and Perry Rivers, Valencia Creek, irrigation channels near Nambrok and Lake Guthridge in Sale (Williams and Serena 2018), indicating that they are habitat generalists.

The impact of flow regime and water availability for Rakali is likely to be similar to that of Platypus.

8.6.3. **Birds, Reptiles and Amphibians**

An abundance of waterbirds, terrestrial birds, amphibians and reptiles can be found along the Thomson River including Australian Magpie, Australian Pelican, Australian Smelt, Australian Wood Duck, Black-fronted Dotterel, Black-winged Stilt, Brown Goshawk, Cape Barren Goose, Caspian Tern, Cattle Egret, Clamorous Reed Warbler, Darter, Dusky Moorhen, Dusky Woodswallow, Eastern Rosella, Feathertail Glider, Grey Butcherbird, Haswell's Froglet, Little Corella, Little Grassbird, Magpie Goose, Marsh Sandpiper, Noisy Miner, Rainbow Lorikeet, Red-necked Avocet, Sooty Owl, Spotted Turtle-Dove, Varied Sittella and White-necked Heron (Source: NatureKit webpage, http://maps.biodiversity.vic.gov.au/viewer/?viewer=NatureKit [viewed 29/11/2019]). Many of these species were recorded in and around Sale Common, not a part of this flow study, however, have been included here for completeness. The species listed above are not directly reliant on particular flow regimes as they are mobile and can move to where water resources are available. Flows may influence the availability of food sources and habitat, especially during breeding times (Spring and Summer).

The Gippsland Water Dragon (*Intellagama lesueurii howitti*) is found in eastern Victoria, along the Thomson River as well as near creeks, river and lakes in forests, woodlands, grasslands and also parkland in urban areas. The Conservation Status of the Water Dragon under the EPBC Act is 'Common'. Gippsland Water Dragons can adapt to a wide variety of flows and are unlikely to be impacted significantly from particular water regimes.

9. **Changes in Character and Condition**

Changes in character and condition of each reach since the 2003 study was completed are outlined in the following tables.

9.1. Reach 2 - Thomson River, Thomson Dam Wall to Aberfeldy River Junction

Table 14: Character and condition of Reach 2

Aspect	2003 condition	What's changed
Hydrology	• Total reversal of seasonal pattern • Dramatic decrease in winter flows (e.g. 93% decrease in September median daily discharge)	Continuation of highly modified flow patterns due to Thomson Dam Water quality classed as near reference condition, low EC, low nutrients.
Geomorphology	• Stable bedrock controlled channel within gorge setting • Some infilling of pools, and encroachment of channel • Deep pools with riffles of varying length depending on local control • Numerous locations of bank undercutting	Limited change likely in these reaches. The area of sensitivity in the confined reaches is the infilling of pools. Limited change has been identified from bushfire and flood combinations (Alluvium, 2014). There is an increased understanding of the likely historic loads released from gold mining into this reach due to mapping mining activity and loads of sediment processed (Davies et al., 2018).
Fish*	• River blackfish Brown trout, Rainbow trout, short-finned eels, Tupong, Short-headed lamprey • No carp • Diversity impacted by downstream barriers (Including Horseshoe tunnel)	Connectivity restored to the reach by Horseshoe Bend fishway in 2019. Expected to result in colonisation of this reach by diadromous species, including Australian grayling, Broad-finned galaxias and Tupong. Apparent recent reduction in Short-headed lamprey numbers in this reach since 2009.
Macroinvertebrates	• Healthy but modified, recovery to natural unlikely, but recovery potential • Main food source terrestrial organic material	Little to no change in macroinvertebrate assemblages. The 3rd ISC scored Aquatic life as 5/10.

Aspect	2003 condition	What's changed
Vegetation	• Good to excellent condition • Encroachment (terrestrialisation) of vegetation	The 3rd ISC scored the Streamside Zone in Reach 2 (ISC site 5) as 9/10. This suggests it was in excellent condition in 2010, the most recent date for ISC assessments. There seems to be no information from VEFMAP vegetation monitoring studies on Reach 2 of the Thomson River, the most upstream site being Th0301 (i.e. in Reach 3) by Water Technology (2015). Despite the lack of empirical data, there seems to be little reason for altering the conclusion that water-dependent vegetation in Reach 2 is in excellent condition and should be protected against degradation. Terrestrial encroachment, however, is still a looming threat, given the position of this reach immediately below the Thomson Dam and above the confluence with the Aberfeldy River. Anecdotal evidence suggests increasing vegetation encroachment in the channel over the last decade and a half, despite increased environmental flows.

*Updated from 2003 report to allow accurate comparison

9.2. Reach 3 – Thomson River, Aberfeldy River Junction to Cowwarr Weir

Figure 27: Two photographs of Reach 3, both just upstream of the Coopers Creek campground. Photographs by Paul Boon, Nov 2019.

Table 15: Character and condition of Reach 3

Aspect	2003 condition	What's changed
Hydrology	Considerable reduction in winter flows but less impacted than Reach 2 due to contributions from unregulated tributaries	Inflows from Aberfeldy continuing to augment flows into this reach. Little change hydrologically, Water quality classed as near reference condition, low EC, low nutrients.
Geomorphology	Some infilling and aggradation occurring	As with Reach 2, limited change likely in these reaches. The area of sensitivity in the confined reaches is the infilling of pools or scouring of alluvial deposits. Previous work by Alluvium (2009) suggest these reaches scoured after the 2007 fire and floods. Enlargement of channel cross-sections resulted in non-compliance of Environmental Flows baseflow inundation stages. They were also suggested to be larger changes than would be likely as a result of Environmental Flows alone. There is an increased understanding of the likely historic loads released from gold mining into this reach due to mapping mining activity and loads of sediment processed (Davies et al., 2018)
Fish*	River blackfish, Brown trout, Rainbow trout, Short-finned eels, Tupong, Short-headed lamprey, low numbers of Australian grayling. Diversity impacted by downstream barriers (Cowwarr Weir).	Connectivity with lower reaches improved via installation of fishway at Cowwarr Weir. Significant Tupong recruitment event in 2017, juvenile fish have been extending from lower reaches into the upper reaches over the past few years (Amtstaetter et al. 2019).
Macroinvertebrates	Similar to Reach 2 but possibility for improved communities due to tributaries	No large scale changes, the 3rd ISC scored Aquatic life as 7/10, most likely due to influence of Aberfeldy River.
Vegetation	Similar to Reach 2, excellent condition, some encroachment	The 3rd ISC scored the Streamside Zone in Reach 3 (ISC site 4) as 8/10. This suggests it was in excellent condition in 2010, the most recent date for ISC assessments. VEFMAP assessments are available for 2009, 2011 and 2014–2015. The most recent VEFMAP assessment (Water Technology 2015) gave a vegetation condition rating for a

Aspect	2003 condition	What's changed
		site in Reach 3 near Coopers Creek (Site Th0301) as High (page 20) but with Blackberry (*Rubus fruticosus spp*. agg) and Gorse (*Ulex europaeus*) as common weed species. Water Technology (2015, page 19) concluded that at this monitoring site "The steep valley margins and minor floodplain pockets [of the Thomson River near Coopers Creek] are now fully vegetated apart from river access areas from the main road. This vegetation is interspersed with a variety of unusual exotic species that have been introduced from mining activities and a diversity of origins".

*Updated from 2003 report to allow accurate comparison

9.3. Reach 4a – Thomson River, Cowwarr Weir to Rainbow Creek Confluence

Figure 28: Reach 4a, showing abundant Blue Periwinkle (*Vinca major*) groundcover and the constrained flow in the main channel of the river. A small bed of Leafy Flat-sedge (*Cyperus lucidus*) was present on the edge of the bank just downstream. Photograph by Paul Boon, Nov 2019.

Table 16: Character and condition of Reach 4a

Aspect	2003 Condition	What's changed
Hydrology	• Large daily fluctuations in flow • Medium size flows reduced, high flows not significantly impacted due to unregulated tributary inflows • Some water loss to groundwater	No large scale changes, good water quality.
Geomorphology*	• Highly sinuous with pools infilling • Not migrating laterally, no lateral migratory features • Sand, mud and gravel bed • Little woody habitat available	This is an avulsive system and this channel is increasingly perched, i.e. it is aggrading further, reducing channel capacity and increasingly becoming fine-grained sediments (sand and silts). The channel is continuing to develop anabranches onto the floodplain between 4a and 4b.
Fish*	• River blackfish, Brown trout, Common carp, Long-finned eels, Short finned eels, Goldfish, Rainbow trout, Tupong and low numbers of Australian grayling • Lack of instream habitat due to historic snag removal • Fishway performance to be assessed	Combined full-width rock ramp and vertical-slot fishway installed.
Macroinvertebrates	• Refuges of natural communities within existing LWD and stream edge areas. • Overall vast reduction in species abundance	No large scale changes, the 3rd ISC scored Aquatic life as 6/10.
Vegetation	• Willows and exotic grasses dominate • Overall condition moderate • Grazing pressure on vegetation	The 3rd ISC scored the Streamside Zone in Reach 4a (ISC site 3) as 5/10. This suggests it was in only moderate condition in 2010, the most recent date for ISC assessments. Brief inspections undertaken as part of the EFTP field visit in late November 2019 provide little reason to significantly vary this conclusion. Water Technology (2015) assessed vegetation at Site Th04a01 in Reach 4a and gave it an overall vegetation condition rating of Medium-Low, noting that understorey alone would

Aspect	2003 Condition	What's changed
		score Low because of the dominance of understorey weeds. This scoring is consistent with observations made by the EFTP during the field inspection, when extensive infestations of Blue Periwinkle (*Vinca major*) and Wandering Tradescantia (*Tradecantia fluminensis*) were observed on the right-hand bank at two sites in Reach 4a (see Figure 8). A second site in Reach 4a examined by Water Technology (2015, page 29) near Heyfield (Site Th04a03) also received an overall vegetation condition rating of Low to Medium-Low.

*Updated from 2003 report to allow accurate comparison

9.4. Reach 4b – Rainbow Creek, Cowwarr Weir to Thomson River Confluence

Figure 29: Reach 4b, Rainbow Creek. Note the almost non-existent riparian zone and absence of native tree or shrub species. Photograph by Paul Boon, Nov 2019

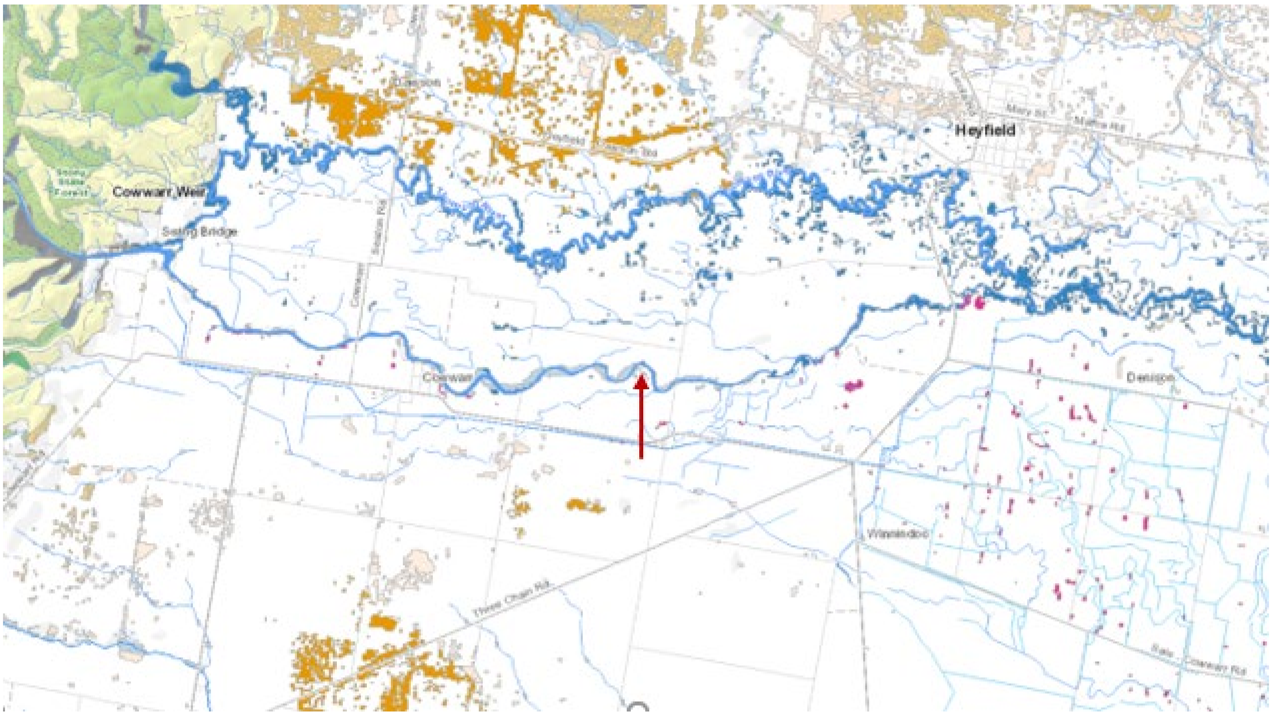


Figure 30: Modelled native vegetation (as 2005 EVCs) of Reaches 4a and 4b. The thin blue line in the middle of the map traces the path of Reach 4b, Rainbow Creek (indicated with the red arrow). The absence of a zone of native riparian vegetation along Rainbow Creek is apparent. Source: NatureKit webpage, http://maps.biodiversity.vic.gov.au/viewer/?viewer=NatureKit [viewed 29/11/2019]

Table 17: Character and condition of Reach 4b

Aspect	2003 condition	What's changed
Hydrology	• Hydrology data based on flow split with Reach 4a • Considerable reduction in winter flows, and flood flows reduced	Cowwarr Weir continues to augment flow reducing flood flows, no large scale changes. Excellent water quality, near reference condition, as per ISC3.
Geomorphology	• Sediment and material supply from erosion of bed and banks, not yet stable • Steeper and more active than Reach 4a • Gravel and rock bed, some deep pools	Currently the DELWP Flagship reach which includes 4a and 4b has had 223,407 m^3 of erosion between 2010 and 2018. The same area had 101,297 m^3 of deposition. Thus, from the volume of sediment that was moved 69 % was erosion and 69 % was deposition. The average yearly rate of erosion was 0.090 m m^{-2} and deposition occurred at a rate of 0.1 m m^{-2}. The channel has scored 8/10 for its Physical Form in the ISC3 and with relatively little change from ISC1 10 years previously.
Fish	• Common carp, short finned and long finned eels, rainbow trout and redfin. • No fish passage to upper Thomson River through Rainbow Creek • Deteriorating habitat	• Fish assemblage - no major changes. • Habitat remains quite poor for fish: mostly shallow, low instream structure and low riparian cover.
Macroinvertebrates	No sampling undertaken in this reach	• The 3rd ISC scored Aquatic life as 9/10, riffles and instream debris observed during site visit to support this.
Vegetation	• Willows and exotic grasses dominate • Overall poor condition • Potential for improvement by development of floodplain environment (within main channel)	The NatureKit webpage shows an almost complete lack of native riparian vegetation along any part of Reach 4b, Rainbow Creek. This mapping is therefore consistent with the image shown in Figure 9 and Figure 10. The 3rd ISC scored the Streamside Zone in Reach 4b (ISC site 17) as a lowly 4/10. This suggests the riparian zone was in poor condition in 2010, the most recent date for ISC assessments. Brief inspections undertaken as part of the EFTP field visit in late November 2019 provide some reason to vary this

Aspect	2003 condition	What's changed
		conclusion to one of Poor or very Poor condition, and it is clearly inconsistent with the lack of any native EVC coverage in the riparian zone in the NatureKit webpage. Site Th04b02 of Water Technology (2015) is in Reach 4b. It received an overall vegetation condition rating of Low (thus also consistent with observations made by the EFTP during the November 2019 field inspection). Water Technology (2015, page 31) remarked on the exotic understorey of Blackberry, Blue Periwinkle and exotic grasses and has remained dominant. Moreover, "Gravel bars have become vegetated with a mix of native and exotic species. Young Wattle saplings, exotic grasses and herbaceous weed species dominate the dry bed and surrounding low-lying bank areas". This too is consistent with observations made by the EFTP during the November 2019 field inspection and with the reduction in flows commented on in the Hydrology section above. Similar scores were recorded for Site Th04b05 by Water Technology (2015, page 34) in Reach 4b, with the conclusion that "The Vegetation Condition Rating at this site has remained Low. The understorey is dominated by exotic Kikuyu and has begun to be overtaken by Blackberry while Willows dominate the overstorey. This site is fenced and not grazed with the exception of one small stock watering point. The sites condition is unlikely to alter from environmental flows alone and would require control of weeds and revegetation to increase condition rating".

9.5. **Reach 5 – Thomson River, Cowwarr Weir to Macalister River Confluence**

Figure 31: Reach 5 near the Gibson King Bridge. Note the canopy dieback in the distance and level on the bank of the 800 ML/day environmental flow received recently. Photograph by Paul Boon, Nov 2019

Table 18: Character and condition of Reach 5

Aspect	2003 condition	What's changed
Hydrology	• Hydrology follows natural seasonal trend, with general reduction in flow magnitude Winter/Spring most significantly impacted by regulation (1 year ARI magnitude now half natural)	Long term average flow since 2003 has reduced to 4.6 ML/d (2002 - 2019 data), from 9.4 ML/d (1963 - 2002 data).
Geomorphology	• Similar to Reach 4a • Additional sediment supplied as a result of Rainbow Creek avulsion	Meandering sand bed high sinuosity and abandoned channels. An alluvial terrace constrains channel migration to the south along the complete length to the confluence with the Macalister. The reach has a relatively high ISC3 score for Physical Form (9/10) which reflects the lack of instream fish barriers, good bank condition and presence of large wood.
Fish*	• Native fish assemblage largely intact. • Introduced species abundant in lower reaches (Carp, Gambusia, Redfin perch, Goldfish)	Native fish assemblage still largely intact and introduced species still abundant. Australian grayling present – variable recruitment but no evidence of decline. Introduced Weatherloach established in lower reaches of Thomson river. Recent records of Dwarf galaxias in wetlands of lower reaches. Recent records of Australian bass in lower reaches.
Macroinvertebrates	Edge habitat macroinvertebrate fauna at reference condition typical of lowland rivers. Similar to Reach 4a	No large scale changes, the 3rd ISC scored Aquatic life as 4/10.
Vegetation	• Patches of native riparian vegetation including tall Eucalypt species rated in moderate to good condition, willows common Considerable loss of riparian wetland vegetation due to reduction in high flows	The 3rd ISC scored the Streamside Zone in Reach 5 (ISC site 2) as a 6/10. This suggests it was in moderate condition in 2010, the most recent date for ISC assessments. Brief inspections undertaken as part of the EFTP field visit in late November 2019 provide little reason to significantly vary this conclusion, with dieback of the eucalyptus canopy observed near the Gibson King Bridge site. The ground layer here was dominated by weeds, including Wandering Tradescantia, Blackberry

Aspect	2003 condition	What's changed
		and exotic grasses. Arguably, therefore, the 2010 ISC score is too high and the vegetation is in poorer condition than a decade ago, although to substantiate such a revision would require repeat detailed field surveys. Site Th0504 of Water Technology (2015) is in the upper parts of Reach 5. It received an overall vegetation condition rating of Medium-Low, primarily because of the presence of willows and Wandering Tradescantia, offset by successful revegetation efforts in some parts. Site Th0505, downstream, received a similar score. It was concluded (page 39) that "The site is fenced from grazing and assuming this continues to be excluded, this site is likely to remain stable in its degraded state unless significant weed control is undertaken"

*Updated from 2003 report to allow accurate comparison

9.6. Reach 6 – Thomson River, Macalister River Confluence to the Latrobe River

Figure 32: Reach 6 at Red Gate Reserve. Note the uncontrolled access of stock to the river, a phenomenon reported also in Water Technology (2015): see text in Table 18 below. Photograph by Paul Boon, Nov 2019

Table 19: Character and condition of Reach 6

Aspect	Current condition	What's changed
Hydrology	• Follows general natural regime pattern • Greater variation between late winter high flows and summer low flows	Slightly higher long term average flow since 2003: 13.65 ML/d average from 2002 - 2019, an increase from 12.13 ML/d (1976 - 2002).
Geomorphology	• Straighter planform to upper reaches • High rates of deposition • Similar to Reach 5 Reduction in water quality compared with upstream reach	Meandering sand bed system with high sinuosity. Anabranching has occurred in this reach. Instream features are vegetated bars and benches, whilst on the floodplain are paleochannels and back swamps. There appears to be a small improvement in the Physical Form scores from ISC1 to ISC3, from 8 to 9. However, the Instream Wood score is low for this reach (0 out of 5)
Fish	Similar to Reach 5	Native fish assemblage still largely intact and introduced species still abundant. Australian grayling present – variable recruitment but no evidence of decline. Introduced Weatherloach established in lower reaches of Thomson river. Recent records of Dwarf galaxias in wetlands of lower reaches. Recent records of Australian bass in lower reaches.
Macroinvertebrates	Edge habitat macroinvertebrate fauna below reference condition	• The 3rd ISC scored Aquatic life as 4/10
Vegetation	• River Red Gum and Swamp Paperbark dominate the vegetation community • Willows also present Riparian vegetation improves closer to Macalister River confluence	The 3rd ISC scored the Streamside Zone in Reach 6 (ISC site 1) as a 7/10. This suggests it was in moderate-to-good condition in 2010, the most recent date for ISC assessments. Brief inspections undertaken as part of the EFTP field visit in late November 2019 provide little reason to vary this conclusion, Site Th0601 of Water Technology (2015) is in the upper parts of Reach 6, just downstream of the confluence with the Macalister River. It received an overall vegetation condition rating of Medium-Low, on the grounds that "There are wide patches of native vegetation and remnant River Red Gums however

Aspect	Current condition	What's changed
		Willows, Blackberries, Tradescantia and exotic grasses dominate the understorey. Ongoing grazing will not allow the condition rating to increase and, assuming both the grazing and human pressures stay at current levels, the site is likely to remain in its degraded state" (page 42). Of note is the recording of EVC 863 Floodplain Reedbed, an EVC not shown in the modelled EVC mapping on the NatureKit webpage. Vegetation condition scores recorded by Water Technology 92015) for the other monitoring site in Reach 6 (Site Th0604) was also Medium-Low.

10. **Risks and Issues**

The current health of the Thomson River is significantly impacted by hydrological changes due to regulation for urban and irrigation demand. Climate change is an impact of a lessor significance compared with regulation impacts. Other factors such as land use and river management practices also contribute to the health of the River. Any attempt to improve environmental conditions through flow augmentation should be combined with management actions to address all factors responsible for the decline in conditions.

Discussions with the EFTP, WGCMA and project stakeholders have identified a number of risks and issues that need to be considered for future health of the River and are outlined in **Table 20**.

Table 20: Risks and issues along the Thomson River

Risk / Issue	Non flow related management techniques
Climate change	
Fire and flood	
Reduction in return flows from modernisation of the MID	
Exotic grasses and weeds	Spraying program
Carp	Carp exclusion cages Biological population control methods
Erosion of banks from stock	Exclusion by fencing Fencing wetland areas
Loss of riparian vegetation, impacting on physical form, fish, macroinvertebrates and platypus	Revegetation Fencing
Wetland connectivity	Either returning or enhancing connectivity through physical changes
Fish death via extraction pumps	Pump inlet screening
Lack of woody sources from bank (Rainbow Creek a focus)	Physical replacement of woody sources
Management of recreational fish stock	Discouraging non-native fish stocking Australian Bass lower system
Cowwarr Weir fish barrier	Install fishway on Rainbow creek
Avulsion into Rainbow Creek	Rockwork of entry points (as per WGCMA 2019b)
Increase to take for Melbourne Water supply (security of entitlement)	
Diversion of Aberfeldy river to meet Melbourne Water supply	
Irrigator behaviour - compliance issues (greatest impact when flows are low)	

11. Identifying Waterway Values

The Thomson River is a high priority waterway and has significant environmental, cultural, social and economic value. Note that physical form values are inherently included within the overarching objectives. Through discussions with the EFTP, Steering Committee and the PAG, the following water dependent values were identified:

Biodiversity:

- Macroinvertebrates
- Fish
    - Diverse native fish assemblages. Species of particular significance include Australian grayling, Dwarf galaxias, Tupong, Australian bass, Short-finned eel and Long-finned eel.
- Crustaceans
    - Crayfish
- Vegetation
    - Microbial biofilms
    - Submerged vascular plants
    - Non-woody fringing vascular plants (e.g. reeds, rushes and sedges)
    - Woody and non-woody vegetation in channel, on benches and in lower riparian zone (maintenance of native water-dependent taxa and minimisation of encroachment by terrestrial plant species)
    - Water-dependent woody riparian trees and shrubs (e.g. Swamp Paperbark)
    - Terrestrial vegetation requiring a specific gully/valley microclimate (e.g. EVCs 18, 29, 39 and 56)
    - Freshwater floodplain wetlands
    - Floodplains
- Fauna
    - Platypus / Rakali
    - Birds
    - Frogs
    - Turtles
    - Gippsland Water Dragon

Ecosystem processes:

- Carbon and nutrient cycles

- Stream substrate condition
- Water Quality
- Channel form diversity (bed and bank)
- Floodplain wetland diversity

Gunaikurnai Traditional Owner Cultural Values:

A list of species that occur along the Thomson River and that are culturally important to the Gunaikurnai people was provided by GLaWAC:

- Flora
    - Wattles
- Fauna
    - Crustacea
        - Gippsland spiny crayfish
    - Fish
        - River blackfish
        - Bream
        - Eel
    - Birds
        - Water hens
        - Black swans
        - Musk duck
        - Pelicans
        - Cormorants
        - Other ducks
        - Fairy wren
    - Mammals
        - Rakali
        - Platypus
        - Bush rats.

Species that are directly dependent on environmental watering were considered as part of the objectives setting process and are covered in **Table 22**. Those species that are not directly dependent on environmental watering were considered out of scope of this assessment.

Social and economic values are outlined in **Table 21**, specifically; What are the values, What information/data exists, and how might the economic benefit of each value be determined for future studies. Please note, potable water supply was identified as a key social / economic value associated with the Thomson River, however, as the focus of the project is Environmental related flows, this is outside of the project scope.

Table 21: Social and economic values summary

Value	Relevant reaches	Description	How does value link to flow?	How might we determine the flow requirements?	What are key characteristics of this flow?	What are the economic benefits?	How might we determine economic benefit?	Potential for disbenefits?
Kayaking / canoeing	2, 3, 4a, 4b, 5 and 6	Kayaking upstream and downstream of Cowwarr weir is popular with people coming from outside the region. Commercial operators run tours.	More flow improves visitation (numbers and quality of experience), up to threshold	Poor, Average and Good flow levels based on Canoeing Vic guide (e.g. flow levels can identify magnitude of flow)	Spring or summer freshes or high baseflow. Duration of at least 2 days during weekends or 5 days during holiday periods	Increased tourism due to visitation for kayaking, majority coming from outside the region	Likely $ spent due to three flow levels (visitation days for poor, average and good kayaking levels). Need to have an estimate of increased numbers for each flow event and then put a $/visit figure based on consumer surplus[3]	Inadequate rubbish disposal, intrusions onto private property. Could reduce benefits by a factor (or cost of collecting rubbish etc) to account for disbenefits if they are likely to be significant (applied to all relevant social and economic values)

[3] Previous literature review work for Melbourne Water has been conducted as part of the Catchment Management Optimisation Project. A figure of $140 per person was used for water-based recreation.

Value	Relevant reaches	Description	How does value link to flow?	How might we determine the flow requirements?	What are key characteristics of this flow?	What are the economic benefits?	How might we determine economic benefit?	Potential for disbenefits?
Fishing – recreational	2, 3, 4a, 4b, 5 and 6	Fishing on named reaches	More flow will improve environment for some species - refer to fish objectives	In accordance with flows for native fish	Spring or summer freshes or baseflow.	Increased tourism	$ per person – value will depend upon whether fishers are mostly day trippers or involve overnight stay[4]	Fishing lines and hooks can damage aquatic environment, rubbish and intrusions to private property
Swimming – Cowwarr Weir	3	Additional swimming for mostly local people – although some out of region tourism (e.g. Traralgon, Sale etc)	More flow in warmer months would improve opportunities for swimming	Suggest as for kayaking	Spring or summer freshes or high baseflow. Duration of at least 2 days during weekends or 5 days during holiday periods	Increased opportunities for mostly for local people	$ per person[5] multiplied by estimated additional swimmers at different flow levels	Additional littering
Birdwatching	2, 3, 4a, 4b, 5 and 6	Increased attractiveness of birdwatching (species dependent upon flow regimes)	Some flow regimes encourage different bird species	Suggest as for kayaking	Spring or summer freshes and baseflow	Increased visitation but numbers not expected to be high	Estimated $ per person multiplied by estimated number of	Assume minimal disbenefits

[4] Previous Melbourne Water work based on literature review used $80 per person per visit. Local information suggests <20 rec fishers/week in Reaches 4a and 4b.

[5] Previous Melbourne Water work based on literature used $33 per visit when water levels are optimal and this could be reduced depending upon the level of flow, e.g. $20 per visit when there is an algal alert; $20 per visit when water levels are at 50%; $16 per visit with water levels at 10%.

Value	Relevant reaches	Description	How does value link to flow?	How might we determine the flow requirements?	What are key characteristics of this flow?	What are the economic benefits?	How might we determine economic benefit?	Potential for disbenefits?
							additional birdwatchers[6]	
Passive recreation	2, 3, 4a, 4b, 5 and 6	Improved passive recreation activities (e.g. picnicking, swimming) for mostly local people	Improved flow can increase the attractiveness of the environment	Users likely to desire sufficient flows to have an enjoyable aesthetic experience	Spring or summer freshes or high baseflow. Duration of at least 2 days during weekends or 5 days during holiday periods	More people enjoying nature and the outdoors	$ per person[7] multiplied by estimated additional swimmers at different flow levels	Additional littering
Camping	2, 3, 4a, 4b, 5 and 6 but mainly 2 and 3	Additional camping (need to understand where campers come from) – Note that there is no camping at Cowwarr Weir	Improved flow can increase the attractiveness of the environment	As for picnickers	Spring or summer freshes or high baseflow. Duration of at least 2 days during weekends or 5 days during holiday periods	More people enjoying nature and the outdoors	Estimated $ per person times average number of days camping x multiplied by additional numbers[8]	Additional littering and potential for fires

[6] Previous Melbourne Water work used $100 per person for birdwatching. Suspect most birdwatching will be associated with canoeing – could estimate a % of canoeists that come because of the birdwatching opportunities alone.

[7] Previous Melbourne Water work based on literature used $33 per visit when water levels are optimal and this could be reduced depending upon the level of flow, e.g. $20 per visit when there is an algal alert; $20 per visit when water levels are at 50%; $16 per visit with water levels at 10%.

[8] Suggest to use $140 per person per day

12. **Objectives Setting**

After the waterway values were identified, the 2003 Earth Tech Environmental Objectives were reviewed by the EFTP in the context of the current condition of each reach and based on latest science. The objectives were determined with a relevance period of around 10 years, after which time it is recommended that the objectives be reviewed in the context of changing climate and management measures.

Each objective relates to an identified value and mechanism which specifies the aspect of the objective targeted. The flow type related to each mechanism is also outlined as well as timing requirements. Refer to **Table 22** for the list of revised objectives.

Note: The use of the term 'maintain' in objective statements outlined below refers to attributes that are in good condition, where we are seeking to maintain that good condition.

Table 22: Thomson River Flow Objectives

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
Macroinvertebrates	Restore or maintain natural macroinvertebrate community	Adequate and permanent inundated habitat for species and life stages	M1	Low flow (depth >0.1m)	All year	2, 3, 4b	-
		Maintenance of habitat quality, sediment	M2	Freshes - flows able to scour fine sediment from rocks	All year	2, 3, 4a, 4b, 5, 6	-
		Maintenance of habitat quality - biofilms (flows able to disturb biofilms)	M3	High flow freshes	Spring	2, 3,4b	-
		Maintenance of habitat quality - detritus (Flows to entrain leaf litter and DOC from riparian zone)	M4	Overbank flows	Autumn - Spring	2, 3, 4a, 4b, 6	-
		Provision of inundated habitat (LWD and edge of channel habitat)	M5	Low flow (pool depth >0.5m)	Throughout year	4a, 5, 6	-
		Maintenance of food supply in edge and LWD habitats	M6	Freshes - flows able to entrain leaves from sand bed areas and transfer leaves to to edge of LWD habitat	Throughout year	4a, 5, 6	-
		Provide adequate water quality (DO and temp) through pools and riffles to	M7	Baseflow	All year	2, 3, 4a	-

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
		facilitate respiration of macroinvertebrates					
		Entrainment of LWD into channel	M8	Bankfull	Any time	4a, 5, 6	-
		Entrainment of leaf litter and DOC	M9	High flow fresh up to bankfull	Autumn / Spring	4a, 5, 6	-
Fish	Diversity of instream habitat to support the whole native fish assemblage	Adequate habitat availability and LWD inundation for species and life stages with preference for pool habitat and complex woody structure	F1a	Summer base flow Pool habitat maintenance (Depth >0.9 m, Velocity <0.5 m/sec)	Summer / Autumn (Dec - May)	4a, 5 and 6	Habitat preference and depth/velocity criteria based on Australian bass (Brown 2011).
		Adequate habitat availability for species and life history stages with preference for run/glide habitats	F1b	Summer base flow Run/glide habitat maintenance (depth 0.4-0.6 m, velocity 0.25-0.5 m/sec)	Summer / Autumn (Dec - May)	2, 3, 4a, 4b, 5	Habitat preference and depth/velocity criteria based on Australian grayling (Dawson and Koster 2018).
		Adequate habitat availability for species and life history stages with preference for riffle habitats	F1c	Summer base flow Riffle habitat maintenance (depth 0.1-0.2 m, velocity >0.6 m/sec)	Summer / Autumn (Dec - May)	2, 3, 4a, 4b	Habitat preference and depth/velocity criteria based on river blackfish (Khan et al. 2004; Koster and Crook 2008). Riffle definition based on Jowett (1993).

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
	Connectivity to facilitate localised movement	Maintain continuous connectivity for localised movement between habitats for small-bodied species	F2	Base flow Low flow (areas of >0.2 m depth over riffles)	All year	2, 3, 4a, 5	Depth criterion for connectivity from WGCMA (2015).
		Cue for downstream migration for adult Short-finned eel, adult Long-finned eel. Cue for upstream migration for juvenile Short-finned eel, juvenile long-finned eel, juvenile Australian bass, juvenile common galaxias. Maintain occasional connectivity for localised fish movement between habitats for large-bodied species	F3	Fresh (areas of >0.4 m depth over riffles)	Feb/Mar	2, 3, 4a, 4b, 5 and 6	Depth criterion from EarthTech (2003)
	Connectivity and environmental triggers for large-scale migrations by diadromous species	Cue for downstream migration for adult Australian Grayling, adult Short-finned eel, adult Long-finned eel, adult Australian bass, adult Common galaxias. Cue for upstream migration for juvenile	F4	Fresh (Autumn) NB: Where possible schedule with Macalister freshes for	April	2, 3, 4a, 5, 6	Timing of migration from Koster et al. (2013; 2018), Amtstaetter et al. (2016) and Reinfelds et al. 2013). Flow magnitude and duration from Amtstaetter et al. (2016).

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
		Long-finned eel, spent adult Australian grayling.		maximum benefit			
		Cue for downstream migration for adult Tupong, adult Australian bass, adult Common galaxias, adult and larval Australian grayling, larval Broad-finned galaxias. Cue for upstream migration for spent adult Australian grayling.	F5	Fresh (late Autumn) NB: Where possible schedule with Macalister freshes for maximum benefit	May	2, 3, 4a, 5, 6	Timing of migration from Koster et al. (2013; 2018), Amtstaetter et al. (2016) and Reinfelds et al. 2013). Flow magnitude and duration from Amtstaetter et al. (2016).
		Extended connectivity for downstream migration by juvenile Short-headed lamprey, Pouched lamprey, adult Tupong, adult Australian bass, adult Common galaxias. Extended connectivity for upstream migration by adult Short-headed lamprey, adult Pouched lamprey.	F6	Winter base flow (areas of >0.4 m depth over riffles)	Winter / Spring (May - Oct)	2, 3, 4a, 5, 6	Timing of migration: short-finned eel (Crook et al. 2014); Tupong (Crook et al. 2010); Australian bass (Reinfelds et al. 2013); Common galaxias (Barbee et al. 2011); short-headed lamprey (Potter 1970). Flow magnitude and duration from Amtstaetter et al. (2016).

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
		Cue for downstream migration for juvenile Short-headed lamprey, adult Short-finned eel. Cue for upstream migration by adult Short-headed lamprey, adult Pouched lamprey, juvenile Short-finned eel, juvenile Tupong, adult and juvenile Australian bass, juvenile Common galaxias, juvenile Australian grayling, Broad-finned galaxias.	F7	Fresh (Spring) NB: Where possible schedule with Macalister freshes for maximum benefit	Oct-Nov	2, 3, 4a, 5, 6	Timing of migration: Short-headed lamprey (Potter 1970; Amtstaetter et al 2019), Tupong (Zampatti et al. 2010; Amtstaetter et al 2019); Short-finned eel (Sloane 1984; Amtstaetter et al 2019), Galaxias species (Amtstaetter et al. 2017; 2019); Australian bass (Reinfelds et al. 2013). Flow magnitude and duration from Amtstaetter et al. (2016). Note: Oct/Nov fresh may be met by provision of F8.
	Lateral connectivity and habitat maintenance to support wetland specialist fish	Provide connectivity between main channel and low-lying freshwater wetlands for dispersal and recolonization by wetland specialists (Dwarf galaxias, Southern pygmy perch).	F8	Sub-bankfull NB: Where possible schedule with Macalister freshes for maximum benefit	Oct/Nov	5, 6	Colonisation of freshwater wetlands by Dwarf galaxias and Southern pygmy perch and benefits of enhancing connectivity and wetting/drying cycles for this species from Coleman (2017) and Hale et al. (2018).

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
Vegetation – Microbial biofilms	Maintain microbial biofilms on submerged surfaces (e.g. gravel, cobbles and coarse woody debris)	Adequate volume and flow of water in-stream to maintain existing biofilms Periodic higher flows to disturb substrata on which biofilms are attached, scour existing biofilms and generate new colonisation sites	V1	Summer-autumn and winter-spring baseflows (will be of different magnitude in the two periods) Freshes of variable flow/velocity to disturb substrata and scour biofilms	Summer-autumn and winter-spring	2, 3	Almost nothing is known of the microbial biofilms in the Thomson River, but they are likely to play an important role in food-web dynamics and nutrient spiralling in the upper reaches. Maintaining microbial biofilms is rarely, if ever, invoked in FLOWS studies and is likely often overlooked as a vegetation objective for upland streams.
Vegetation – Submerged vascular plants	Maintain or where possible enhance native submerged vascular plants such as eelweed (*Vallisneria americana*), milfoils (*Myriophyllum* spp.), pondweeds (*Potamogeton* spp.) and, possibly, Water Ribbon (*Cycnogeton procerum*)	Adequate volume and flow of water in-stream throughout the year to maintain obligately submerged taxa Periodic higher flows to permit downstream dispersal of propagules and sexual and asexual recruitment	V2	Summer-autumn and winter-spring baseflows (will be of different magnitude in the two periods) Freshes to disperse propagules (for sexually recruiting	Summer-autumn and winter-spring	2, 3, 4a, 5	Prior detailed vegetation studies (e.g. VEFMAP) have focussed on fringing and riparian vegetation, and submerged vascular plants have received little monitoring effort. It is therefore unclear in which reaches of the Thomson submerged vascular plants are present. For this investigation it is assumed they are present

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
				species) and plant fragments (for clonal species)			in all reaches, although likely to have only a scattered distribution. Prior VEFMAP reports have reported that scattered submerged native aquatics (e.g. as *Potamogeton* spp. and *Myriophyllum* spp.) occur in parts of the stream not subjected to strong currents but even so the main parts of the river channel seems not to support these types of plants widely (e.g. VEFMAP 2009). Note also the possible presence of the exotic submerged aquatic weed Canadian Pondweed (**Elodea canadensis*) in Reaches 2 and 3, possibly downstream as well.
Vegetation – Non-woody fringing vascular plants	Maintain or where possible enhance native non-woody fringing vegetation such as Common	Damp or wet substratum to maintain adult plants Flow variability to maintain zonation of vegetation	V3	Summer - autumn and winter-spring baseflows (will be of different	Summer-autumn and winter-spring	2, 3, 4a, 5, 6	-

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
	Reed (*Phragmites australis*), rushes (*Juncus* spp.), knotweeds (*Persicaria* spp.), Leafy Flat-sedge (*Cyperus lucidus*), Swamp Club-sedge (*Isolepis inundata*) and River Club-sedge (*Schoenoplectus tabernaemontani*)	according to elevation and flow requirements of individual taxa Periodic higher flows to permit downstream dispersal of propagules and sexual and asexual recruitment		magnitude in the two periods) Freshes of various magnitudes to maintain vertical plant zonation Freshes to disperse propagules (for sexually recruiting species) and plant fragments (for clonal species)			
Vegetation – Woody and non-woody vegetation in channel, on benches and in lower riparian zone (prevention)	Prevent colonisation of in-stream channel, low-lying benches and lower riparian zone by undesirable taxa, especially by terrestrial or weedy plant species intolerant of	Prevent encroachment of terrestrial weed taxa intolerant of prolonged submergence by periodic or permanent inundation of stream, low-lying benches and lower parts of the riparian zone	V4	Summer-autumn and winter-spring baseflow to prevent colonisation of stream channel (may be of different magnitude in	Summer-autumn and winter-spring	2, 3, 4a, 4b, 5, 6	The duration and frequency of inundation required to prevent colonisation of aquatic habitats by native trees and shrubs is poorly understood, as is the timing and duration of inundation required to kill exotic weeds that have

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
	prolonged inundation			the two periods) Freshes to prevent colonisation of low-lying benches and lower riparian zone			already colonised benches and the lower riparian zone (e.g. Blue Periwinkle *Vinca major* and Wandering Tradescantia *Tradescantia fluminensis* in Reaches 4a and 4b). Colonisation of the stream channel by undesirable native taxa under reduced flows (e.g. by Common Reed) is also possible in Reaches 3, 4a and 4b.
Vegetation – Water-dependent woody riparian trees and shrubs	Maintain water-dependent taxa of existing EVCs in riparian zones along river.	Damp or wet substratum to maintain adult plants Flow variability to maintain zonation of vegetation according to elevation and flow requirements of individual taxa Periodic higher flows to permit downstream dispersal of propagules and sexual and asexual recruitment	V5	Summer-autumn and winter-spring baseflows (will be of different magnitude in the two periods) Freshes of various magnitudes to maintain	Summer-autumn and winter-spring	3, 4a, 4b, 5, 6	The main EVC of concern is EVC 56 Floodplain Riparian Woodland which has the water-dependent Swamp Gum (*Eucalyptus ovata*) as an important canopy-forming tree. EVC 53 Swamp Scrub, with its water-dependent Swamp Paperbark (*Melaleuca ericifolia*) is also relevant in some smaller tributaries of Reach 3.

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
				vertical plant zonation Freshes to disperse propagules (for sexually recruiting species) and plant fragments (for clonal species)			
Vegetation – Maintain cool-damp valley microclimates required for surrounding terrestrial vegetation	Maintain local microclimates (especially lower air temperature and relative humidity) in valleys and gullies required by surrounding terrestrial EVCs that require damp conditions (e.g. EVCs 18,29, 39 and 56)	Presence of water in-stream creates a localised gully/valley microclimate with lower temperature and relative humidity in nearby terrestrial areas. The plant taxa in these EVCs are not directly water-dependent but do require the moderated climatic conditions generated by the presence of a nearby stream.	V6	Summer-autumn and winter-spring baseflows (will be of different magnitude in the two periods)	Summer-autumn and winter-spring	2, 3, 4a	A novel concept that recognises the role played by streams in modifying nearby terrestrial microclimates (see Section 7.2.3 above). This concept has rarely been invoked in FLOWs studies to date and the mechanism responsible and required flows are poorly understood. Relevant EVCs include EVC 18 Riparian Forest, EVC 29 Damp Forest, EVC

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
							39 Montane Wet Forest and EVC 56 Floodplain Riparian Woodland in Reaches 2,3 and 4a.
Vegetation – Freshwater floodplain wetlands	Maintain and where possible enhance native vegetation in billabongs and other floodplain wetlands (e.g. EVC 334 Billabong Wetland Aggregate and EVC 681 Deep Freshwater Marsh)	Floodplain wetlands are inundated when connected to river via floodrunners etc below level of the top of bank (i.e. inundation of floodplain wetlands not requiring overbank flows)	V7	High but sub-bankfull (e.g. very large fresh)	Anytime, but preferably spring	5 (lowest parts only), 6	Relate to commence-to-flow values established for a suite of floodplain wetlands in Reach 6.
Vegetation – Floodplains	Enhance native foodplain vegetation (especially EVC 56 Floodplain Riparian Woodland)	Maintain adults and enhance recruitment of juvenile water-dependent plants on lower floodplain	V8	Overbank	Anytime, but preferably spring	6	Note the requirement of environmental flows not to inundate private land on the floodplain.
Platypus / Rakali	Increase abundance of Platypus / Rakali	Localised Platypus / Rakali movement between habitats to increase foraging opportunities and refuge from predators	P1	Baseflow	All year	4a and 5	-
Platypus	**Avoid** bankfull flows during Oct to March (breeding season)	Bankfull flows increase the risk of juveniles in burrows drowning or being displaced	P2	Bankfull	October to March	4a and 5	Note the objective is to **avoid** bankfull flows, not target

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
Birds, amphibians, reptiles	Support populations of birds, reptiles and amphibians	Inundate wetlands / low lying areas on floodplain to maintain habitat and increase food sources	FN1	Overbank / bankfull	Spring and summer	All	-
Geomorphology	Maintain / enhance physical form and functioning through refuge habitat provision	Maintain deep pools for refuge habitat (fish)	G1	Baseflow	Spring and summer	All	-
Geomorphology	Maintain / enhance physical form and functioning through slackwater habitat provision	Provide slow and shallow habitat for larval/juvenile fish and macroinvertebrates	G2	Baseflow	Various seasons coincident with biotic cycles	All	-
Geomorphology	Maintain / enhance physical form and functioning through hydraulic habitat diversity	Provide velocity and depth diversity (runs, glides, pools) and maximise wetted perimeter	G3	Baseflow	Various seasons coincident with biotic cycles	All	-
Geomorphology	Maintain / enhance physical form and functioning through woody debris habitat provision	Maintain depth over large woody debris for macroinvertebrates	G4	Baseflow	Spring and summer	All	-
Geomorphology	Maintain / enhance physical form and functioning through bank stability	Maintain toe vegetation to trap sediments and stabilise banks	G5	Baseflow	Spring and summer	All	-

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
Geomorphology	Maintain / enhance physical form and functioning through maintaining sediment substrate condition	Prevent sediment smothering by mobilising fine sediments	G6	Fresh	All year, particularly spawning periods	2, 3, 4a, 5, 6	-
Geomorphology	Maintain / enhance physical form and functioning through maintaining sediment condition and diversity	Turnover sediment to maintain substrate condition and diversity	G7	Fresh	All year	2, 3, 4a, 5, 6	
Geomorphology	Maintain / enhance physical form and functioning through bed disturbance, channel maintenance refuge habitat	Maintain channel form, depth diversity, prevent pool infilling (particularly Reach 4a)	G8	Fresh	All year, particularly prior to low flow periods	2, 3, 4a, 5, 6	-
Geomorphology	Maintain / enhance physical form and functioning through bar and bench maintenance	Maintain bars and benches by mobilising and depositing sediments on existing bars and benches	G9	Fresh	All year	2, 3, 4a, 5, 6	-

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
Geomorphology	Maintain / enhance physical form and functioning through bank condition	Deposit and drape sediments (and seeds) on riverbanks	G10	High flows / sub-bankfull	Piggy-back tributary inflows	2, 3, 4a, 5, 6	-
Geomorphology	Maintain / enhance physical form and functioning through pool habitat maintenance	Maintain depth diversity through pool creation	G11	High flows / sub-bankfull	All year	All	
Geomorphology	Maintain / enhance physical form and functioning through bar and bench formation	Build bars and benches by mobilising sediments	G12	High flows / sub-bankfull	All year	All	-
Geomorphology	Maintain / enhance physical form and functioning through recruiting OM, carbon and large wood	Inundate flood runners and anabranches (sub-bankfull)	G13	High flows / sub-bankfull	All year	All	-
Social / economic	Maintain recreation opportunities in Cowwarr Weir (swimming, fishing, birdwatching, canoeing, picnicking)	Increased flow to increase the attractiveness of the environment	S1	Baseflow	All year	3	-

Value	Objective	Mechanism	ID	Flow type / hydraulic criteria	Timing	Relevant reaches	Comments / justification
	Maintain and enhance kayaking / canoeing opportunities along the river	Increased flow improves quality of experience	S2	High Baseflow Freshes	Spring / summer	2, 3, 6	-
	Maintain opportunities for camping (presence of running water or lake)	Increased flow to increase the attractiveness of the environment	S3	Baseflow	All year	2, 3	-

*Objectives relating to water quality and carbon cycling are included in the fish, macroinvertebrate and geomorphic objectives

13. **References**

Alluvium (2014) Assessment of the impacts of recent bushfires in Thomson River and Traralgon Creek catchments. A report for the West Gippsland CMA, Traralgon.

Alluvium (2019) Improving understanding to inform environmental water management and allocation: River flow changes and environmental water shortfalls in Central Gippsland. Report P118101R01 by Alluvium Consulting Australia for West Gippsland CMA, Traralgon.

Amtstaetter, F. (2010) Thomson and Macalister rivers environmental flows monitoring program: 2010 native fish survey report. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria.

Amtstaetter, F., O'Connor, J. and Pickworth, A. (2016) Environmental flow releases trigger spawning migrations by Australian grayling *Prototroctes maraena*, a threatened, diadromous fish. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(1), pp.35-43.

Amtstaetter, F., O'Connor, J., Borg, D., Stuart, I. and Moloney, P. (2017) Remediation of upstream passage for migrating Galaxias (Family: Galaxiidae) through a pipe culvert. *Fisheries Management and Ecology*, *24*(3), pp.186-192.

Amtstaetter, F., O'Connor, J., Tonkin, Z, Koster, W., Stuart, I and Hale, R. (2019) VEFMAP Stage 6: Monitoring fish response to environmental flow delivery in Victorian coastal rivers. Unpublished Client Report for the Water and Catchments Group. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Arai, T., Kotake, A., Lokman, P.M., Miller, M.J. and Tsukamoto, K. (2004) Evidence of different habitat use by New Zealand freshwater eels *Anguilla australis* and *A. dieffenbachii*, as revealed by otolith microchemistry. *Marine Ecology Progress Series*, *266*, pp.213-225.

Australian Institute for Disaster Resilience (2012) Flood - Gippsland Victoria, June, 2012. https://knowledge.aidr.org.au/resources/flood-gippsland-victoria-2012/ [viewed 28/11/2019]

Australian National Herbarium (2019) Australian flora statistics. https://www.anbg.gov.au/aust-veg/australian-flora-statistics.html [viewed 28/11/2019]

Australian Platypus Conservancy (2020) Rakali/Water-rat - Australia's "otter". https://platypus.asn.au/rakali/ [viewed 22/1/202]

Barbee, N.C., Hale, R., Morrongiello, J., Hicks, A., Semmens, D., Downes, B.J. and Swearer, S.E. (2011) Large-scale variation in life history traits of the widespread diadromous fish, *Galaxias maculatus*, reflects geographic differences in local environmental conditions. *Marine and Freshwater Research*, *62*(7), pp.790-800.

Benzie, V. (1968) Stages in the normal development of *Galaxias maculatus attenuatus* (Jenyns). *New Zealand Journal of Marine and Freshwater Research, 2*, 606-627.

Bice, C. M., Zampatti, B. & Koster, W. (2019) Tracking lamprey spawning migration in the River Murray. South Australian Research and Development Institute (SARDI), Adelaide. SARDI Publication No. F2019/000190-1. SARDI Research Report Series No. 1027. 36 pp.

Boon, P.I. (2012) Coastal wetlands of temperate eastern Australia: will Cinderella ever go to the ball? *Marine and Freshwater Research 63*, 845-855.

Boubée, J.A.T. & Williams, E.K. (2006) Downstream passage of silver eels at a small hydroelectric facility. *Fisheries Management and Ecology, 13*, 165-176.

Brock, M. A. & Casanova, M. T. (1997) Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. *Frontiers in ecology: building the links* (Eds N. Klomp & I. Lunt), pp. 181−192. Elsevier, Oxford, UK.

Brock, M.A. & Casanova, M.T. (2000) Are there plants in your wetland? Revegetating wetlands. Land & Water R&D Corporation, Canberra.

Brown, P. (2011) Australian bass movement, migration and habitat suitability in the Snowy River. *Freshwater fish resources in the Snowy River, Victoria.*, p.67.

Cadwallader, P.L. & Backhouse, G.N. (1983) A guide to the freshwater fish of Victoria. US Government Printing Office.

Campbell, I.C. (1986) Life Histories of some Australian Siphlonurid and Oligoneuriid Mayflies (Insecta: Ephemeroptera). *Australian Journal of Marine and Freshwater Research*, *37*, 261-88.

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

Catford, J. A., W. K. Morris, P. A. Vesk, C. J. Gippel, & B. J. Downes (2014) Species and environmental characteristics point to flow regulation and drought as drivers of riparian plant invasion. *Diversity and Distributions*, *20*, 1084–1096.

Chessman, B.C. (1986) Dietary studies of aquatic insects from two Victorian rivers. *Australian Journal of Marine and Freshwater Research*, *37*, 129-146.

Coleman, R.A., Weeks, A.R. & Hoffmann, A.A. (2013) Balancing genetic uniqueness and genetic variation in determining conservation and translocation strategies: a comprehensive case study of threatened dwarf galaxias, *Galaxiella pusilla* (Mack)(Pisces: Galaxiidae). *Molecular Ecology*, *22*(7), pp.1820-1835.

Coleman, R.A., Raadik, T.A., Pettigrove, V. & Hoffmann, A.A. (2017) Taking advantage of adaptations when managing threatened species within variable environments: the case of the dwarf galaxias, *Galaxiella pusilla* (Teleostei, Galaxiidae). *Marine and Freshwater Research*, *68*(1), pp.175-186.

Colmer, T. D. & Voesenek, L. A. C. J. (2009) Flooding tolerance: suites of plant traits in variable environments. *Functional Plant Biology*, *36*, 665-681.

Cook, B.D., Bunn, S.E. & Hughes, J.M. (2007) Molecular genetic and stable isotope signatures reveal complementary patterns of population connectivity in the regionally vulnerable southern pygmy perch (*Nannoperca australis*). *Biological Conservation*, *138*(1-2), pp.60-72.

Cooperative Research Centre for Freshwater Ecology (2001) Development of a Rehabilitation Plan for the lower Thomson and Macalister Rivers: A scoping Study, Technical Report 5/2001, Cooperative Research Centre for Freshwater Ecology, University of Canberra, ACT 2601.

Crook, D.A., Macdonald, J.I., O'Connor, J.P. & Barry, B. (2006). Use of otolith chemistry to examine patterns of diadromy in the threatened Australian grayling *Prototroctes maraena*. *Journal of Fish Biology*, *69*(5), pp.1330-1344.

Crook, D.A., Macdonald, J.I. & Raadik, T.A. (2008) Evidence of diadromous movements in a coastal population of southern smelts (Retropinninae: Retropinna) from Victoria, Australia. *Marine and Freshwater Research, 59*, 638-646.

Crook, D. A., W. M. Koster, J. I. Macdonald, S. J. Nicol, C. A. Belcher, D. R. Dawson, D. J. O'Mahony, D. Lovett, A. Walker, & Bannam, L. (2010) Catadromous migrations by female tupong (*Pseudaphritis urvillii*) in coastal streams in Victoria, Australia. *Marine and Freshwater Research, 61*, 474–483.

Crook, D.A., Macdonald, J.I., Morrongiello, J.R., Belcher, C.A., Lovett, D., Walker, A. & Nicol, S.J. (2014) Environmental cues and extended estuarine residence in seaward migrating eels (*Anguilla australis*). *Freshwater Biology*, *59*(8), pp.1710-1720.

Crowther, D. & Papas, P. (2016) Riparian vegetation functions that support aquatic insects. Arthur Rylah Institute for Environmental Research Unpublished Client Report for Fisheries Victoria, Department of Economic Development, Jobs, Transport and Resources. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Davis, K. T., Dobrowski, S. Z., Holden, Z. A., Higuera, P. E., & Abatzoglou, J. T. (2019) Microclimatic buffering in forests of the future: the role of local water balance. *Ecohydrology*, *42*, 1−11.

Dawson, D.R. & Koster, W.M. (2018) Habitat use and movements of Australian grayling (*Prototroctes maraena*) in a Victorian coastal stream. *Marine and Freshwater Research*, 69(8), pp.1259-1267.

Doody, T. M., Holland, K. L., Benyon, R. G., & Jolly, I. D. (2009) Effect of groundwater freshening on riparian vegetation water balance. *Hydrological Processes: An International Journal*, *23*(24), 3485-3499.

Doody, T. M., Benger, S. N., Pritchard, J. L., & Overton, I. C. (2014) Ecological response of *Eucalyptus camaldulensis* (river red gum) to extended drought and flooding along the River Murray, South Australia (1997–2011) and implications for environmental flow management. *Marine and Freshwater Research*, *65*(12), 1082-1093.

DSE (2010) Index of Stream Condition: the third benchmark of Victorian river condition. West Gippsland region. Department of Sustainability and Environment, East Melbourne. https://www.water.vic.gov.au/data/assets/pdf_file/0022/34816/ISC_Part_8_West_Gippsland.pdf [accessed 26/11/2019]

Dugdale, S. J., Malcolm, L. A., Kantola, K., & Hannah, D. M. (2018) Stream temperature under contrasting riparian forest cover: understanding thermal dynamics and heat exchange processes. *Science of the Total Environment*, *610*, 1375−1389.

Earth Tech (2003) Thomson River Environmental Flow Requirements & Options to Manage Flow Stress. Report for West Gippsland Catchment Management Authority, Department of Sustainability and Environment, Melbourne Water Corporation, Southern Rural Water. September 2003.

Earth Tech (2005) Thomson River environmental flow requirements and options to manage flow stress. Earth Tech Engineering. Melbourne, Victoria.

Frood, D. (2012) Water and salinity regime and depth preferences for Victorian wetland ecological vegetation classes. Department of Sustainability and Environment, East Melbourne.

GHD (2015) Assessment of Accuracy of Baseflow Studies Latrobe, Thomson Macalister and Mitchell Rivers. A report for the Department of Environment, Land, Water and Planning, May 2015.

GLAWAC (2015) Gunaikurnai Whole of Country Plan. Gunaikurnai Land and Waters Aboriginal Corporation, Traralgon.

GLAWAC (2020) Carran Carran - The Thomson River. 23/4/2020.

Gorman, O.T. & Karr, J.R. (1978) Habitat structure and stream fish communities. *Ecology*, *59*(3), pp.507-515.

Gray, D (2011) Floods inundate Gippsland farms, close roads. Article in the Age Newspaper. Retrieved from: https://www.theage.com.au/national/victoria/floods-inundate-gippsland-farms-close-roads-20110811-1iouk.html [accessed 26/11/2019]

Greet, J., Webb, A.J. & Downes, B.J. (2011a) Flow variability maintains the structure and composition of in-channel riparian vegetation. *Freshwater Biology*, *56*: 2514-2528.

Greet, J., Webb, A.J. & Cousens, R.D. (2011b) The importance of seasonal flow timing for riparian vegetation dynamics: a systematic review using causal criteria analysis. *Freshwater Biology, 56*: 1231−1247.

Greet, J., R. D. Cousens & J. A. Webb (2012) Flow regulation affects temporal patterns of riverine plant seed dispersal: potential implications for plant recruitment. *Freshwater Biology, 57*, 2568–2579.

Greet, J., R. D. Cousens & J. A. Webb (2013) Seasonal timing of inundation affects riparian plant growth and flowering: Implications for riparian vegetation composition. *Plant Ecology, 214*, 87–101.

Hale, R., Coleman, R., Sievers, M., Brown, T.R. & Swearer, S.E. (2018) Using conservation behaviour to manage ecological traps for a threatened freshwater fish. *Ecosphere*, *9*(8), p.e02381.

Harding, D.J., Dwyer, R.G., Mullins, T.M., Kennard, M.J., Pillans, R.D. & Roberts, D.T. (2017) Migration patterns and estuarine aggregations of a catadromous fish, Australian bass (*Percalates novemaculeata*) in a regulated river system. *Marine and Freshwater Research*, *68*(8), pp.1544-1553.

Harris, J. H. (1986) Reproduction of the Australian bass, *Macquaria novemaculeata* (Perciformes : Percichthyidae) in the Sydney Basin. *Marine and Freshwater Research, 37,* 209-235.

Harris, J.H. & Silveira, R. (1999) Large-scale assessments of river health using an Index of Biotic Integrity with low-diversity fish communities. *Freshwater Biology*, *41*(2), pp.235-252.

Jacobs, APC & cesar (2016) Understanding the environmental water requirements of platypus. Report by Jacobs, Australian Platypus Conservancy and cesar for Melbourne Water.

Johnson, M. F. & Wilby, R. L. (2015) Seeing the landscape for the trees: metrics to guide riparian shade management in river catchments. *Water Resources Research*, *51*, 3754–3769.

Jones C.S. & Mole B. (2018) VEFMAP Stage 6: Monitoring vegetation response to environmental flow delivery in Victoria 2017/18. Arthur Rylah Institute report to the Department of Environment, Land, Water and Planning, Melbourne.

Jones C.S. & Vivian. L. (2019) Monitoring vegetation response to environmental flow delivery in Victoria. Arthur Rylah Institute for Environmental Research. Unpublished Client Report for the Water and Catchments Group, Department of Environment, Land, Water and Planning.

Jowett, I.G. (1993) A method for objectively identifying pool, run, and riffle habitats from physical measurements. *New Zealand journal of marine and freshwater research*, *27*(2), pp.241-248.

Khan, M.T., Khan, T.A. & Wilson, M.E. (2004) Habitat use and movement of river blackfish (*Gadopsis marmoratus R*.) in a highly modified Victorian stream, Australia. *Ecology of Freshwater Fish*, *13*(4), pp.285-293.

Koster, W. (2006) Thomson and Macalister rivers environmental flows monitoring: native fish component 2006. Data report for West Gippsland Catchment Management Authority. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W. & Crook, D. (2006) Thomson and Macalister rivers environmental flows monitoring program – Native fish component: Summary report 2005. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W. & Dawson, D. (2008) Thomson and Macalister rivers environmental flows monitoring program – Native fish component: 2008 data summary. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W. M. & Crook, D.A. (2008) Diurnal and nocturnal movements of river blackfish (*Gadopsis marmoratus*) in a south-eastern Australian upland stream. *Ecology of Freshwater Fish 17*, 146–154.

Koster, W., Dawson, D. & Ramsey, D. (2009) Thomson and Macalister rivers environmental flows monitoring program: 2009 native fish survey report. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria.

Koster, W. M., D. R. Dawson, & Crook, D.A. (2013) Downstream spawning migration by the amphidromous Australian grayling (*Prototroctes maraena*) in a coastal river in south-eastern Australia. *Marine and Freshwater Research, 64,* 31–41.

Koster, W.M., Amtstaetter, F., Dawson, D.R., Reich, P. & Morrongiello, J.R. (2017) Provision of environmental flows promotes spawning of a nationally threatened diadromous fish. *Marine and Freshwater Research*, *68*(1), pp.159-166.

Koster, W. M., D. A. Crook, D. R. Dawson, S. Gaskill, & Morrongiello, J.R. (2018) Predicting the influence of streamflow on migration and spawning of a threatened diadromous fish, the Australian Grayling *Prototroctes maraena*. *Environmental Management, 61*, 443-453.

Lancaster, J. (2019) Egg masses of some stream-dwelling caddisflies (Trichoptera: Hydrobiosidae) from Victoria, Australia. *Austral Entomology*, *58*.

Lawson, J.R., Fryirs, K.A., Lenz, T. & Leishman, M.R. (2015) Heterogeneous flows foster heterogeneous assemblages: relationships between functional diversity and hydrological heterogeity in riparian plant communities. *Freshwater Biology, 60*, 2208–2225.

Lee, F. and Perry, G.L. (2019) Assessing the role of off-take and source–sink dynamics in the extinction of the amphidromous New Zealand grayling (*Prototroctes oxyrhynchus*). *Freshwater Biology*, *64*(10), pp.1747-1754.

Levy, M (2012) Water surges towards lakes entrance after two day deluge. Article in the Sydney Morning Herald Newspaper. Retrieved from: https://www.smh.com.au/environment/weather/water-surges-towards-lakes-entrance-after-two-day-deluge-20120606-1zuww.html [accessed 26/11/2019]

McDowall, R. M., & Eldon, G.A. (1980) The ecology of whitebait migrations (Galaxiidae: Galaxias spp.). Fisheries Research Bulletin No. 20. New Zealand Ministry of Agriculture and Fisheries.

McPhail, L., Cheetham, M., Markham, A., Martin, J., Brooks, A., Vietz, G., Pearson, B., Tait, J. & Pietsch, T. (2018) Development of the stream rehabilitation guidelines for Queensland, in: Proceedings of the 9th Australian Stream Management Conference (G. J. Vietz, I. D. Rutherfurd, eds.), 12 – 15 August 2018, Hobart, Tasmania, pp. 305-308.

Merritt, D.M., Scott, M.L., Leroy Poff, N., Auble, G.T. & Lytle, D.A. (2010) Theory, methods and tools for determining environmental flows for riparian vegetation: Riparian vegetation-flow response guilds, *Freshwater Biology*, *55*, no. 1, pp. 206-225.

Miller, K. A., Webb, J. A., de Little, S. C., Stewardson, M. J. & Rutherford, I. D. (2015) How effective are environmental flows? Analyses of flow-ecology relationships in the Victorian Environmental Flow Monitoring and Assessment Program (VEFMAP) from 2011-2014. Melbourne.

Moore, R. D., Spittlehouse, D. L., & Story, A. (2005) Riparian microclimate and stream temperature response to forest harvesting: a review. *Journal of the American Water Resources Association*, *41*, 813–834.

Nguyen, T.T.T. & Ingram, B.A. (2011) Genetic diversity of Australian bass (*Macquaria novemaculeata*) in Victoria. Fisheries Victoria, Department of Primary Industries, Queenscliff, Vic.

O'Connor, W.G. & Koehn, J.D. (1998) Spawning of the broad-finned Galaxias, *Galaxias brevipinnis Günther* (Pisces: Galaxiidae) in coastal streams of southeastern Australia. *Ecology of Freshwater Fish*, 7, 95-100.

Park, G., Roberts, A. & Rutherfurd, I. (2019) Thomson Rainbow Creek Waterway Management Plan. INFFER analysis – Preliminary results. Report by Natural Decisions to WGCMA.

Potter, I.C. (1970) The life cycles and ecology of Australian lampreys of the genus Mordacia. *Journal of Zoology*, *161*(2), pp.487-511.

Potter, I.C., Hilliard, R.W. & Bird, D.J. (1980) Metamorphosis in the Southern Hemisphere lamprey, *Geotria australis*. *Journal of Zoology*, *190*, 405-430.

Practical Ecology (2009) Monitoring environmental flows in the Thomson and Macalister Rivers: Vegetation assessments 2009. Report to West Gippsland CMA, Traralgon.

Reich, P. & Downes, B.J. (2004) Relating larval distributions to patterns of oviposition: evidence from lotic hydrobiosid caddisflies. *Freshwater Biology*, *49*, 1423–1436.

Reinfelds, I.V., Walsh, C.T., Van Der Meulen, D.E., Growns, I.O. & Gray, C.A. (2013) Magnitude, frequency and duration of instream flows to stimulate and facilitate catadromous fish migrations: Australian bass (*Macquaria novemaculeata Perciformes*, Percichthyidae). *River Research and Applications*, *29*(4), pp.512-527.

Roberts, J. & Marston, F. (2011) *Water regime for wetland and floodplain plants: a source book for the Murray-Darling Basin*. National Water Commission, Canberra.

Rogers, K. & Ralph, T.J. (2011) *Floodplain wetland biota in the Murray-Darling Basin: water and habitat requirements*. CSIRO Publishing, Collingwood.

Rogers, K., Ralph, T.J. & Saintilan, N. (2012) The use of representative species as surrogates for wetland inundation. *Wetlands*, *32*, 249–256.

Ryan, J. G., & McAlpine, C. A. (2005) Simulating the feedback between land cover configuration and ecohydrological functioning in complex adaptive landscapes. Paper presented at the International Congress on Modelling and Simulation (MODSIM05), December 12-15, Melbourne (Australia).

Sandercock, P., Treadwell, S., Szemis, J., Boon, P., Koster, K. & Griffiths, J. (2018) Environmental flow study review for the Tarago and Bunyip rivers. Jacobs Australia Pty Ltd. Bendigo, Victoria.

Schmidt, D.J., Crook, D.A., Macdonald, J.I., Huey, J.A., Zampatti, B.P., Chilcott, S., Raadik, T.A. & Hughes, J.M. (2013) Migration history and stock structure of two putatively diadromous teleost fishes, as determined by genetic and otolith chemistry analyses. *Freshwater Science*, *33*(1), pp.193-206.

Schmidt, D.J., Crook, D.A., O'Connor, J.P. & Hughes, J.M. (2011) Genetic analysis of threatened Australian grayling *Prototroctes maraena* suggests recruitment to coastal rivers from an unstructured marine larval source population. *Journal of Fish Biology*, *78*(1), pp.98-111.

SKM (2012) Yarra River environmental flow study. Sinclair Knight Merz. Melbourne, Victoria.

Sloane, R.D (1984a) The upstream movements of fish in the Plenty River, Tasmania. Papers and Proceedings of the Royal Society of Tasmania 118:163-171.

Sloane, R.D. (1984b) Upstream migration by young pigmented freshwater eels (*Anguilla australis australis Richardson*) in Tasmania. *Marine and Freshwater Research*, 35(1), pp.61-73.

SRW (2016) Catchment Statement for Central Gippsland and Moe Groundwater Catchments version 2. Southern Rural Water, August 2016.

SRW (2019) Macalister Irrigation District Background, http://www.srw.com.au/projects/mid-modernisation/mid-modernisation-background/

State Emergency Service (2015) Sale Local Flood Guide. Flood information for the Thomson River at Sale. Retrieved from: https://www.ses.vic.gov.au/documents/112015/134935/Sale+Local+Flood+Guide/abf08a45-16d9-4de6-8357-870a750768c2 [accessed 26/11/2019]

Streamology (2020a) Thomson River Environmental Flows and Management Review: Flow Recommendations Paper. Report prepared by Streamology for West Gippsland CMA, June 2020.

Streamology (2020b) Thomson River Environmental Flows and Management Review: Shortfalls and Risk Assessment Paper. Report prepared by Streamology for West Gippsland CMA, June 2020.

VEWH (2017) Thomson Passing Flows Working Group Discussion Paper. Outcomes of Agenda Item 6, Thomson Passing Flows Working Group meeting 19 June 2017.

VEWH (2019) Thomson River, Retrieved from: from http://www.vewh.vic.gov.au/rivers-and-wetlands/gippsland-region/thomson-river, [accessed 26/11/2019]

Victorian State Government (2017a) Consolidated Bulk Entitlement (Thomson River – Environment) Order 2005 as at June 2017. Under Water Act 1989. Victorian Government Printer.

Victorian State Government (2017b) Consolidated Bulk Entitlement (Thomson River – Melbourne Water) Order 2014 as at June 2017. Under Water Act 1989. Victorian Government Printer.

Victorian State Government (2018) Bulk Entitlement (Thomson / Macalister – Southern Rural Water) conversion order 2001 as at 7 June 2018. Under Water Act 1989. Victorian Government Printer.

Victorian State Government (2005) Bulk Entitlement (Thomson Macalister Towns – Gippsland Water) conversion order 2005. Under Water Act 1989. Victorian Government Printer.

Vietz, G.J., Rutherfurd, I.D., Stewardson, MS. & Finlayson, B.L (2012) Hydrodynamics and sedimentology of concave benches in a lowland river. *Geomorphology*, *147-148*, 86-101, doi: 10.1016/j.geomorph.2011.07.033.

Vietz, G. J., Sammonds, M. J. & Stewardson, M. J. (2013) Impacts of flow regulation on slackwaters in river channels, Water Resources Research, *49*(4), 1797.

Vietz, G. J., Lintern, A., Webb, J. A., Straccione, D. (2017) River bank erosion and the influence of environmental flow management, Journal of Environmental Management, *61*(3), 454-468.

Water Technology (2012) Monitoring environmental flows in the Thomson and Macalister Rivers: Vegetation assessments 2011. Report to West Gippsland CMA, Traralgon.

Water Technology (2015) Monitoring environmental flows in the Thomson and Macalister Rivers: Vegetation assessments 2014–2015. Report to West Gippsland CMA, Traralgon.

Waters, J.M., Shirley, M. & Closs, G.P. (2002) Hydroelectric development and translocation of *Galaxias brevipinnis*: a cloud at the end of the tunnel? *Canadian Journal of Fisheries and Aquatic Sciences*, *59*(1), pp.49-56.

Webb, J. A., S. C. de Little, K. A. Miller, M. J. Stewardson, I. D. Rutherfurd, A. K. Sharpe, L. Patulny, & N. L. Poff (2015) A general approach to predicting ecological responses to environmental flows: making best use of the literature, expert knowledge, and monitoring data. *River Research and Applications*, *31*, 505–514.

Webb, J.A., Stewardson, M.J. & Koster, W.M. (2010) Detecting ecological responses to flow variation using Bayesian hierarchical models. *Freshwater Biology*, *55*(1), pp.108-126.

Webb, J.A., Wallis, E.M. & Stewardson, M.J. (2012) A systematic review of published evidence linking wetland plants to water regime components. *Aquatic Botany, 103*, 1−14.

Webb, J.A., Miller, K.A., King, E.L., de Little, S.C, Stewardson, M.J., Zimmerman, J.K.H. & Poff, N.L. (2013). Squeezing the most out of existing literature: a systematic re-analysis of published evidence on ecological responses to altered flows. *Freshwater Biology*, *58*, 2439−2451.

Webb, J.A., Vietz, G.J., Koster, W.M. & Lintern, A. (2018) Evaluating responses to environmental flows using hydraulics: improved ecological realism and transferability among systems. Proceedings of the 12th International Ecohydraulics Conference, Tokyo, Japan, 19-24 August, 2018.

West Gippsland Catchment Management Authority (2015) Draft Macalister River Environmental Water Management Plan. West Gippsland Catchment Management Authority, Traralgon.

West Gippsland Catchment Management Authority (2019a) Thomson River Fishway Questions. Accessed from https://www.wgcma.vic.gov.au/thomson-river-fishway-questions, [accessed 26/11/2019]

West Gippsland Catchment Management Authority (2019b) Thomson River - Rainbow Creek Waterway Management Plan. West Gippsland Catchment Management Authority, Traralgon.

Williams and Serena (2018) Distribution of the Australian Water-rat *Hydromys chrysogaster* in Victoria: findings from community based sightings and live-trapping surveys. *The Victorian Naturalist*, *135*(3), 71-83.

Windecker, S. M. & Vietz, G. J. (2014) Assessing the influence of environmental flows on physical habitat, in: Australian Stream Management Conference, Catchments to Coast (G. J. Vietz, I. D. Rutherfurd, R. M. Hughes, eds.), June 30 to July 2, 2014, Townsville, Queensland, pp. 140-142.

Zampatti, B.P., Bice, C.M. & Jennings, P.R. (2010) Temporal variability in fish assemblage structure and recruitment in a freshwater-deprived estuary: the Coorong, Australia. *Marine and Freshwater Research*, *61*(11), pp.1298-1312.

Zavadil, E., Moar, D., & Vietz, G. (2011) Fluvial Geomorphology of the Thomson River. Prepared by Alluvium consulting for the West Gippsland Catchment Management Authority.