North Central CMA Region
Environmental Water Management Plan for the Campaspe River System

NORTH CENTRAL
Catchment Management Authority
Connecting Rivers, Landscapes, People

EWMP Area: Campaspe River downstream of Lake Eppalock to the Murray River

Department of Environment and Primary Industries

VICTORIAN ENVIRONMENTAL WATER HOLDER

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The North Central CMA Region Environmental Water Management Plan for the Campaspe River System is a a ten year plan, compiled from the best available information. It will be subject to a five-yearly review.

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Executive summary

The Campaspe River Environmental Water Management Plan (EWMP) sets out long-term objectives for the priority environmental values of the Campaspe River, downstream of Lake Eppalock to the Murray River. The EWMP is an important part of the Victorian Environmental Water Planning Framework. It provides the five to ten year management intentions, based on scientific information and stakeholder consultation, that can be used by the respective agencies; North Central Catchment Management Authority (CMA), Department of Environment and Primary Industries (DEPI) and the Victorian Environmental Water Holder (VEWH); for both short and longer-term environmental water planning.

This EWMP is not a holistic management plan for the river, but is focused on environmental water management so that the Campaspe River can continue to provide environmental, social, cultural and economic values for all users.

The following components are the main sections featured in the Campaspe River EWMP. A summary of the main conclusions to facilitate appropriate environmental water management in the Campaspe River into the future are summarised below.

Hydrology and system operations

Flow in the Campaspe River downstream of Lake Eppalock is regulated by the operation of the Lake Eppalock, Campaspe Weir and Campaspe Siphon. Due to this regulation current flows in the Campaspe River are characterised by longer periods of low flow and shorter periods of high flow compared to natural.

Water dependent values

The Campaspe River flows directly to the Murray River and has populations of threatened native fish, including Murray Cod, Golden Perch and Murray-Darling Rainbowfish. The river provides important in-stream habitat for aquatic fauna (e.g. Platypus) and has a relatively intact River Red Gum canopy along the river banks. Many native vegetation communities within the catchment are considered endangered or vulnerable.

Ecological condition and threats

The river is currently in relatively poor condition. Its native fish population, in particular its large bodied fishes, have consistently been captured at very low frequencies over the last six years of monitoring. There is very little evidence of recruitment of River Red Gum trees and the riparian zone primarily comprises a large very old (pre European settlement) trees. These two key components of the river ecology require targeted management of environmental water to facilitate natural recruitment.

Management objectives

A long-term management goal has been defined for the Campaspe River:

> **Campaspe River long term management goal**
> To rehabilitate the Campaspe River's highly valued and ecologically important River Red Gum communities, native fish populations and facilitate its connection to the Murray River through the provision of an appropriate water regime.

The ecological objectives and hydrological objectives that sit under the long-term management goal for the Campaspe River were assessed in 2006 (SKM 2006a) and have been reviewed and refined during the development of this EWMP (Jacobs 2014a). These objectives prescribe the environmental watering regime for the river.

Managing risks to achieving objectives

The threats to achieving the ecological objectives that are external to environmental water are identified. These include things such as instream barriers to fish movement and grazing of riparian vegetation.

Environmental water delivery infrastructure

The constraints to the delivery of environmental water (such as bankfull flows) have been identified. Infrastructure recommendations have been made and include the upgrade of the outlet at Lake

Eppalock to enable greater flows to be delivered and to prevent coldwater pollution that is currently experienced.

Demonstrating outcomes

Monitoring is required to allow the CMA to adaptively manage annual environmental watering (intervention monitoring). It is also required to enable the CMA and VEWH to demonstrate the long term outcomes of the implementation of the Campaspe River EWMP. As the State is currently reviewing the Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP), the Campaspe River EWMP recommends a suite of intervention and long-term monitoring activities that will meet the monitoring requirements.

Consultation

Key stakeholders, including DEPI, VEWH and Goulburn Murray Water (GMW) have been engaged during the development of this EWMP. The Campaspe Environmental Water Advisory Group (EWAG) also plays an important role in advising the North Central CMA on its management of environmental water in the Campaspe River. Local landholder, irrigator, environmental and indigenous community interests are represented on the Campaspe EWAG.

Knowledge Gaps

The management actions in the Campaspe River EWMP are based on the best available information. A number of knowledge gaps have been identified during the development of the EWMP, particularly around implementation of the winter and summer fresh events required to achieve ecological objectives for vegetation and the disturbance of slackwater habitat required to achieve ecological objectives for native fish.

Acknowledgments

Acknowledgement of Country

The North Central Catchment Management Authority (North Central CMA) acknowledges Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

Contributions to the Campaspe River EWMP

The information contained in the Campaspe River Environmental Water Management Plan (EWMP) has been sourced from a variety of reports and field inspections and from individual knowledge and expertise. The North Central CMA acknowledges the assistance of the following people in preparing this EWMP:

- Suzanne Witteveen, Andrea Keleher and Peter Johnson, Department of Environment and Primary Industries (DEPI)
- Caitlin Davis, Victorian Environmental Water Holder (VEWH)
- David Straccione and Kerrie Weber, Commonwealth Environmental Water Holder (CEWH)
- Geoff Earle (Goulburn Broken CMA)
- Andrew Shields (Goulburn Murray Water)
- Andrew Sharpe and Peter Sandercock (Jacobs), Paul Boon (Dodo Environmental), Paul Humphries (Charles Sturt University), Melody Serena (Australian Platypus Conservancy) (Environmental Flows Technical Panel)
- Terry Hillman and Jane Roberts (Expert Review Panel)
- Michelle Maher, Louissa Rogers, Emer Campbell, Darren White, Bree Bisset, Kira Woods, Rebecca Horsburgh, Peter McRostie, Tim Shanahan, Lyndall Rowley and Barry Hancock (North Central CMA).

1. Introduction

Management of environmental water is planned and implemented through a framework of key documents. Figure 1 illustrates the strategies, scientific reports and operational documents required for environmental water management in Victoria (DEPI 2013a). The North Central Catchment Management Authority (CMA) has recently developed the North Central Waterway Strategy - 2014-2022 which is an integrated strategy for managing and improving the region's waterways (rivers, streams and wetlands). The strategy sets priorities and outlines a regional works program to guide investment over the next eight years (North Central CMA 2014a). For the Campaspe River below Eppalock the North Central Waterway Strategy aims are:

- To improve the condition of the Lower Campaspe River from moderate to good (based on the Index of Stream Condition (ISC)) by 2050.
- To improve the condition of the riparian zone of the Lower Campaspe River by 2021 with a measured increase of one point in the streamside zone sub-index of the ISC.
- That the delivery of environmental flows are maximised contributing to increased hydrology and aquatic life ISC scores by 2021.

The North Central CMA is being funded through the Department of Environment and Primary Industries (DEPI) 'Victorian Basin Plan Environmental Water Management Plan (EWMP) Program' to prepare an EWMP for the Campaspe River. Once completed, annual seasonal watering proposals for the Campaspe River will be informed by the EWMP.

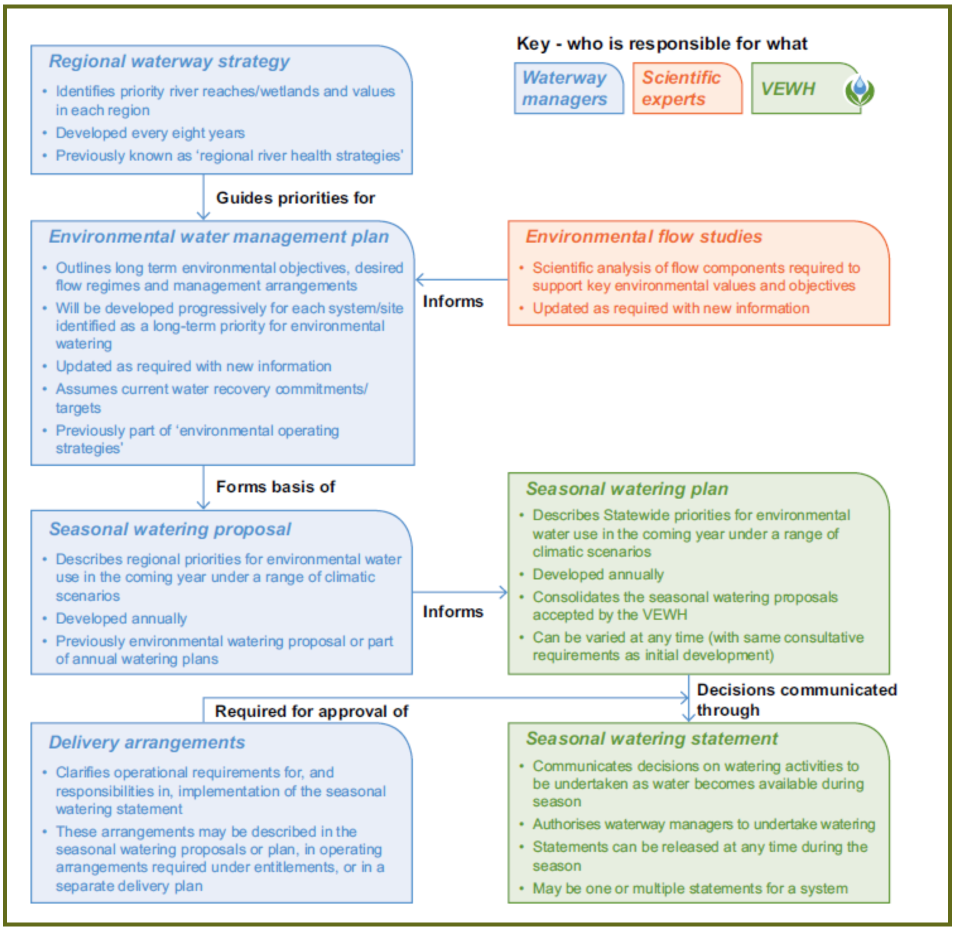

Figure 1: Planning framework for decisions about environmental water management in Victoria.

1.1. Purpose and scope of the Campaspe River Environmental Water Management Plan

The Campaspe River EWMP is a ten year management plan that describes the ecological values present, long-term goal for the river and priority ecological objectives and recommended flow regime to achieve the objectives. It is based on both scientific information and stakeholder consultation and will be used by the North Central CMA when making annual environmental watering decisions, as well as DEPI and the Victorian Environmental Water Holder (VEWH) for both short and longer-term environmental water planning (DEPI 2014a).

The key purposes of the EWMP are to:

- identify the long-term objectives and water requirements for the river
- provide a vehicle for community consultation, including for the long-term objectives and water requirements of the river
- inform the development of seasonal watering proposals and seasonal watering plans
- inform Long-term Watering Plans that will be developed by the State under the Basin Plan Chapter 8 (DEPI 2014a).

The scope of this EWMP is the three river reaches of the Campaspe River downstream of Lake Eppalock (Figure 2). An EWMP for Reach 1, which is the Coliban River, will be prepared separately. All other tributaries to the Campaspe River are unregulated.

1.2. Development process

The Campaspe River EWMP has been developed in collaboration with stakeholders including DEPI, VEWH and Goulburn Murray Water (GMW). A number of tasks were undertaken to develop the EWMP including:

- **Scoping and collating information:** a significant amount of technical work, monitoring and research has been undertaken on the Campaspe River to date.
- **Reconvening the Environmental Flows Technical Panel (EFTP):** The Campaspe River Environmental Flows Assessment was undertaken in 2006. The EFTP was reconvened to refine the ecological objectives and update the flow regime (including rerunning the HEC-RAS model) based on monitoring results and up-to-date scientific understandings on flow requirements of flora and fauna.
- **Workhop with the Victorian Environmental Water Holder (VEWH):** A workshop was held with the VEWH to develop a ten year water regime management approach (prioritising objectives and flow components) and to establish a monitoring program to allow the North Central CMA and the VEWH to demonstrate the outcomes of delivering environmental water in the Campaspe River.
- The outputs of these three tasks were analysed and provided evidence for the following sections:
    - **Water dependent values:** environmental values were derived from various sources identified during data collation. Additional data identified during the EFTP review was also incorporated, specifically related to Platypus. The water dependent values (fauna, vegetation communities and flora) are presented by reach. Terrestrial species that, due to large-scale clearing of woodland habitat throughout the catchment, are dependent on the vegetation within the riparian zone are also documented. Social values (cultural heritage, recreation and economic) are described.
    - **Ecological condition and condition trajectory without environmental water:** the condition, as reported in the Murray Darling Basin Wide Sustainable Rivers Audit and the Victorian statewide Index of Stream Condition, is discussed in light of Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) findings and analysis. The condition trajectory under a “do-nothing” scenario considers the flow regime under a consumptive water regulated system only.

- **Management objectives:** the water management goal and the ecological objectives for the river are based on the water dependent values recorded in the river, the current condition and the condition trajectory. The objectives are also aligned with the broader environmental outcomes proposed in the Basin Plan draft Environmental Watering Strategy.

  Hydrological objectives and the flow recommendations are based on known watering requirements of the objectives and outputs of the HEC-RAS modelling.

- **Managing risks:** the risks to achieving the ecological objectives for the Campaspe River are based on monitoring data, community concerns and best-available river health scientific knowledge as provided by the EFTP. Management actions to mitigate the risks are recommended (and included as Complementary Actions).

  Risks associated with the delivery of environmental water are also documented. Management actions to mitigate these risks relate to intervention monitoring and operational decision making.

  Residual risk assumes that management actions are fully implemented.

- **Environmental water delivery infrastructure:** current constraints in delivering the environmental flow recommendations are identified.

- **Demonstrating outcomes:** monitoring to adaptively manage the delivery of environmental water and to demonstrate the outcomes against the ecological objectives are based on best available science monitoring method and workshop outcomes with the VEWH.

- **Knowledge gaps and recommendations:** knowledge gaps were identified during the process of developing the ecological objectives, management actions and undertaking the risk analysis. An action list with timeframes has been developed whilst developing the EWMP, including a review of this EWMP in five years time.

- **Consultation:** consultation activities to date have included presenting components of the EWMP to the Campaspe Environmental Water Advisory Group (Campaspe EWAG) and engaging stakeholders and technical experts.

2. Site overview

The Campaspe River catchment extends from the Great Dividing Range in the south to the Murray River in the North. It covers a total area of approximately 4,000 square kilometres (km2) which corresponds to approximately 17 percent of the North Central region. The catchment is approximately 150 km long and has an average width of 25 km (Figure 2) (North Central CMA 2014b.

2.1. Site location

The Campaspe River catchment lies in the east of the North Central CMA region and is bordered by the Cobaw and Mt Camel Ranges to the east and Mt Alexander to the west. The Campaspe River is the major waterway in the catchment flowing 245 km north from its headwaters near Woodend to its confluence with the Murray River at Echuca. Figure 2 illustrates the main features of the Campaspe River.

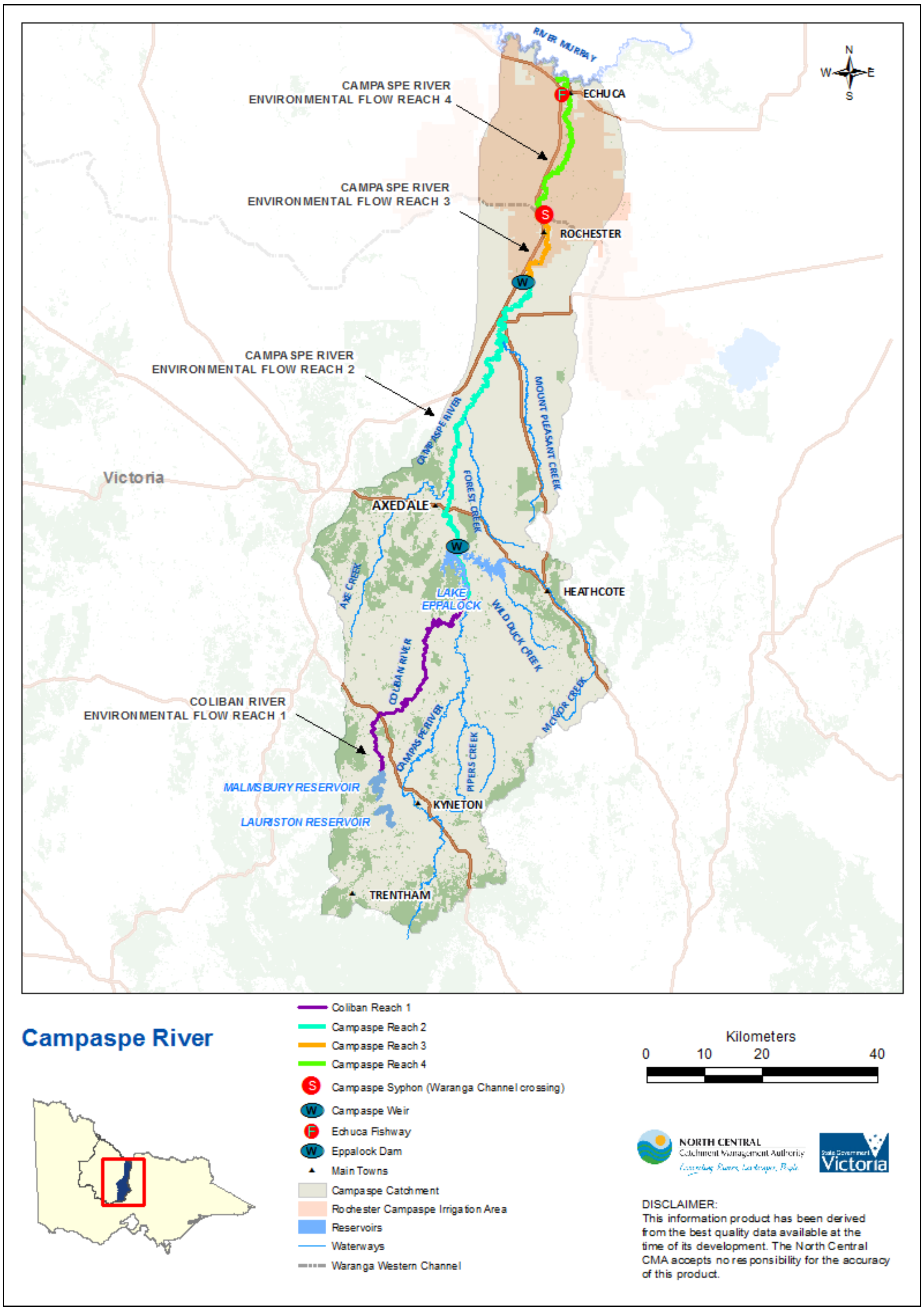

Figure 2: Campaspe River location map

2.2. Catchment setting

Climate

Annual rainfall in the Campaspe River basin ranges from 1080 mm on the Great Dividing Range in the south to approximately 400-500 mm on the drier northern plains (Lorimer & Schoknecht, 1987). Rainfall is generally higher in winter and most of the runoff occurs in late winter and early spring. The Campaspe basin covers 0.4 percent of the Murray-Darling Basin (MDB) and contributes about 0.9 percent of its total runoff (CSIRO 2008).

Hydrophysical characteristics

The upper and lower sections of Campaspe River are delineated by Lake Eppalock. This is a major water storage that harvests natural inflows from the upper section of the catchment. The Campaspe's major tributary is the Coliban River, which flows from Trentham, through the three Coliban Water storages (Lauriston, Malmsbury and Upper Coliban reservoirs) before reaching Lake Eppalock. The Campaspe River below Lake Eppalock is divided into three sections by artificial instream structures, the Campaspe Weir and the Campaspe Siphon. In the Campaspe River Environmental Flows Assessment (SKM 2006c) these sections are referred to as Reaches 2, 3 and 4.

From Lake Eppalock the river is a typical lowland river with relatively flat gradients with features such as moderate sinuosity, warmer, more turbid, slow-flowing water with fine sediment beds (Thoms & Sheldon 2000). Figure 3 illustrates the change in profile commencing from the source in the Great Dividing Range to the Murray River at Echuca. The floodplain is narrow, being approximately one kilometre wide, until it approaches Echuca where it broadens out to more than two kilometres.

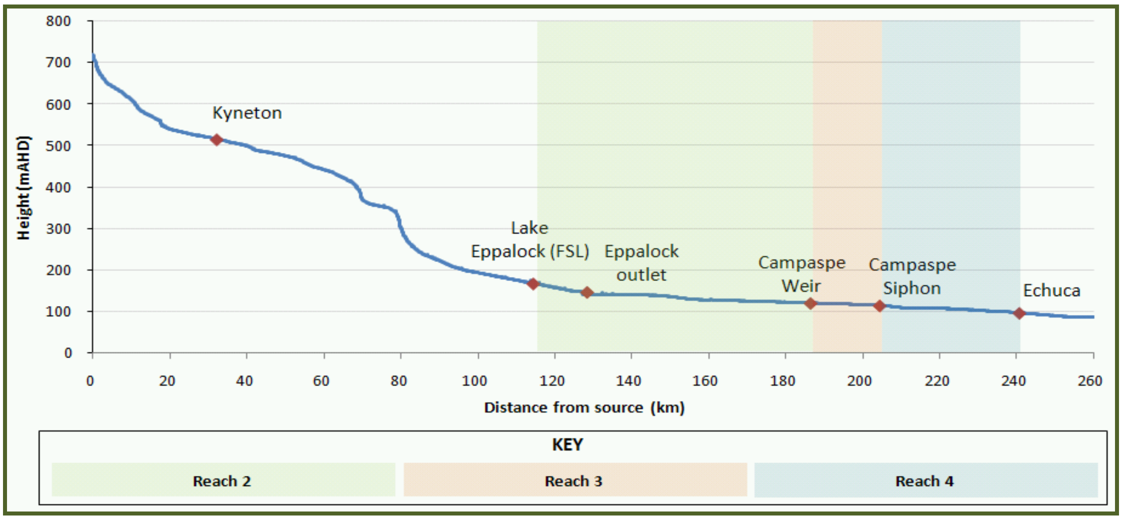

Figure 3: Profile of Campaspe River

<u>Reach 2</u> extends for approximately 85 km from the Lake Eppalock spillway to the Campaspe Weir and it begins in the Goldfields bioregion and then enters the Victorian Riverina bioregion just north of Axedale (DEP1 2014c). This section has three major tributaries, Forest Creek and Mount Pleasant Creek that enter from the east and Axe Creek (which is fed by Sheepwash Creek) that enters from the southwest near Axedale (North Central CMA 2006). Forest Creek and Mount Pleasant Creek are ephemeral, so the inflows from Axe Creek are the greatest natural input to the lower Campaspe River (SKM 2006b).

In this reach, the Campaspe River flows across bedrock through a deep gorge for six kilometres then through a combination of narrow gorge-like areas and wide valleys with small alluvial flats to the Axe Creek confluence (SKM 2006a; Aquade 2011). A survey undertaken in 2012 identified 24 deep pools that were three metres or deeper in a 35 kilometre section of the river between Lake Eppalock and the Bendigo Murchison Road. Pool 15, which is located near Backhaus Lane, is the deepest and longest pool recorded at 1.7 km long and 6.8 m deep (SKM 2012a). The lower sections of this reach meander across a broad alluvial floodplain to the Campaspe Weir nine kilometres north of Elmore (North Central CMA 2006).

<u>Reach 3</u> extends for 15 km from the Campaspe Weir and the Campaspe Siphon and is located within the Victorian Riverina bioregion. The channel deepens significantly through Reach 3. The floodplain

continues to be confined within high terraces, but in this reach tends to open out and floodrunners and other secondary channels are present (SKM 2012b). There are no unregulated tributary inflows to this section of the river (North Central CMA 2006). There are a number of pools in this reach too; however these are not as deep or as long as in Reach 2.

Reach 4 extends from the Campaspe Siphon and the confluence of the Campaspe River with the Murray River. It meanders for approximately 45 km through the lowland alluvial plains and is located within the Victorian Riverina Bioregion. The channel continues to deepen but the floodplain broadens and floodwaters extending across a broad area (SKM 2006a). In 2014, the North Central CMA coordinated the replacement of the gauge weir located in Echuca by a rock ramp fishway reinstating the hydrological connection between the Campaspe and Murray rivers even at low flows (Darren White pers. comm. [North Central CMA], 7 August 2014).

There are no significant wetland systems within the Campaspe catchment, although the water storages (Lake Eppalock and Campaspe Weir) support some wetland values and contribute to drought refuge areas (North Central CMA 2014b).

2.3. Land status and management

Land status

The Campaspe River flows through urban, peri-urban and rural townships including Kyneton, Elmore, Rochester and Echuca. The primary land use adjacent to the Campaspe River is grazing and cropping farmland (SKM 2006b).

The management of riparian areas along the Campaspe River is influenced by land status. The VEAC River Red Gum Investigation (2008) recommended that public riparian land, particularly in Reach 4, be classified as community use areas or natural features reserves.

Fifty-five kilometres of river frontage was alienated from the Crown before May 1881 and is privately owned (NCCMA 2013b). Around 32 kilometres of Crown land river frontage is leased to private landholders and there are small pockets of Crown land reserve under direct or delegated management. With a significant length of the Campaspe River being privately owned, restricting stock access to the river and riparian frontage is a challenge, particularly when a large proportion of the frontage remains unfenced. Seventy four percent of the Campaspe River is not fenced on either bank. Twenty four percent of the river is fenced on either the west or east side of the river and only two percent of the Campaspe River riparian zone is fenced on both banks. Figure 4 shows protected public and fenced private riparian land.

The Caring for the Campaspe project will provide incentives to landholders to fence riparian frontage, with the aim to fence 40 kilometres by 2016. This will increase the total length of fenced riparian zone to about 30% (Angela Gladman pers. comm. [North Central CMA Caring for the Campaspe Project Manager], 11 August 2014). The North Central CMA is currently preparing a funding proposal for phase 2 of the Caring for the Campaspe Project.

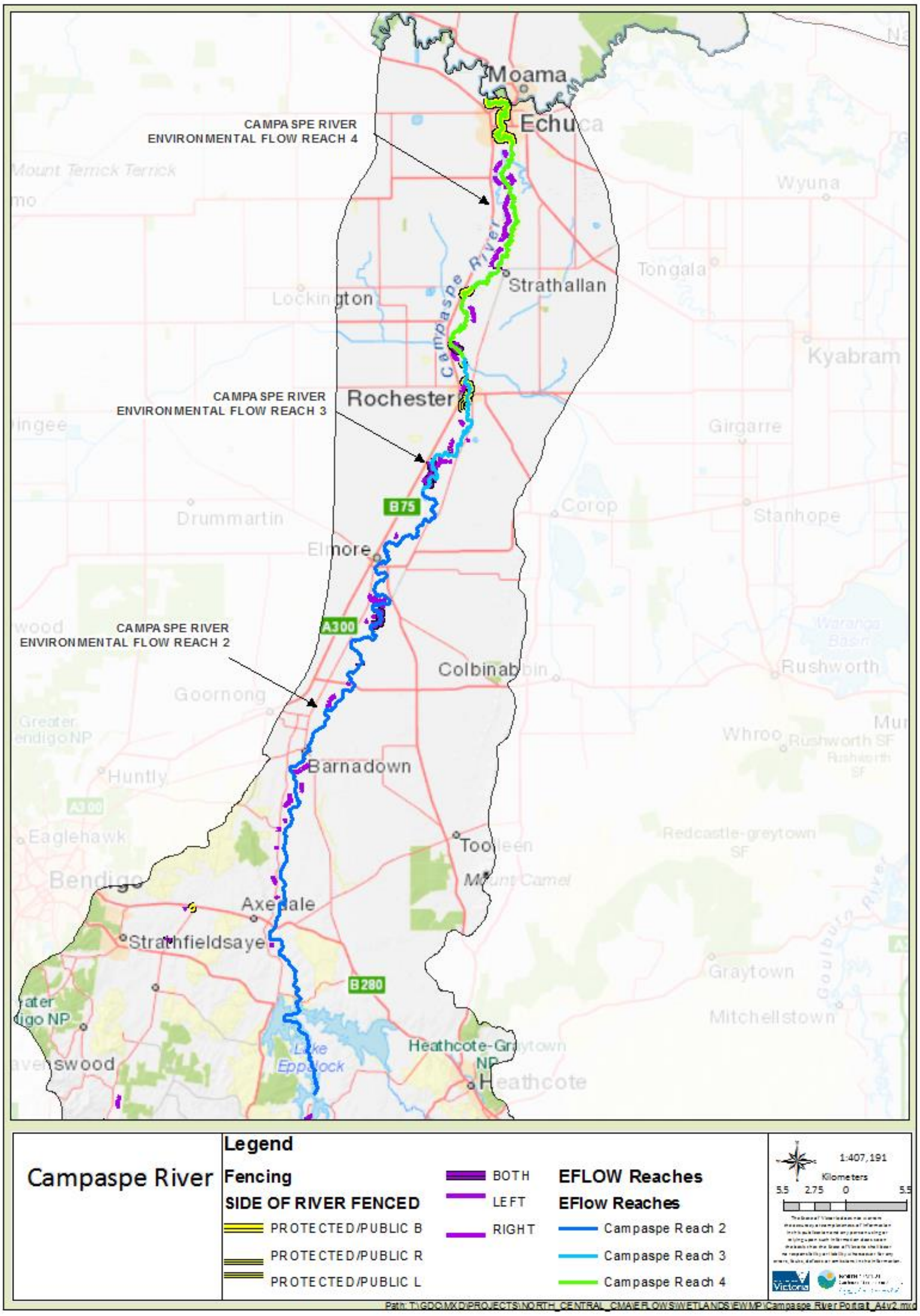

Figure 4: Protected public and fenced private riparian land along the Campaspe River

Environmental Water Management

There are several agencies directly involved in environmental water management in Victoria, and other agencies, such as public land managers, play an important role in facilitating the delivery of environmental watering outcomes. Table 1 summarises the agencies and groups that have involvement in environmental water management in the Campaspe River.

Table 1: Roles and responsibilities for environmental water in the Campaspe River (DEPI 2013a and VEWH 2014)

Agency/group	Responsibilities/involvement
Department of Environment and Primary Industries (DEPI)	Manage the water allocation and entitlements framework. Develop state policy on water resource management and waterway management approved by the Minister for Water and Minister for Environment and Climate Change. Develop state policy for the management of environmental water in regulated and unregulated systems. Act on behalf of the Minister for Environment and Climate Change to maintain oversight of the VEWH and waterway managers (in their role as environmental water managers).
Victorian Environmental Water Holder(VEWH)	Make decisions about the most effective use of the Water Holdings, including use, trade and carryover. Authorise waterway managers to implement watering decisions. Liaise with other water holders to ensure coordinated use of all sources of environmental water. Publicly communicate environmental watering decisions and outcomes.
Commonwealth Environmental Water Holder (CEWH)	Make decisions about the use of Commonwealth water holdings, including providing water to the VEWH for use in Victoria. Liaise with the VEWH to ensure coordinated use of environmental water in Victoria. Report on management of Commonwealth water holdings.
Murray-Darling Basin Authority (MDBA)	Implementation of the Murray-Darling Basin Plan - the Basin Plan sets legal limits on the amount of surface water and groundwater that can be taken from the Basin from 1 July 2019 onwards. Integration of Basin wide water resource management Manager of The Living Murray water entitlements
North Central Catchment Authority (North Central CMA) Waterway Manager	Identify regional priorities for environmental water management in regional Waterway Strategies In consultation with the community assess water regime requirements of priority rivers and wetlands to identify environmental watering needs to meet agreed objectives identify opportunities for, and implement, environmental works to use environmental water more efficiently. Propose annual environmental watering actions to the VEWH and implement the VEWH environmental watering decisions. Provide critical input to management of other types of environmental water (passing flows management, above cap water) report on environmental water management activities undertaken.
Goulburn Murray Water (GMW)	Water Corporation – Storage Manager and Resource Manager Work with the VEWH and waterway managers in planning for the delivery of environmental water to maximise environmental outcomes Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental water Ensure the provision of passing flows and compliance with management of diversion

	limits in unregulated and groundwater systems
Parks Victoria	Land Manager Implement the relevant components of EWMPs. Operate, maintain and replace, as agreed, the infrastructure required for delivery of environmental water, where the infrastructure is not part of the GMW irrigation delivery system. Where agreed, participate in the periodic review of relevant EWMPs. Manage and report on other relevant catchment management and risk management actions required due to the implementation of environmental water.
Input and advice into Campaspe River environmental watering	
Traditional Owners/ Community Groups	The delivery of environmental water is likely to provide other benefits that depend on the condition of our waterways, such as supporting social and cultural values.
Campaspe River Environmental Water Advisory Group (Campaspe EWAG)	The Campaspe EWAG consists of key stakeholders and community representatives who provide advice to the North Central CMA on the best use of environmental water for the Campaspe River. Current membership is provided in Appendix 1.

Other stakeholders with an interest in environmental watering include environmental groups, recreational users, local government, other water entitlement holders, landholders and local communities. It is important that the interests and values of these groups are incorporated in planning for, and management of, environmental water (DEPI 2014a).

2.4. Environmental water sources

The Campaspe River has access to a number of water sources which are described below and summarised in Table 2. Water shares are classed by their reliability and there are two types in Victoria. High-reliability water shares (HRWS), which is a legally recognised, secure entitlement to a defined share of water. Low reliability water shares (LRWS) which are water shares with a relatively low reliability of supply. Allocations are made to high-reliability water shares before low-reliability shares (DEPI 2014b).

The total volume of water available to the Campaspe River includes unregulated flows, environmental entitlements, passing flows and consumptive water. The volume of environmental water is 57,396 ML HRWS and 5,443 ML LRWS. This water has different conditions and levels of certainty, as described below.

Environmental Water Sources

Bulk Entitlement (Campaspe System - Goulburn Murray Water) Conversion Order 2000

The right to water in the Campaspe River was defined in 2000 through the Bulk Entitlement (Campaspe System - Goulburn Murray Water) Conversion Order. While there is no separate Environmental Bulk Entitlement, water for the Campaspe environment is defined as 'passing flows' within Goulburn Murray Water's and Coliban Water's Bulk Entitlements as well as unregulated river flows. The Campaspe Bulk Entitlement (2000a) provides for minimum passing flows in sections of the Campaspe River downstream of Lake Eppalock to protect environmental values based upon recommendations by an environmental flows scientific panel (Marchant et al. 1997). The 2012 BE amendment allows for the reduction and banking of passing flows in Lake Eppalock for later deployment. There is no passing flow requirement for the reach between the Campaspe Weir and the Campaspe Siphon (Reach 3), however in most cases water will be passed down this reach to supply requirements below the Campaspe Siphon (unless sourced from the Waranga Western Channel) (Victorian Government 2000a).

Campaspe River Environmental Entitlement 2013

The purpose of this Instrument is to grant the VEWH an environmental entitlement for water recovered through the decommissioning of the Campaspe Irrigation District (CID) as part of Stage 1 of the GMW Connections Project. The water recovered is made up of 15,052 ML of purchased HRWS and 8,100 ML of long-term average loss savings, or Long Term Cap Equivalent (LTCE). VEWH is responsible for paying storage and supply costs for the 15,052 ML entitlement. It does not have to pay storage and supply costs for the 8,100 ML, however this entitlement cannot be carried over.

Within 12 months of 1 July 2013, the VEWH, together with the Storage Manager, must develop operating arrangement for the supply of water under this entitlement. VEWH must also ensure that there is adequate metering within the Campaspe River System to demonstrate compliance with this entitlement (Victorian Government 2013).

Commonwealth Environmental Water Holder (CEWH)

Under the Federal Government's water buyback scheme or *Restoring the Balance in the Murray-Darling Basin Program*, as at 14 March 2012, a total of 6,547 ML of HRWS and 395 ML of LRWS have been purchased in the Campaspe River catchment. This water is held by the CEWH, which is responsible for the management and deployment. The stated objective of this program is to purchase water entitlements so that the water can be used for environmental purposes (DoE 2014). The water purchased from the Campaspe River catchment can be used to benefit environmental assets in this catchment and downstream. The CEWH also has the option to trade water in and out of the Campaspe as required. The use of this water in the Campaspe River system is not guaranteed and is at the discretion of the CEWH (Australian Government 2013).

Environment Entitlement (Campaspe River - Living Murray Initiative 2007)

The Living Murray Initiative aims to recover up to 500 GL of environmental water to achieve environmental benefits for six icon sites (not including the Campaspe River) along the River Murray. This entitlement is managed by the Murray-Darling Basin Authority (MDBA). Due to the unbundling process and the 80:20 sales deal water package, the Living Murray Initiative holds 126 ML HRWS and 5,085 ML LRWS in Lake Eppalock. This water's primary target will be for deployment to the icon sites; however there is the opportunity for deployment to provide additional benefit to the Campaspe River system en-route to the Living Murray Icon sites. The use of this water in the Campaspe System is not guaranteed and is at the discretion of the MDBA (Victorian Government 2007).

Bulk Entitlement (River Murray Flora and Fauna) Conversion Order 1999

The Victorian River Murray Flora and Fauna Bulk Entitlement provides 27,600 ML HRWS in the Murray System. It is held by the VEWH for the purpose of providing for flora and fauna needs. It has been used in a range of wetlands including Gunbower Forest (Living Murray icon site) and the Goulburn River system wetlands. It can also be traded on the water market on an annual basis. The use of this water in the Campaspe River system is not guaranteed and is at the discretion of the VEWH (Victorian Government 2011).

Other water sources

Inter Valley Transfer – Goulburn Valley Account

The Goulburn Inter Valley Transfer (IVT) provides water from the Goulburn River System (Lake Eildon) allocated to the Murray River and this can be delivered via the Waranga Western Channel and Reach 4 of the Campaspe River. This contributes to summer environmental flows for Reach 4 and is negotiated on an annual basis with the system operator.

Inter Valley Transfer – Campaspe Valley Account

The Campaspe IVT comprises water that has been traded from the Campaspe to the Murray. This water is stored in Lake Eppalock and is delivered through Reaches 2, 3 and 4. GMW consults with the North Central CMA when delivering this water. This EWMP will provide some guidance on options for delivery of IVT water to align with flow recommendations. IVT – Campaspe Account water can also be intercepted by the Waranga Western Channel at the Campaspe Siphon, although the energy costs are prohibitive.

Table 2: Summary of water sources available for the Campaspe River system

Water Entitlement	Volume (ML)	Responsible Agency
Environmental Water		
Campaspe Environment Entitlement 2013	15,052 ML HRWS, 8,100 ML HRWS & LRWS LTCE	Victorian Environmental Water Holder
Bulk Entitlement (Campaspe System - Goulburn Murray Water) Conversion Order 2000	Water is available to the environment under the BE as passing flows. This volume is not quantified as an average annual volume	Goulburn Murray Water
Commonwealth Environmental Water Holdings	6,547 ML HRWS 395 ML LRWS	Commonwealth Environmental Water Holder
Environment Entitlement Campaspe River - Environment Entitlement (Campaspe River - Living Murray Initiative 2007)	126ML HRWS 5,085 ML LRWS	Murray-Darling Basin Authority
Bulk Entitlement (River Murray Flora and Fauna) Conversion Order 1999	27,600 ML HRWS	Victorian Environmental Water Holder
Other water sources		
Inter Valley Transfer - Goulburn	Water required in the Murray system may be deliver via from the Waranga Western Channel and Reach 4 of the Campaspe River.	Murray-Darling Basin Authority and Goulburn Murray Water
Inter Valley Transfer - Campaspe	40 GL @ August 2014	Goulburn Murray Water

2.5. Related agreements, policy, plans and activities

There are a number of policies, strategies, plans and activities that are specifically relevant to the environmental water management of the Campaspe River. Relevant state, national and international legislation, policy and agreements include:

- State legislation (such as the *Water Act 1989, Catchment and Land Protection (CaLP) Act 1994, Flora and Fauna Guarantee (FFG) Act 1988, Aboriginal Heritage Act 2006, Traditional Owner Settlement Act 2010, Conservation, Forests and Lands Act 1987* and *Crown Land (Reserves) Act 1978*
- National legislation (such as *the Water Act 2007 and Water Amendment Act 2008 (Cth), the Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and the *Native Title Act 1993*)
- Murray-Darling Basin Authority policies (such as The Living Murray Initiative and the Murray-Darling Basin Plan). The Campaspe River has an environmental entitlement of 28 GL, as well as access to other water sources. This entitlement presents the opportunity to meet a large proportion of the recommended flow regimes, and presents the opportunity to set ambitious targets for the recruitment of vegetation, fish and Platypus. It is possible that with additional water recovered under the Basin Plan all flow components recommended for the river could be achieved.
- International agreements (such as the Convention on Conservation of Migratory Species of Wild Animals (Bonn or CMS), Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA), Republic of Korea- Australia Migratory Bird Agreement) (ROKAMBA).

Strategies, programs and projects relevant to the Campaspe River EWMP include:

- Victorian Waterway Management Strategy 2013 (VWMS) – this strategy outlines the direction for the Victorian Government's investment over an eight year period (beginning in 2012/13). The overarching management objective is to maintain or improve the environmental condition of waterways to support environmental, social, cultural and economic values (DEPI 2013a).
- 2014-2022 - North Central Waterway Strategy – this regional strategy is an action out of the VWMS and provides the framework for managing rivers and wetlands with the community over the next eight years. It delivers key elements of the VWMS including developing work programs to maintain or improve the environmental condition of waterways in the north central region. A major focus for the RWS for the next eight years in the Campaspe Basin involves implementing the Caring for Campaspe Project, and planning and delivery of environmental water.
- Caring for the Campaspe Project – the North Central CMA applied for Victorian Government funding to complement the delivery of environmental water and achieve an improvement in river health. The project will work closely with land managers to deliver fencing, weed control and revegetation works along the Campaspe River on both privately-owned and public land. This four year project was announced by the Minister for Water in March 2013 and is funded through the Environment Contribution Levy (North Central CMA 2013a).
- Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) – the Campaspe River is a part of this state-wide program. The project commenced in 2006 and has funded yearly fish surveys, water quality monitoring, vegetation and physical habitat mapping for the Campaspe River. The future of this project is currently unknown, however yearly fish surveys will continue until 2016 and vegetation surveys have been confirmed for 2016. Refer to Section 9.

3. Hydrology and system operations

3.1. River hydrology

Prior to European settlement, flows would have been seasonally variable. **Figure 5** shows the average flow volume (ML/d) over a year under “natural” and “regulated without environmental water” conditions. The river would have had high base flows (>500 ML/day) in winter and spring and regular freshes above 1500 ML/day, primarily in late winter/ early spring. During summer and autumn the river flow would have been very low (>50 ML/day) with periods of cease to flow and intermittent freshes of up to 500 ML/day (McGuckin and Doeg 2001; SKM 2006c). Under pre-regulation conditions the Campaspe River reaches (2, 3 and 4) would have a mean annual flow of 640 ML/day, 825 ML/day and 890ML/day respectively (SKM 2006c).

Regulation has changed the seasonality of flow regime components e.g. prolonged higher flows over summer/autumn in Reaches 2 and 3 and much lower flows in winter and changed the frequency and duration of most flow regime components (SKM 2006b). Under current conditions, without environmental water, the mean annual flow has been reduced to only 420 ML/day, 360 ML/day and 325 ML/day respectively. This has not only reduced the inflow, but has decreased the flow pattern down the river, with the higher reach having greater flow and progressively reducing the flow downstream.

During the early 2000s to late 2010, Victoria experienced a severe and extended drought, the Millennium Drought, during which time the Campaspe River was severely flow stressed. Lake Eppalock remained below 15% capacity for an eight year period. The low inflows impacted on allocations during this period, with the Campaspe River system allocated 39%, 31%, 0%, 18% and 0% of entitlements from the 2004-05 to 2008-09 water years. Environmental water management operated under a Ministerial Qualification of Rights, and flows within the river were significantly reduced (GMW 2007).

In 2010-11 widespread heavy rains across northern Victoria resulted in two periods (September 2010 and January 2011) of high flow including overbank flows in the Campaspe River, commencing its recovery from the drought. Lake Eppalock spilled in November 2010 and has remained at high levels since, resulting in spills and pre-release flows to river.

The decommissioning of the CID has impacted the hydrology of the Campaspe River. The GMW Bulk Entitlement (2000) lists a total of 37,170 ML of HRWS on the Campaspe River system. Approximately 15,052 ML has been surrendered from the CID closure, a reduction of 40%, and an additional 8,100 ML of Long Term Cap Equivalent (LTCE) including both HRWS and LRWS for losses associated with the provision of the CID entitlement has also been returned for environmental use.

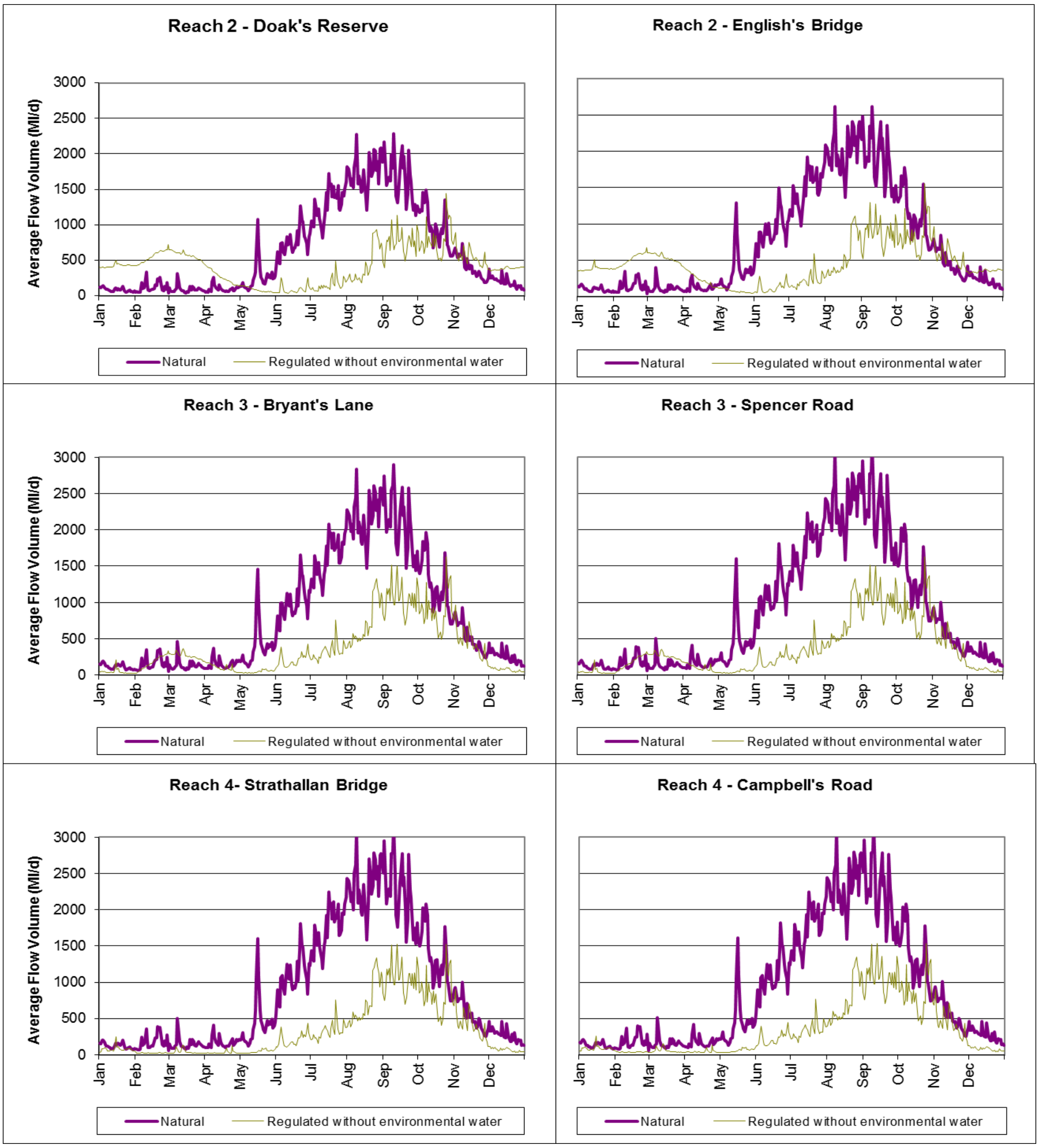

Figure 5: Pre and post regulation hydrographs of the Campaspe River (Source: SKM, 2006)[1]

Groundwater surface water interaction

The Campaspe basin contains part of the Lower Campaspe Valley Water Supply Protection Area (WSPA) and part of the Shepparton WSPA. GMW manages groundwater resource supply licences and domestic and stock use in the area and the towns of Elmore and Trentham (DEPI 2013b).

Prior to development of the catchment and rising groundwater levels the entire river is likely to have been a losing stream with areas over the Deep Lead contributing significant volumes of water to groundwater aquifers (Aquade 2011).

The geology of Reach 2 includes the Calivil Formation, Shepparton Formation and Newer Volcanic basalt. Immediately adjacent to the river is a thin and relatively narrow Coonambidgal Formation with which it is assumed to be in direct hydraulic communication. This reach of the river has a strong hydraulic connection with the Deep Lead aquifer and is a losing stream (Aquade 2011).

Reach 3 flows to the west of the Deep Lead and as a consequence there is a less direct hydraulic interaction between the Deep Lead aquifer and the river compared to Reach 2. Aquade (2011) has identified that this reach is a gaining stream with the stream-aquifer flux driven by the head gradient between the Shepparton Formation and the river, and controlled by the conductance of the shallow Shepparton Formation aquitard (Aquade 2011). This is an acquired phenomenon in the last 30 years

[1] Plots are based on inputs to the Goulburn-Broken-Campaspe-Loddon REALM model and use estimated inflows from 1891-2005

as a result of changes to river and catchment hydrology under the irrigation development of the 20th century (Aquade 2011). The salinity of the groundwater that interacts with this reach of the river has been recorded at between 4000 and 6900 EC. Under low flow conditions stratification can occur in deep pools of Reach 3, although salinity levels have been reported to be less than 660EC for 95% of the time (SKM 2009).

Hydrographs for bores adjacent to Reach 4 show that the Shepparton Formation groundwater levels have been relatively stable, at approximately 2-4 m above river level, for most of their recorded history (approx. 40 years), indicating that the river is a gaining stream in this reach particularly in periods of low flow (SKM 2009; Aquade 2011). Groundwater salinity in this reach has been recorded at much higher concentrations than in Reach 3. Consequently saline stratification of the water column in deep pools is evident during prolonged low flow periods. For example, maximum salinity concentrations in the bottom layer of a pool at Fehring Lane reached 12,000 µS/cm, compared with surface salinity concentrations of around 2,000 µS/cm during a monitoring program from 2007 to 2009 (SKM 2009)

An assessment of the saline pools in Reach 4 undertaken in by SKM (2009) found that:

- stratification of pools is occurring, with three distinct zones (at flows of 10ML/d):
    - Surface to 60cm depth – low salinity and high DO
    - Depth 70cm to 120cm - transition zone is evident (deterioration of water quality)
    - Below 130cm - salinities and DO levels do not meet water quality guidelines with conditions anoxic and unsuitable for native fish populations
- flows greater than 25ML/d are required to get full mixing of stratified pools; although stratification reoccurs within a relatively short period (approximately 10 days) once flow is reduced.
- flows of 10ML/day provide a freshwater lens 60cm in depth, but do not mix the stratified pools (based on current groundwater levels).

Water Quality

Other than the salinity risks posed by stratification of deep pools in Reach 4, other water quality issues in the Campaspe River include:

<u>Nutrients</u>

High nutrient levels are considered a main threat to river health throughout the Campaspe River Catchment. The Campaspe River catchment is estimated to generate 73 tonnes of phosphorus and 383 tonnes of nitrogen each year and discharge from the Campaspe River has had a noticeable effect on nutrient levels in the River Murray at times (SKM 2006b). Algal blooms periodically occur in Lake Eppalock, Malmsbury Reservoir, Campaspe Weir and in other sections of the Campaspe River (SKM 2006b).

<u>Temperature</u>

Cold water pollution is a serious risk to the Campaspe River. A recent study, undertaken to determine the impact of releasing high volumes of water over the summer period, found that the cold water releases from Lake Eppalock still influenced a drop in water temperature in Reach 4, with a reduction to 20°C (Jacobs 2014a).

<u>Dissolved Oxygen</u>

Low dissolved oxygen levels are a serious water quality and are most pronounced in pools within the Campaspe River downstream of the Campaspe Siphon (where stratification occurs) (SKM 2006b).

3.2. System operations – history of use

Discharge in the Campaspe River is measured at four established gauging stations in the river downstream of Lake Eppalock and at Axe Creek at Longlea. Water levels are also measured in the Campaspe Weir (Table 3).

Table 3: Victorian Water Quality Monitoring Network flow gauging stations

Gauging Station ID	Location	Period of Record
406207	Campaspe River at Lake Eppalock tail gauge	October 1976 to September 2013
406201	Campaspe River at Barnadown	March 1881 to September 2013
406202	Campaspe River at Campaspe Siphon	November 1976 to September 2014
406214	Axe Creek at Longlea	November 1976 to September 2013
406218	Campaspe Weir	January 1990 to September 2014
406265	Campaspe River at Echuca	March 1992 to March 2013

3.2.1. Water management and delivery

Management of flow downstream of Lake Eppalock comprises operation of three instream structures by Goulburn Murray Water. These were constructed in response to consumptive water demands within the Campaspe catchment and Northern Victorian irrigation development.

- In 1882, the Campaspe Weir was constructed 12 km south of Rochester with a capacity of 2,700 ML. The weir pool delivers irrigation water through the east and west channels.
- In 1902, the Campaspe Siphon was constructed 2 km north of Rochester. The Western Waranga Channel (WWC) crosses the river at this point and the siphon structure allows water from the Goulburn River to be diverted into the Campaspe River (SKM 2006a).
- The most significant structure on the Campaspe River is Lake Eppalock (completed in 1964 with a capacity of 304,000 ML). Lake Eppalock was constructed to secure water for the Campaspe Irrigation Area, to safeguard the Coliban Supply system and allow increased development of urban areas (North Central CMA 2014a).

Farm Dams: there are nearly 13,000 farm dams in the Campaspe River catchment. Dam density varies throughout the area; however they particularly influence inflows to the river in areas where they are very dense, such as the Axe Creek catchment. Detailed modelling of farm dam interception in the Campaspe Basin has been completed and found that under the base case (i.e. historical climate) farm dams reduce natural streamflow by between 6% and 40% (SKM 2008).

Flow from Lake Eppalock to Reach 2 is regulated by the operation of the Lake Eppalock offtake. Flow from Reach 2 to Reach 3 is regulated by the operation of the Campaspe Weir. Reach 3 receives Campaspe River water that passes under the Campaspe Siphon. At this point flow (water from the Goulburn system) can also be released from the WWC to Reach 4 or Campaspe River water can be pumped from the Campaspe River to the Waranga Western Channel (WWC).

Regulation of the Campaspe River has diverted approximately 50% of mean annual discharge for irrigation, stock and domestic use. The total volume of water available for allocation and the total volume used in 2011/12 is shown in Table 4 (DEPI 2013b).

Table 4: Summary of total water resources available for allocation and total water use in 2011/12 (DEPI, 2013b)

Water source	Total water resource (ML)	Total use (ML)
Surface water	184,744	58,835
Groundwater	66,204	16,760
Recycled water	2,554	1,942

The GMW Bulk Entitlement (2000) lists a total of 37,170 ML of HRWS on the Campaspe River system. Approximately 15,052 ML has been surrendered from the decommissioning of the Campaspe Irrigation District (CID), a reduction of 40%, and an additional 8,100 ML of LTCE including both HRWS and LRWS for losses associated with the provision of the CID entitlement has also been returned for environmental use. Whilst a significant irrigation entitlement volume has been reduced, there are still a large number of irrigation diverters extracting directly from the river or trading water out of the system. As mentioned in Section 3.1, this primarily occurs in the warmer months which is the inverse of the seasonal inflow. The introduction of carryover and spillable water accounts, will also impact flows in the Campaspe River.

3.2.2. Environmental watering

The right to provide environmental water in the Campaspe River was defined in 2000 through the Bulk Entitlement (Campaspe System – Goulburn Murray Water) Conversion Order. At this time there was no separate Environmental Entitlement, just defined passing flows as recommended by Marchant et al. (1997). During the Millennium Drought two *Qualification of Rights* were enforced by the Minister for Water (July 2007 to June 2010 period) securing water supplies for critical human needs. During this time there were prolonged 'cease to flow' periods in the river.

The management of environmental water has had a major shift since the flooding of 2010. Increased storage levels, Victorian and Commonwealth Water Holdings and the creation of the Campaspe River Environmental Entitlement have enabled the North Central CMA to deliver the majority of the environmental flows recommendations from SKM (2006c):

- 2011-12: provision of winter base flows and three winter high flow events (two of which were due to storage spills and pre-releases by the storage operator)
- 2012-13: provision of winter base flows, a reduced winter fresh and freshes provided in early September, October and November
- 2013-14: provision of winter base flows and two winter high flow events (North Central CMA 2012 2013b and 2014b).

Note: Goulburn Murray Water operational releases continue to exceed the summer base flow recommendations.

Flows (natural and managed) over the last ten years have been compared to the recommended flow regime for Reach 2 and Reach 4 for the Campaspe River in Appendix 2. A comparison was not completed for Reach 3 as a complete flow dataset is not available.

4. Values

4.1. Water dependent environmental values

4.1.1. Listings

The Campaspe River has high ecological value due to its connection to the Murray River, its large, very old River Red Gum (*Eucalyptus camaldulensis*) trees, its extensive complex instream woody habitat (IWH) (snags) and its native fish populations. Table 5 details the legislation, agreements, conventions and listings that are relevant to species found on the Campaspe River.

Table 5: Legislation, agreements, convention and listings relevant to the site, or species recorded in the Campaspe River

Legislation, Agreement or Convention	Jurisdiction	Listed R2	Listed R3	Listed R4
Japan Australia Migratory Birds Agreement (JAMBA)	International	✓	×	×
China Australia Migratory Birds Agreement (CAMBA)	International	✓	×	×
Korea Australia Migratory Birds Agreement (ROKAMBA)	International	×	×	×
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)	International	×	×	×
Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)	National	✓	✓	✓
Flora and Fauna Guarantee Act 1988 (FFG Act)	State	✓	✓	✓
DEPI advisory lists	State	✓	✓	✓
R2, R3, R4: Reach 2, Reach 3, Reach 4				

4.1.2. Fauna

The Campaspe River supports a wide variety of fauna species. A full list of species recorded along the Campaspe River can be found in Appendix 3.

Fish

Twelve native fish species of conservation significance have been recorded in the Campaspe River. Three of these, Murray Cod (*Maccullochella peelii*), Macquarie Perch (*Macquaria australasica*) and Trout Cod (*Maccullochella macquariensis*) are listed under the EPBC Act 1999. Murray Cod is the only one of these species that has been recorded in all three reaches of the Campaspe River; records of Macquarie Perch and Trout Cod are confined to Reach 2 and Reach 4 respectively. It should however be noted that Macquarie Perch has not been recorded since November 1983 and its current distribution is unknown.

The Murray-Darling Rainbowfish (*Melanotaenia fluviatilis*), a FFG Act 1988 listed species, was recorded for the first time in approximately 100 years during the 2013 VEFMAP surveys (Jacobs 2014b) and in the 2014 VEFMAP surveys this species had significant numbers and a wide distribution (they were captured at every survey site in Reach 3 and at two sites in Reach 4). This species has been absent from previous fish surveys and was presumed lost from this river (Jacobs 2014b). FFG Act 1988 listed species Silver Perch (*Bidyanus bidyanus*) has been recorded in Reach 4 in small numbers in most VEFMAP surveys since 2008 (Jacobs, 2014b). A single record of Flat-headed Galaxias (*Galaxias rostratus*) downstream of Rochester, captured during a fish survey conducted in 1997 (Marchant et al. 1997) and a single record of Southern Pygmy Perch (*Nannoperca australis*) at Echuca from 1975 (DEPI 2013c). No other records of these species are known for the Campaspe River catchment (McGuckin & Doeg 2001).

The conservation status of near threatened for Golden Perch (*Macquaria ambigua*) is only relevant for natural populations. This species has been recorded in every reach. It is stocked at Campaspe Weir and in Reach 4 (DEPI 2013d). Although in the recent VEFMAP surveys calcein dye was not detected on many captured individuals and a number of small (juvenile) Golden Perch have been captured, as is not always possible to detect calcein dye when it is present, it is prudent not to make inferences to the Golden Perch population in the Campaspe River being natural without further research (Jacobs, 2014b).

All of the significant species recorded in the Campaspe River are listed under the FFG *Lowland Riverine Fish Community of the Southern Murray-Darling Basin*. Historically this community was dispersed throughout the lowland areas of the Murray and Darling River systems but anthropogenic change has altered this distribution and abundance (SAC 1998). The Campaspe River supports eleven of the fifteen fish species in this ecological community (Table 6).

Table 6: Significant fish species recorded on the Campaspe River

Common Name	Scientific Name	R2	R3	R4	EPBC status	FFG status	Vic status
Flat-headed Galaxias	*Galaxias rostratus*			✓		L	VU
Golden Perch (natural populations)	*Macquaria ambigua*	✓	✓	✓			NT
Macquarie Perch^	*Macquaria australasica*	✓			EN	L	EN
Murray Cod	*Maccullochella peelii*	✓	✓	✓	VU	L	VU
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis (Murray-Darling lineage)*		✓	✓		L	VU
Silver Perch	*Bidyanus bidyanus*			✓		L	VU
Southern Pygmy Perch	*Nannoperca australis*			✓			VU
Trout Cod	*Maccullochella macquariensis*			✓	EN	L	CR

Legend
R2, R3, R4: Reach 2, Reach 3, Reach 4
✓**: recorded**
EPBC status: ENdangered, VUlnerable
FFG status: Listed as threatened,
Vic Status: CRitically endangered, ENdangered, VUlnerable, Near Threatened

Waterbirds

Twelve water dependent bird species have been recorded along the Campaspe River (Table 7). The record source for waterbirds is from the Victorian Biodiversity Atlas (VBA) which records presence only and does not describe what these water dependent species were using the river for (e.g. breeding). It should be noted that active surveys have not been conducted for waterbirds along the Campaspe River and therefore the significance of the river for threatened species is relatively unknown.

Table 7: Significant waterbird species recorded on the Campaspe River

Common Name	Scientific Name	R2	R3	R4	EPBC status	Treaty	FFG status	Vic Status
Australasian Shoveler	*Anas rhynchotis*	✓	✓					VU
Azure Kingfisher	*Alcedo azurea*			✓				NT
Ballion's Crake	*Porzana pusilla palustris*	✓					L	VU
Eastern Great Egret	*Ardea modesta*	✓	✓			C/J	L	VU
Gull Billed Tern	*Gelochelidon nilotica macrotarsa*			✓			L	EN
Hardhead	*Aythya australis*	✓	✓					VU
Intermediate Egret	*Ardea intermedia*			✓			L	EN
Musk Duck	*Biziura lobata*	✓						VU
Nankeen Night Heron	*Nycticorax caledonicus hillii*	✓		✓				NT
Pied Cormorant	*Phalacrocorax varius*	✓						NT
Royal Spoonbill	*Platalea regia*	✓						NT

Legend
R2, R3, R4: Reach 2, Reach 3, Reach 4
✓**: recorded**
EPBC status: Endangered
FFG status: Listed as threatened
Treaty: CAMBA, JAMBA
DEPI advisory list: CRitically endangered, ENdangered, VUlnerable, Near Threatened

Frogs and Reptiles

Three common frog species, Plains Froglet (*Crinia parinsignifera*), Common Froglet (*Crinia signifera*), and Southern Bullfrog (*Limnodynastes dumerilii*) have been recorded at all reaches of the Campaspe River. The Eastern Long-necked Turtle (*Chelodina longicollis*) has also been recorded in all reaches. This species has recently been included in the DEPI Advisory List of Threatened Vertebrate Fauna (April 2013) as data deficient.

Mammals

Although not listed under legislation the national conservation status of Platypus has recently been elevated to near threatened (CSIRO 2014) which is recognition of the fact that Platypus numbers have been declining in many areas over the last few decades and that the species has already disappeared from some catchments (Melody Serena pers. comm. [Australian Platypus Conservancy], July 2014). To date Platypus live-trapping surveys have not been conducted along the Campaspe River. However, fish surveys captured Platypus as by-catch since the late 1990s. More than half of landholders owning river frontage between Lake Eppalock and the Campaspe Weir who were interviewed in the early 2000s reported seeing Platypus on an occasional or more frequent basis, consistent with resident animals being present (Jacobs 2014a). In Reach 4 landholders mainly reported one-off sightings or two to three sightings in a single short period, suggesting that dispersing juveniles or older vagrants (e.g. males searching for mates) (Jacobs 2014a). The Campaspe River Platypus population is an importance source population to recolonise

Macroinvertebrates

As part of the Victorian Biological Assessment Program the Campaspe River is monitored for macroinvertebrates. The macroinvertebrate community is generally diverse and typical of a lowland system, however it supports a number of filter feeding species that are normally associated with cool, faster flowing upland streams, likely in response to the cold summer irrigation releases from Lake Eppalock (SKM 2006b). The majority of the taxa are tolerant indicating poor water quality (SKM 2006b).

4.1.3. Vegetation communities and flora

The vegetation communities of the Campaspe River are restricted within a narrow riparian zone that rarely extends into the floodplain beyond the crest of the river bank. The dominant riparian EVC is Floodplain Riparian Woodland (EVC 56), which is present in each reach of the Campaspe River and occupies approximately 83% of the area within the river and narrow riparian zone (Table 8). This EVC is characterised by River Red Gum (*Eucalyptus camaldulensis*) as the dominant canopy species over a medium to tall shrub layer with a ground layer consisting of amphibious and aquatic herbs and sedges (DSE 2004a). The understorey and ground layers are currently depleted (Jacobs 2014a).

Table 8: Area and conservation status of current EVCs of the Campaspe River

Bioregion	EVC Name	EVC #	Bioregional Conservation Status	Area (ha)
Reach 2				
Goldfields	Floodplain Riparian Woodland	56	Endangered	154.1
Victorian Riverina	Floodplain Riparian Woodland	56	Vulnerable	629.2
	Wetland Formation	74	Endangered	3.9
Reach 3				
Victorian Riverina	Floodplain Riparian Woodland	56	Vulnerable	165
	Wetland Formation	74	Endangered	4
Reach 4				
Victorian Riverina	Floodplain Riparian Woodland	56	Vulnerable	538
	Grassy Riverine Forest	106	Depleted	23
	Lignum Swampy Woodland	823	Vulnerable	<1
	Riverine Chenopod Woodland	103	Vulnerable	7
	Riverine Grassy Woodland	295	Vulnerable	10
Source: DEPI 2013c; VEAC 2008				

The next dominant EVC, Wetland Formation (EVC 74) was a general wetland EVC mapping unit used to classify aquatic vegetation communities prior to the revision of the Victorian wetland EVC typology. It was described as dominated by sedges (especially on shallower verges) and/or aquatic herbs. Emergent vegetation including rushes on sand banks scattered stands and in-stream vegetation and Water Ribbons (*Triglochin* spp.) was extensive throughout the river prior to and during the drought (SKM 2013). This vegetation was largely washed out during the floods of 2010/11, however small stands persist, primarily in Reach 2. The rare Sand Rush (*Juncus psammophilus)* in Reach 2 was observed near the Campaspe Weir pool in 2012 (I. Higgins pers. obs. [North Central CMA, botanist], 2012). A full list of flora species recorded in the Campaspe River can be found in Appendix 4.

Table 9: Significant flora species recorded at Campaspe River

Common Name	Scientific Name	EPBC status	FFG status	Vic Status
Sand Rush	*Juncus psammophilus*			r
Conservation Status: **Vic Status:** r - rare in Victoria,				
Source: I. Higgins pers. obs. [North Central CMA botanist], 2012				

4.2. Habitat

The Campaspe River also has high habitat values additional to habitat that flora and vegetation communities provide. The entire length of the river has a very high volume of complex instream woody habitat (IWH) (snags) as “river improvement” programs of the late 1970s and early 1980s that removed IWH for flood mitigation were not undertaken in the Campaspe River.

The Campaspe River geomorphology includes two very important habitat features. The river, particularly in Reach 2, is characterised by a high number of very large deep pools (SKM 2012a). These provide important drought refuge during periods of low to no flow. At periods of low flow in summer extensive slackwater areas are engaged and provide warm nutrient rich nursery habitat for many native fish species (e.g. the FFG listed Murray-Darling Rainbowfish) (Jacobs 2014a; SKM 2007).

4.3. Terrestrial flora and fauna that depend on the riparian woodland habitat

A number of threatened terrestrial flora and fauna have been recorded within 100 metres of the Campaspe River. These species are likely to depend on the riparian zone along the river due to the large scale land clearing of woodland habitat within the Campaspe River catchment.

EPBC listed Swift Parrot (*Lathamus discolour*) and FFG listed Barking Owl (*Ninox connivens*), Diamond Firetail (*Stagonopleura guttata*), Grey-crowned Babbler (*Pomatostomus temporalis temporalis*) Hooded Robin (*Melanodryas cucullata cucullata*) have been recorded within Reach 2, with the Hooded Robin also being recorded in Reach 3.

FFG listed Squirrel Glider (*Petaurus norfolcensis*) has been recorded at Reach 4 including the billabong site which is part of the anabranch that stems from the Campaspe upstream of Strathallan Road and re-joins the river upstream of Echuca. Table 10 shows the significant terrestrial fauna species that have been recorded within 100 metres of the Campaspe River.

Table 10: Significant terrestrial fauna species that inhabit the Campaspe River riparian zone downstream of Lake Eppalock

Common Name	Scientific Name	Reach	EPBC status	Treaty	FFG status	Vic Status	Last record
Barking Owl	*Ninox connivens*	2			L	EN	
Black-chinned Honeyeater	*Melithreptus gularis*	2				NT	
Brown Treecreeper	*Climacteris picumnus victoriae*	2,3,4				NT	
Diamond Firetail	*Stagonopleura guttata*	2,3			L	NT	
Fork-tailed Swift	*Apus pacificus*	2		C/J			
Grey-crowned Babbler	*Pomatostomus temporalis temporalis*	2			L	EN	
Hooded Robin	*Melanodryas cucullata cucullata*	2,3			L	NT	
Swift Parrot	*Lathamus discolour*	2	EN		L	EN	
Squirrel Glider	*Petaurus norfolcensis*	4			L	EN	

Legend
EPBC status: Endangered
FFG status: Listed as threatened
Treaty: CAMBA, JAMBA
DEPI advisory list: CRitically endangered, ENdangered, VUlnerable, Near Threatened

Source: DEPI 2013c

EPBC listed Velvet Daisy-bush (*Olearia pannosa* subsp. *cardiophylla*) has been recorded in the Riparian Zone of Reach 4. FFG listed Buloke (*Allocasuarina luehmannii*) has been recorded in Reach 2. The records in Table 11 are from the VBA and therefore extent and distribution of the significant species are not known.

Table 11: Significant terrestrial flora species that inhabit the Campaspe River riparian zone downstream of Lake Eppalock

Common Name	Scientific Name	Reach	EPBC status	FFG status	Vic Status
Austral Trefoil	*Lotus australis*	2			k
Blunt-leaf Pomaderris	*Pomaderris helianthemifolia* subsp. *minor*	2			r
Buloke	*Allocasuarina luehmannii*	3		L	
Pale Flax-lily	*Dianella sp. aff. longifolia* (Riverina)	4			v
Late-flower Flax-lily	*Dianella tarda*	2			v
Southern Swainson-pea	*Swainsona behriana*	2			r
Velvet Daisy-bush	*Olearia pannosa* subsp. *cardiophylla*	2	VU	L	v
Wetland Blown-grass	*Lachnagrostis filiformis var.2*	4			k

Conservation Status:
EPBC Status = VUnerable;
FFG status = Listed under the *Flora and Fauna Guarantee Act 1988* **;**
Vic Status: v- vulnerable in Victoria, r - rare in Victoria, k – poorly known in Victoria

4.4. Ecosystem Functions

'Ecosystem function' is the term used to define the biological, geochemical and physical processes and components that take place or occur within an ecosystem. Ecosystem functions relate to the structural components of an ecosystem (e.g. vegetation, water, soil, atmosphere and biota) and how they interact with each other, within ecosystems and across ecosystems (Maynard et al. 2012). Ecosystem functions critical to support the primary water dependent environmental values of the Campaspe River include (but are not limited to):

- Food production – a critical ecosystem function is the conversion of matter to energy for uptake by biota. Structural components include substrate surfaces (e.g. IWH, rocks and gravel) for biofilms, and plant matter. Interactions between primary producers and consumers such as zooplankton and macroinvertebrates break down the carbon and nutrients required for higher order consumers

- Reproduction – recruitment of new individuals is important for the river's primary values, native fish and River Red Gum trees. Fish require nursery habitats such as slackwater areas to provide suitable conditions for native fish larvae metamorphosis (linked to food web function). Breeding is required in most years for small bodied fish in particular, and given the reduced number of large bodied fish in the system it is recommended that conditions suitable for spawning of large bodied fish, such as Murray Cod, are provided in most years

  River Red Gum trees require high flows in spring to facilitate germination events. Follow up watering is required in a second year to water germinated saplings. Due to the long lived nature of this species recruitment events are only required a couple of times in a decade.

- Movement/Dispersal – movement of individuals throughout the river is linked to the food web function. By providing alternative flows different areas of the river are accessible for foraging by fish and other aquatic fauna. Flow and connectivity also facilitates dispersal of juveniles either to other areas within the Campaspe or the Murray River system.

The Basin Plan specifies the need to "identify priority environmental assets and priority ecosystem functions, and their environmental watering requirements" (Australian Government 2012, p68). Section 8.50 of the Basin Plan outlines the method for identifying ecosystem functions that require environmental watering and their environmental watering requirements (Schedule 9—Criteria for identifying an ecosystem function). The Campaspe River's ecosystem functions that meet the assessment indicators are described in Appendix 5.

4.5. Social Values

The primary purpose of environmental water entitlements is to achieve environmental benefits. However, the delivery of environmental water for this purpose will provide other benefits that depend on the condition of our waterways, such as supporting social and cultural values.

4.5.1. Cultural Heritage

Aboriginal cultural heritage

Traditionally, Indigenous people have a strong affinity with waterways and water bodies, as a vital source of food, water and camping sites in traditional lifestyles. The alluvial plain of the Campaspe River was first inhabited by a number of Indigenous groups. At the Campaspe and Murray River junction the Wollithiga group of the Bangerang tribe ranged the river forests. The river, named "Yalooka" by the Aboriginal people, was the chief source of all food.

> "*They hunted fish, opossoms and ducks, sometimes using canoes carved from red gum. Yams, a kind of sweet potato, and myrnong, called native carrot, grew along the watercourses*" (Thomas, 1979 cited in North Central CMA, 2006).

The Campaspe River is the boundary between the Dja Dja Wurrung clan to the west and Taungurung clan to the east. Rochester is the boundary area between Dja Dja Wurrung and Taungurung to the south and Yorta Yorta to the north. According to the Aboriginal Cultural Heritage sites register, there are fourteen sites of cultural significance along the lower Campaspe River. These are predominantly shell deposits, scarred trees and mounds, with some artefact sites (DPCD 2008).

4.5.2. Recreation

The Campaspe River is a valuable recreation area in the North Central CMA region and has high passive recreation values. AVIRA (2013) rates camping as very high, with downstream of Elmore being extremely popular with caravans and motor home tourists. The site has been listed in a number of touring guides and 40-50 caravans' camp at the reserve during peak periods.

Recreational fishing is rated as very high for all reaches of the Campaspe River and this reach is stocked by the Department of Environment and Primary Industries (DEPI) (Fisheries) with Murray Cod and Golden Perch annually (DEPI 2013d). The Campaspe Weir is also considered to be one of the best fishing areas along the Campaspe River with anglers making catches of both of these stocked fish species (DPI 2010).

Other social values that are rated as very high include swimming, canoeing and riverside tracks (e.g. 3 km walking track along the Campaspe River banks, Echuca). Non power boating and site-seeing also provides some value.

4.6. Economic Values

The Campaspe River supports a diverse range of enterprises along its length. Many, including farming enterprises are located some distance from the river and their interaction with other businesses and business resources, in the absence of detailed studies, is impossible to define. General economic values of the Campaspe River are listed as follows:

- Water carrier to distribute water to irrigation, industrial and urban users
- Water source for primary production that underpins the regional economies of many rural Victorian communities, such as Rochester and Elmore
- Water source for rural towns
- Dryland stock watering in areas outside of the irrigation area (AVIRA 2013).

4.7. Conceptualisation of the Site

The conceptual understanding of the ecology and ecological functions of the Campaspe River is shown in Figure 6.

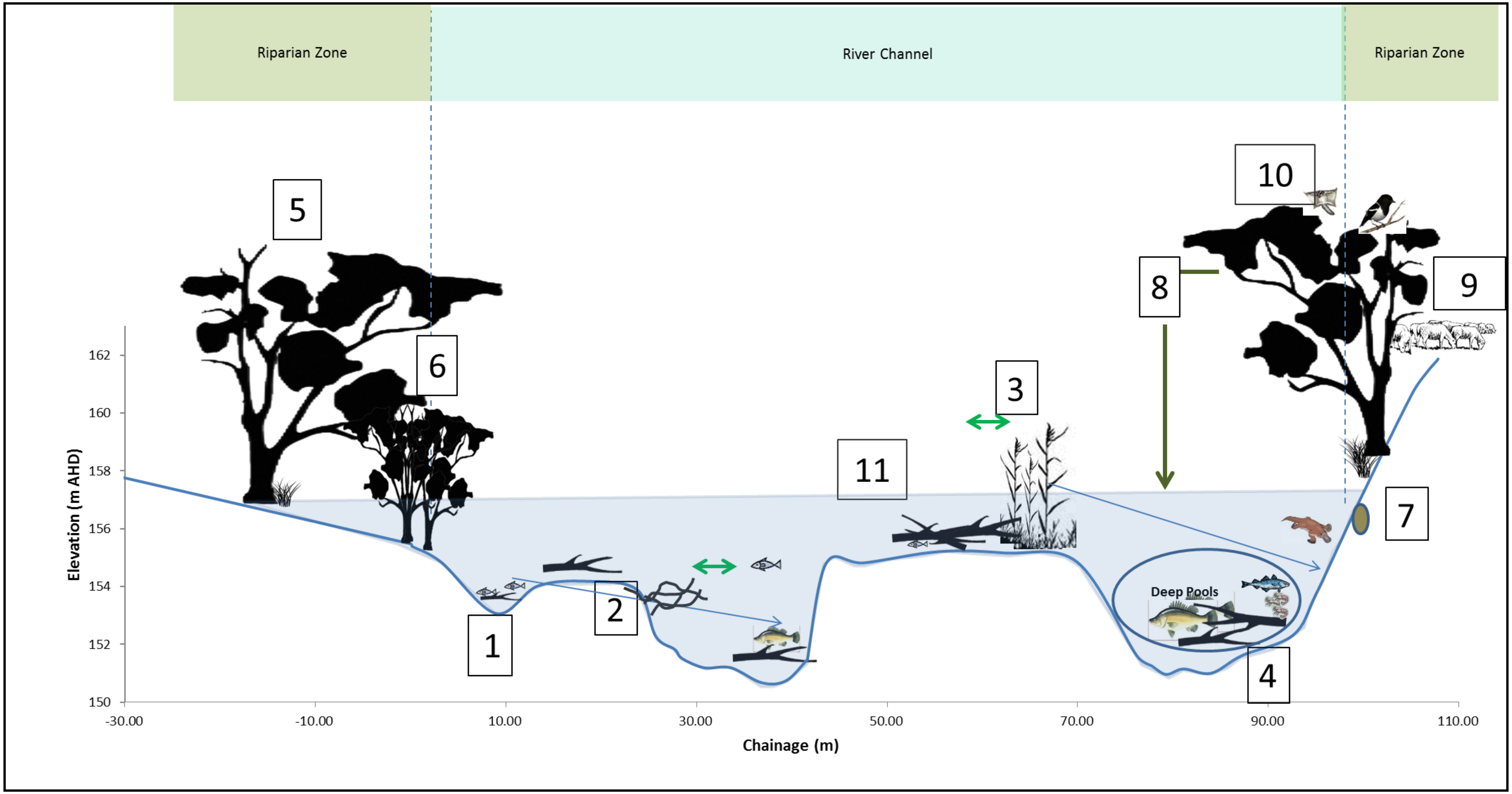

Figure 6: Cross section indicating conceptual understanding of the Campaspe River ecology. Applicable reach is identified.

1. The early life stages of fish require nursery habitats, and for many fish these are slackwater areas (no or negligible flow). These provide sheltered, usually warm, food-rich areas conducive for survival and growth. Either the adults spawn there or larvae move there themselves (Jacobs 2014a; SKM 2007) (Reach 2,3 and 4)
2. Instream vegetation exists in small stands in Reach 2 after 2011 floods reduced instream flora extent. Slow-flowing pools may develop large stands of submerged taxa, such as *Triglochin app.* (Jacobs, 2014a). Differing climate (dry, average, wet) and flows (low, fresh, bankfull) will cause stands to expand and contract within the wetted areas of the channel. Instream vegetation provides shelter and food for macroinvertebrates, small fish and tadpoles which provide food for Platypus and Large bodied fish
3. Emergent vegetation exists in small stands in Reach 2 after 2011 floods significantly scoured extensive stands from the channel. Freshes from late winter to early summer will encourage germination of a diversity of emergent species (such as *Bolboschoenus spp*. *Eleocharis* spp. or *Phragmites*). Emergent vegetation provides shelter for macroinvertebrates and frogs, small fish when inundated. Both instream and emergent vegetation are carbon sources
4. Reach 2 is characterised by a high proportion of large deep pools. These pools provide important habitat, particularly for large bodied fish and platypus. Are critical during periods of low to no flow for refuge.
5. Riparian zone primarily comprises large very old (pre European settlement) River Red Gum trees with very little evidence of recruitment and sparse understory (Reach 2, 3 and 4)
6. Spring freshes promote Red Gum recruitment on benches.
7. High flows in August are expected to cue Platypus to establish breeding burrows higher on the bank (Reach 2 and 3)
8. Riparian vegetation is a source of carbon (e.g. leaf litter, insects) and instream woody habitat to the river (Reach 2, 3 and 4)
9. The riparian zone is restricted to a very narrow margin along the river and is abutted by agricultural land. Only 14% of the river is currently fenced (Reach 2, 3, and 4)
10. A large number of threatened terrestrial species are dependent on the riparian zone of the Campaspe River as the catchment is extensively cleared (Reach 2, 3 and 4)
11. The Campaspe River has a high loading of complex instream woody habitat. These are a critical component of the river ecology providing shelter, sites for primary production (e.g. biofilms) and are areas of high productivity (zooplankton, macroinvertebrates).

The conceptual understanding of groundwater/surface water interactions is shown in Figure 7.

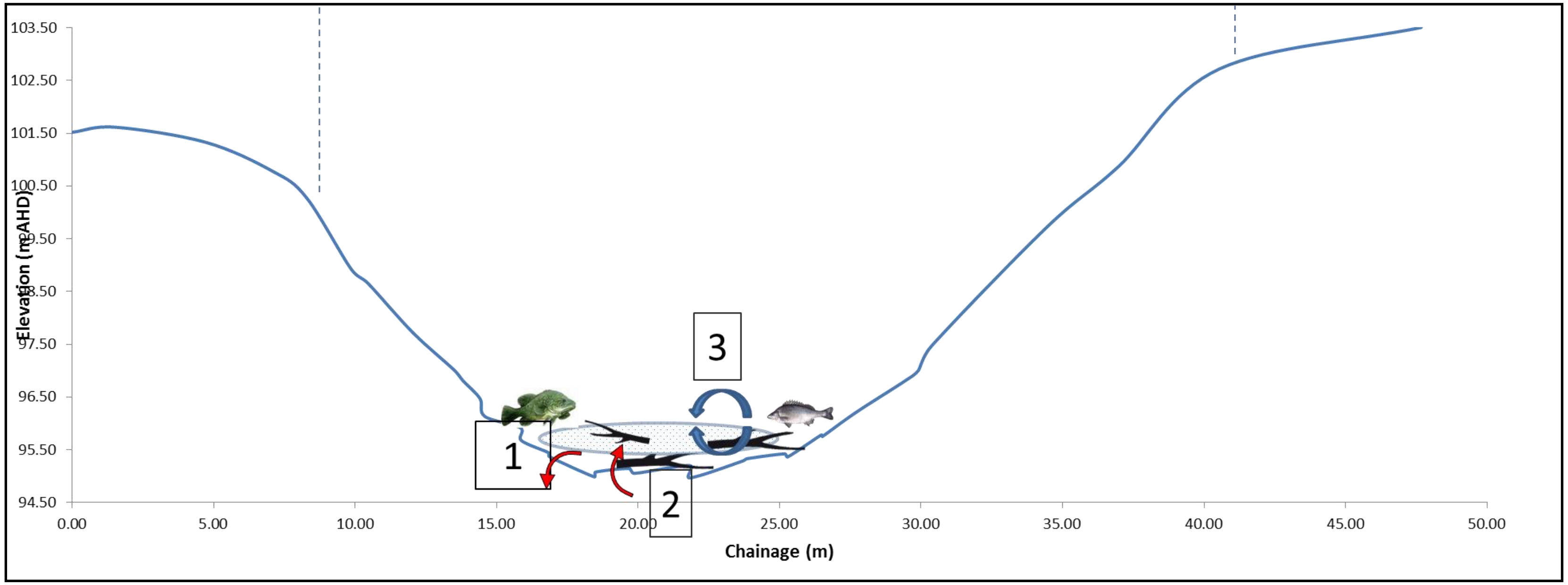

Figure 7: Conceptual understanding of groundwater/surface water interactions in the Campaspe River

1. Reach 2 is a losing stream (i.e. loses to groundwater system).
2. Reach 3 and Reach 4 are predominantly gaining streams (i.e. groundwater intrudes into the river bed).
3. Due to groundwater intrusion, under very low or no flow conditions (under 25 ML/day) the deep pools in Reach 4 (and to a lesser extent Reach 3), stratify, with denser, more saline water (with associated low DO) at the bottom of the pools. At flows of >10 ML/day <25 ML/day a freshwater lens sits on top of the saline pool

4.8. Significance

The Campaspe River is highly significant as a tributary river within the Murray-Darling Basin. It provides important ecological and biodiversity linkages in a region and landscape that has been highly modified, particularly now that the Echuca gauge weir has been upgraded to include fish passage.

The river has significant habitat values such as extensive and complex IWH, large deep pools, and extensive areas that form slackwater under low flows. IWH is a critical structural component for the river, supporting food webs and providing shelter for macroinvertebrates, native fish (e.g. Murray Cod) and other aquatic fauna (Jacobs 2014a). Deep pools provide important drought refuge during periods of low to no flow. Slackwater areas when engaged provide warm nutrient rich nursery habitat for many native fish species (e.g. the FFG listed Murray-Darling Rainbowfish) (Jacobs 2014a; SKM 2007).

The Campaspe River supports, or has been known to support, fauna and flora of national, regional and local conservation significance, in particular EPBC listed native fish such as the Murray Cod, Trout Cod and Macquarie Perch.

The river features a large number of very old (estimated to pre-date European Settlement) River Red Gum trees within the riparian zone (SKM 2006b). The River Red Gum community is almost continuous for the entire length of the river, although recruitment of new trees is required to ensure this community is sustained (Jacobs 2014a). Many native vegetation communities within the catchment are considered endangered or vulnerable.

5. Ecological Condition and Threats

5.1. Context

Rainfall conditions significantly improved in the 2010 Winter/Spring period resulting in natural high river flows. In January 2011 extensive flooding occurred in the Campaspe River catchment providing extensive overbank flows.

The Campaspe River is a 'working' river and its condition is reflective of its multiple uses, in particular, its role in harvesting, storing and delivering water for consumptive needs. Generally regulated management harvests natural inflows, usually during winter and spring, and releases higher flows over the warmer months of the year when evaporation exceeds precipitation. This type of managed flow regime characterised by seasonal inversion and lack of overbank floods, is inappropriate for many water dependent environmental values along the river (Jacobs 2014a).

The current condition has also been impacted by the extreme weather events of the Millennium Drought and the 1 in 100 year floods that occurred in January 2011 (as discussed in Section 3). Lake Eppalock nearly dried during the drought and coupled with low to zero irrigation allocations, the North Central CMA was unable to deliver most of the recommended environmental flows. Sections of the Campaspe River contracted to a series of isolated pools. Pools in the lower reaches of the river became highly saline, the health of River Red Gums along much of the river declined and emergent plants such as Phragmites and Typha encroached into the river channel. The 2011 flood scoured most of the established vegetation from the channel, as well as instream vegetation. River Red Gum recruitment was beyond the confined riparian zone and where that aligned with agricultural land the saplings have been removed (Jacobs 2014a).

Further, other threats such as instream barriers, historic commercial harvesting of fish in the Murray-Darling Basin, introduced flora and fauna, land clearing, livestock access and grazing of river banks, have all degraded the condition on the Campaspe River (Humphries & Winemillar 2009; Jacobs 2014a; O'Brien et al. 2006).

5.2. Current Condition

Previous condition assessments

The Sustainable Rivers Audit (SRA) was undertaken at a Murray-Darling Basin scale. The SRA provides scientifically robust assessments of the ecological health of the Basin's 23 river valleys, based on assessment of observations of fish, macroinvertebrates, vegetation, physical form and hydrology. These are then compared to the reference condition[2] for the Valley to derive the score. SRA 1 is based on data collected from 2004 – 2007 and assessed fish, macroinvertebrates and hydrology. SRA 2 is based on data collected from 2008 to 2010 and includes additional reports on physical form and vegetation. Direct comparison between values for the two SRA assessment reports are valid in some cases (Davis *et al*. 2012) however, changes in methodology and additional information collated needs to be considered. The Campaspe Valley was divided into three zones, the upland, the slopes and the lowland. Table 12 details the results of the two SRA reports. It should be noted that the MDBA has issued a caveat that SRA 2 results should be interpreted in the context that prevailing climate conditions for period in which the data were collected included the severe Millennium Drought.

Table 12: MDBA Sustainable River Audit indices ratings and trajectories for the Campaspe River

Parameter	SRA 1	SRA 2
Fish (SR-F1)	Lowlands: Extremely poor 2	Lowlands: Extremely poor 3
Macroinvertebrates (SR-MI)	Lowlands: Poor 48	Good 80
Vegetation (SR-VI)	Not assessed	Very poor 21
Physical Form (SR PI)	Not assessed	Moderate 67
Hydrology	Lowlands: poor to moderate	Moderate 61
Ecosystem health Rating	Lowland: Very poor	Very Poor
Source: Adapted from Davis et al. 2008; Davis et al. 2012.		

[2] Reference condition is an estimate of condition had there been no significant human intervention (i.e. pre European settlement) in the landscape, provides a benchmark for comparisons

The Index of Stream Condition (ISC) is a statewide assessment of river condition. ISC measures the relative health across hydrology, physical form, stream side zone, water quality and aquatic life against a reference condition[3]. Assessments were undertaken in 1999, 2004 and 2010 (DEPI 2013e). Due to the changes made to the methods for all five sub-indices, it is difficult to make direct comparisons using the sub-index scores. It should be noted that the ISC reaches are delineated differently to environmental flow reaches, ISC reach numbering starts at the Murray River while environmental flow reaches starts at Malmsbury Reservoir on the Coliban River. ISC Reaches 1 to 5 align with the Campaspe River downstream of Lake Eppalock. The results of the three assessments against the ISC reaches (aligned against FLOWS reaches) are shown in Table 13.

Table 13: 1999, 2004 and 2011 Index of Stream Condition sub - indices scores and trajectories for the Campaspe River

ISC Reach No.	E-flow No.[1]	Physical Form			Stream-side zone			Hydrology			Water Quality			Aquatic Life			Total Score			Condition			Change
		99	04	10	99	04	10	99	04	10	99	04	10	99	04	10	99	04	10	99	04	10	
1	4	6	6	7	5	5	7	2	1	6	-	-	5	-	5	5	18	18	28	VP	M	M	+
2	4	6	6	6	5	6	7	2	1	6	8	7	8	9	5	6	24	21	31	P	M	M	+
3	3/4	5	4	7	6	5	7	3	0	10	6	7+	6	-	5	7	23	16	34	P	P	M	+
4	2	5	4	8	6	6	6	3	0	10	8	8+		9	8	7	26	19	36	Ma	M	G	+
5	2	5	4	7	6	5	6	3	0	10	7	8	10	-	8	7	23	18	36	P	M	G	+

KEY:
VP- very poor; P- poor; Ma- marginal; M- moderate; G- Good
+ -Positive; 0 -no change; -- negative
[1]indicative environmental flows reach number

Source: adapted from DSE 1999, DSE 2004b DEPI, 2013d

Vegetation

The Vegetation SRA score from the Millennium Drought and the three ISC Streamside Zone Scores indicate that vegetation along the Campaspe River has been in poor condition , albeit slightly improving from 2004 to 2010 under ISC (DEPI 2013e). This slight improvement in ISC scores for streamside zone cannot be confidently interpreted as an improvement in condition, because the method and sampling protocol changed from 2004 to 2010.

Both vegetation assessments relate to the width and continuity of the riparian zone. The ISC score of moderate condition was based on variable results for vegetation diversity. The riparian zone was highly fragmented and was rated as “poor” for vegetation width, a reflection of the fact the Campaspe River riparian zone is largely restricted to within the channel (SKM 2013). Large old trees that are estimated to pre-date European settlement are located along the crest of the bank, with younger age classes scattered sparsely on various benches. The VEFMAP 2013 vegetation surveys found that the understory was sparse and dominated by exotics (SKM 2013). Observations during the field trip by the EFTP on 1 August 2014 (see Section 1.2) confirmed that this was still the case, and noteworthy that there is little evidence of River Red Gum or understorey recruitment for the majority of the sites visited (Jacobs 2014a). River Red Gum recruitment that occurred in response to the January 2011 flood was observed very high on the banks, beyond the crest, along Crown land. Saplings had been cleared on all agricultural land (Figure 8).

[3] Reference condition has the same definition as the SRA.

Figure 8: Successful recruitment of River Red Gum at Doaks Reserve in an area of the riparian zone (left hand photograph) in comparison with an absence of recruitment in an adjacent unfenced area recently plowed agricultural field (right hand photograph). Photographs by Paul Boon 1/08/2014.

The Environmental Flows Assessment (SKM 2006c) designed its objectives and flow recommendations to halt and attempt to reverse the encroachment of emergent plants such as Phragmites and Typha into the river channel, which had expanded due to years of low flow conditions during the drought. The flooding of January 2011 removed the reed beds, as well as the instream vegetation such as *Triglochin* spp. and *Myriophyllum* spp. (Jacobs 2014a). Since the floods there has been limited recruitment of emergent and instream vegetation in Reach 2, and virtually no recruitment in Reaches 3 and 4. Apart from the intrinsic value of the flora species, the “missing” vegetation also reduces habitat diversity and food sources for macroinvertebrates, fish larvae and small fish. In fact, the extensive encroachment of emergent vegetation was suggested to be supporting the macroinvertebrate community in SRA 2, giving the theme a moderate score (Davis et al. 2012)

Fish

The SRA score for native fish was “extremely poor” in both audits. The score is low because a number of species expected to be present were not recorded during either audit, recruitment evidence was limited to Australian Smelt and Carp Gudgeon and exotic species contributed to just over 50% of abundance and more than 70% of the biomass. Most of the native fish captured were small-bodied species and their mean biomass was less than a tenth of that of the alien fish. The majority of the biomass was Common Carp (*Cyprinus carpio*) (Davies et al. 2012). Common Carp is a generalist species, persisting under a wide range of conditions and exploiting a wide range of food sources (Weber & Brown 2009).

VEFMAP monitoring supports the SRA fish assessment (Jacobs 2014b). Figure 9 shows that the biomass in each reach is dominated by exotic fish. Very low numbers of large bodied fish, such as Murray Cod and Golden Perch have been captured (despite Murray Cod and Golden Perch being stocked) in all reaches and low numbers of Silver Perch (not stocked) in Reach 4.

Historically large bodied fish are likely to have been represented in far greater numbers and contributed to a much greater proportion of the biomass (Davies et al. 2008; 2012; Humphries and Winemiller 2009). Further, Murray-Darling Basin species that would have historically been present and abundant are presumed lost from the river (Davies et al. 2008; 2012; Jacobs 2014a). Table 14 shows the native fish species expected to be present and relevant abundance in a reference condition lowland inland river (Davis et al. 2008; 2012).

Cold water pollution, as discussed in Section 3.1, is a significant risk to native fish, particularly at times when spawning would be occurring, as many native fish require temperatures above 20°C to spawn. Common Carp on the other hand can spawn at temperatures as low as 15°C (Lintermans 2009; Lugg & Copeland 2014).

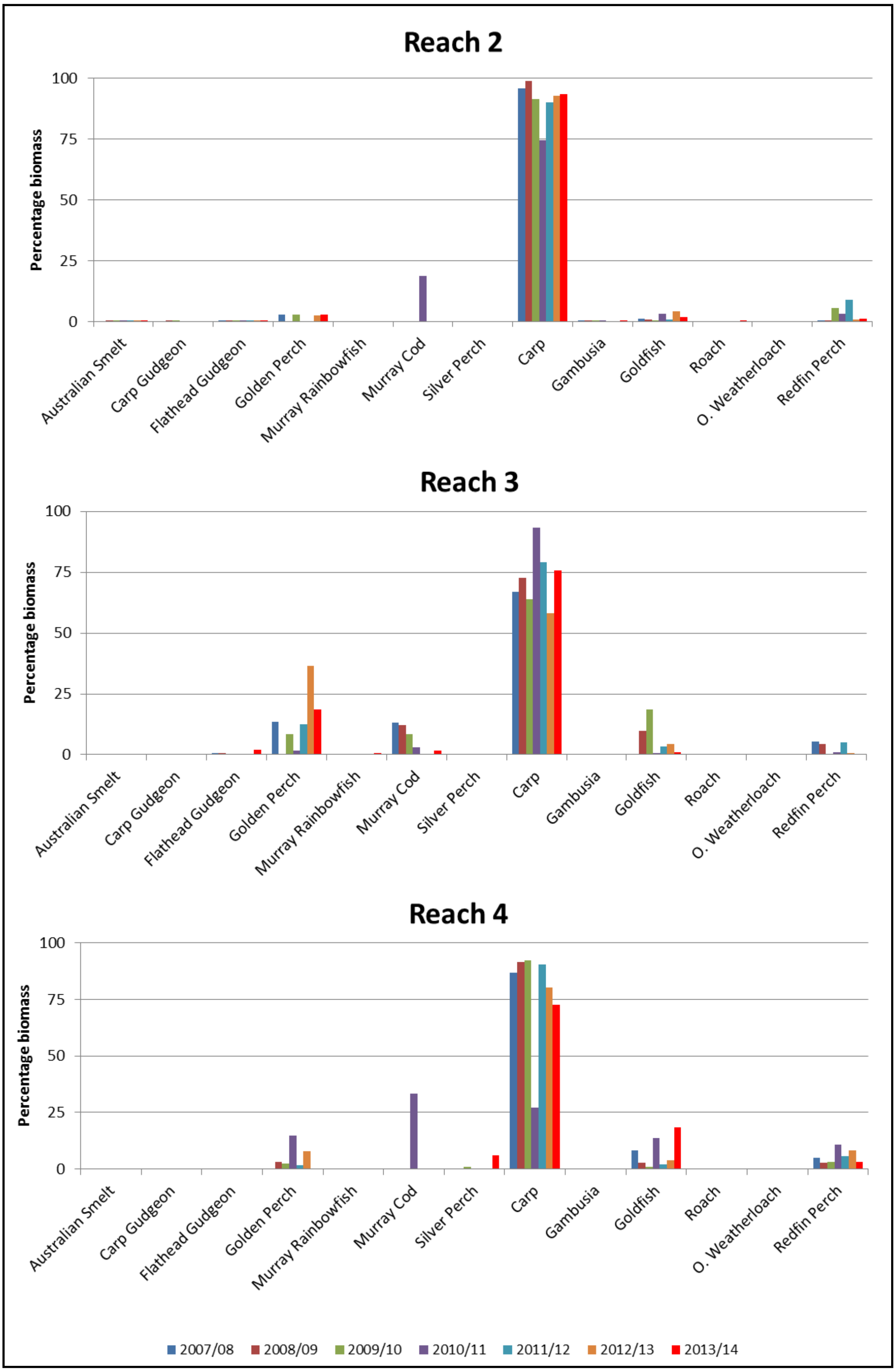

Figure 9: Biomass of native fish vs exotic fish as captured in VEFMAP fish surveys (Jacobs 2014b)

Table 14: Pre-1750 fish species and their rarity

Common Name	Scientific Name	Rarity
Common		
Australian Smelt	*Retropinna semoni*	5
Flathead Gudgeon	*Philypnodon grandiceps*	5
Golden Perch	*Macquaria ambigua ambigua*	5
Gudgeon	*Hypseleotris spp*	5
Murray Cod	*Maccullochella peelii*	5
Moderate		
Bony Herring	*Nematalosa erebi*	3
Freshwater Catfish	*Tandanus tandanus*	3
Macquarie Perch	*Macquaria australasica*	3
Murray Jollytail	*Galaxias rostratus*	3
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*	3
Obscure Galaxias	*Galaxias sp1*	3
River Blackfish	*Gadopsis marmoratus*	3
Silver Perch	*Bidyanus bidyanus*	3
Southern Purple-spotted Gudgeon	*Mogurnda adspersa*	3
Trout Cod	*Maccullochella macquariensis*	3
Unspecked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	3
Uncommon		
Congolli	*Pseudaphritis urvillei*	1
Dwarf Flathead Gudgeon	*Philypnodon sp1*	1
Murray Hardyhead	*Craterocephalus fluviatilis*	1
Shorthead Lamprey	*Mordacia mordax*	1
Southern Pygmy Perch	*Nannoperca australis*	1
Key: 5= common, 3= moderate, 1= uncommon,		
Source: Davis et al. 2008; Davis et al. 2012.		

Macroinvertebrates

The macroinvertebrate community in the Campaspe River downstream of Lake Eppalock is dominated by species that can tolerate relatively poor water quality and is typical of many lowland rivers in Northern Victoria (Jacobs 2014a). Both SRA and ISC scores are based on presence/absence of tolerant vs intolerant taxa (Davis et al. 2008; Davis et al. 2012; DEPI 2013e). However, despite the dominance of tolerant taxa indicating poorer water quality from reference condition, the majority of the functional groups are present. These functional groups are integral to the food web of the Campaspe River. They play a significant role in breaking down coarse particulate organic material, nutrient spiralling and other ecological processes and a diversity of taxa are an important food source for fish, Platypus and other aquatic biota (Jacobs 2014a).

5.3. Condition Trajectory - Do nothing

While a significant irrigation entitlement volume has been reduced, there are still a large number of irrigation diverters extracting directly from the river channel or trading water out of the catchment. Further, there will be no change to the way Lake Eppalock is managed during a flood, pre-releases will only be made when the storage is close to full and there is rain forecast. The introduction of carryover and spillable water accounts, will further impact flows in the Campaspe River.

A particular risk is the Campaspe Valley Account which holds water traded by Campaspe Irrigators with water users in the Murray (currently around 40GL). The call for this water is likely to be during the warmer dryer months and this, coupled with irrigation usage on the Campaspe River, means that the inverted seasonal pattern of flow releases will still occur with releases being higher than the summer low flow recommendation and lower volumes in the winter/spring months as water is harvested by storages.

If environmental water is not delivered to the Campaspe River:

- There is a very real risk that without high flow freshes in spring the riparian zone will significantly decline as the older trees die.

- That native fish populations will decline due to:
    - Unsuccessful recruitment of native fish due to flushing out of slackwater habitat by discharges of irrigation water at high flow rates through the summer unless properly managed
    - Loss of young-of-year fish due to negligible flows in winter restricting the river to pools where small fish are more vulnerable to predation
    - Potential loss of all life stages of fish at periods of very low flow due to stratification of saline pools at periods of low flow, particularly in Reach 4, and associated dissolved oxygen loss.
- Negative impacts on macroinvertebrates due to rapidly fluctuating levels (which is how irrigation water is delivered under the modernised automated system) interrupting macroinvertebrate lifecycles impacting on the functional group diversity within the river (Violin et al. 2011). Macroinvertebrates are a critical component of the food web, both as a food source, and through functions such as breaking down carbon and detritus (Jacobs, 2014a).

6. Management Objectives

6.1. Management Goal

The long term management goal for the Campaspe River has been derived from a variety of sources including technical reports, the VWMS and North Central Waterway Strategy goals and incorporates the environmental values identified in Section 4, and seeks to address the condition and condition trajectory discussed in Section 5.

Campaspe River long term management goal
To rehabilitate the Campaspe River's highly valued and ecologically important River Red Gum communities, native fish populations and facilitate its connection to the Murray River through the provision of an appropriate water regime.

6.2. Ecological Objectives

The ecological objectives established under the Campaspe River Environmental FLOWS assessment (SKM 2006c) have been reviewed by the original EFTP (Jacobs 2014a). The review recognised that while some of the objectives differed slightly between reaches, they are generally consistent across the whole river.

The ecological objectives shown in Table 15 are to be achieved through the provision of environmental water over the next ten years. Appendix 6 provides the ecological objectives as established in the update of the flows study and identifies the reach each ecological objective applies to.

Table 15: Ecological objectives for the Campaspe River

Objective	Justification
1. Maintain/Increase River Red Gum: To maintain adult River Red Gum trees and facilitate successful recruitment	River Red Gum trees an important, intrinsic component of river ecosystem biodiversity.[4]
2. Increase native fish: To increase the population size, with an appropriate age structure of small and large-bodied native fish known to occur in the Campaspe River. E.g. Golden Perch, Murray Cod and Murray-Darling Rainbowfish	Native fish play an important role in freshwater ecosystems and are a vital part of food webs. Some species are high-level predators and others consume algae, plants and invertebrates like insects and shrimp. In turn, fish are a vital source of food—for other fish, waterbirds and shorebirds, turtles and other aquatic fauna.[5]
2.1 Maintain/increase diversity and productivity of macroinvertebrates and macroinvertebrate functional feeding groups	Macroinvertebrates are a critically important component of the food web: • They extract carbon from leaf litter and primary producers such as diatoms, algae and macrophytes available to higher order consumers such as fish and Platypus. • Different functional groups serve different ecological functions; e.g. shredders convert fallen leaves to coarse and fine particulate organic matter that can be consumed by other biota and allows material to more readily move downstream; filter feeders can affect nutrient spiralling rates by sieving food from the water column.

[4] This objective aligns with expected outcomes under the draft Basin-wide Environmental Watering Strategy for River Red Gum.

[5] This objective aligns with expected outcome under the draft Basin-wide Environmental Watering Strategy for native fish.

Objective	Justification
2.2 Increase extent/maintain emergent littoral macrophytes (e.g. Phragmites, rushes, reeds and sedges) on benches and edges of channel, but limit their encroachment into the middle of the channel	Fringing emergent plants were common throughout the reach prior to the 2011/12 floods, but are now rare. They are an important component of the stream ecosystem and provide habitat, sediment and bank stability and support food webs.
2.3 Increase extent/maintain instream aquatic plants (e.g. Water Ribbons, Eel Grass)	Instream plants were common throughout the river prior to the 2011/12 floods, but are now rare. They are an important component of the stream ecosystem and provide shelter for small fish and support food webs.
2.4 Control salinity and stratification in deep pools	High salinity and low dissolved oxygen concentrations are a threat to aquatic biota. Freshes can periodically mix stratified pools.
3. Facilitate recolonisation by native fish species that have been presumed lost e.g. Trout Cod, River Blackfish and Macquarie Perch.	These species would have historically been abundant in the river. • Reach 2 and 3: The ability to achieve this objective will depend on opportunities for fish passage past the Campaspe Weir and Campaspe Siphon that will allow fish to move into the reach from the Murray and Reaches 3 and 4. • Reach 4: the recent replacement of the Echuca flow gauge weir with a rock ramp fishway should allow more species to recolonise this reach.[6]
4. Platypus - Maintain/increase resident breeding population by facilitating successful recruitment at least every second year and promote safe dispersal by juveniles.	The Campaspe River is an important source of juvenile Platypus to facilitate recolonisation of the Murray River.
5. Maintain/Improve connectivity between the Campaspe River reaches and between the Campaspe River and the Murray River	Connectivity facilitates dispersal and movement of plant propagules, micro and macro invertebrates, fish, frogs, turtles and Platypus as well as carbon and nutrient cycling.[7]

[6] This objective aligns with expected outcome under the draft Basin-wide Environmental Watering Strategy for native fish.

[7] This objective aligns with expected outcome under the draft Basin-wide Environmental Watering Strategy for connectivity

6.3. Campaspe River flow recommendations

Flow recommendations describe the water regimes required for achieving ecological objectives. All values identified have components of their life-cycle or process that are dependent on particular flow components for success e.g. native fish require certain timing, duration and frequency of flooding to successfully breed and maintain their population.

To meet the hydrological requirements of the Campaspe River EWMP, flow recommendations have been set considering the following factors:

- the preferred timing of watering events
- the recommended duration for watering events
- the tolerable intervals between events (condition tolerances)
- the volume required to provide these events – per event / per season.

The flow recommendations are presented as two seasons (summer and winter) as per the FLOWS method (DEPI 2013f). The summer season also encompasses autumn and the winter season encompasses spring. This roughly aligns with the natural shift from wetter weather and greater inflows in winter and spring, and dryer weather with greater evaporation and less inflows in summer and autumn. Where values require particular timing for water this has been identified (in Table 16).

Appendix 6 details the hydrological requirements in terms of the frequency, duration, and timing for all of the ecological objectives.

Table 16: Annual flow recommendations

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Cease-to-flow	0 ML/day	1-5 weeks	**Reach 2:** Dry - 1-2 events between January and April in dry years acceptable, but avoid cease-to-flow in more than 2 consecutive years Ave – Wet: not at all **Reach 3 & 4:** Not recommended	**Reach 2:** Not recommended for the reach, however it will be acceptable in some years if there is limited environmental water. If the river is allowed to stop flowing, it will be necessary to monitor water quality in pools to ensure conditions don't deteriorate too much (e.g. dissolved oxygen drops below 4 mg/L). **Reach 3 & 4:** The CMA does not recommend a cease-to-flow event in this reach because there are fewer deep refuge pools than Reach 2 and there is also some saline (up to 5,000 EC) groundwater intrusion that will affect water quality and increase stratification in pools if there is no surface flow.	-	**Reach 2:** Likely to be detrimental to water quality, prevent re-colonisation by instream vegetation, stress macroinvertebrates in riffle habitats and limit Platypus dispersal if occurs in later summer early autumn. Deep pools will be a critical refuge for all aquatic biota during cease-to-flow events **Reach 3 & 4:** Likely to be detrimental to water quality, prevent re-colonisation by instream vegetation, stress macroinvertebrates in riffle habitats and limit Platypus dispersal if occurs in later summer early autumn.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Summer low flow	10-50 ML/day	6 months Dec-May	Vary the magnitude of flow within the prescribed range throughout Dec-May. Higher magnitude in Dec, gradual decline through Jan-Feb then gradual rise from Mar-May	Ave: Target average low flow of 20-30 ML/day in average years. Dry: In dry years the low flow can be closer to 10 ML/day for most of the season. Wet: In wet years the flow can be closer to 50 ML/day for most of the season. 50 ML/day also acceptable when IVT needs to be delivered through the Reach. Flows greater than 50 ML/day may be too high for slackwater habitats	**2** **2.1** **2.2** **2.3** **2.4** **4**	**General:** The low flow is critical for maintaining a variety of aquatic riverine habitats. Provides sufficient volume of water to engage riffle and run habitats for macroinvertebrates, fish and aquatic plants and foraging habitat for platypus. High diversity and abundance of habitat is important for river food webs; it determines the potential biomass of macroinvertebrates and food for fish and Platypus. **Fish:** Maintains slackwater habitats which are productive areas for zooplankton and nursery habitats for many native fish, especially opportunistic low flow specialists such as Carp Gudgeon and Murray Rainbowfish. **Vegetation:** Maintaining a low flow will allow native instream vegetation to colonise the channel margins. **Macroinvertebrates:** Varying low flow magnitude over the season will inundate fallen wood to varying degrees, which will promote growth of biofilms, support macroinvertebrates and provide habitat for fish. **Water quality:** Maintains water in deep pools and maintains water quality or at least a layer of freshwater at the top of those pools. **Platypus:** Connecting flow through reach will also allow Platypus to safely move between pools while foraging and ensure adequate food for lactating females.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Summer fresh	50-200 ML/day Aim for 75-125 ML/day in an average flow year	1-3 days at peak with moderate ramp up and slower ramp down	3 events per year 1 event Dec-Feb with peak at 1 day 2 events Mar-May with peak at 2-3 days	The summer fresh aims to increase water depth by 15-30 cm compared to the summer low flow and therefore its magnitude will vary each year. <u>Ave:</u> Aim for 75-125 ML/day in average years when summer low flow is 20-30 ML/day. <u>Dry</u> In years when the low flow is 10 ML/day the fresh only needs to be 50-75 ML/day. <u>Wet:</u> In years when the summer low flow is around 50 ML/day the summer fresh should be 125-200 ML/day. <u>Caveat:</u> A summer fresh between December and February is required for maintenance/ recruitment of emergent vegetation, however a fresh at this time will flush out slackwater habitats. Therefore the EFTP recommended that the CMA does not actively deliver more than one fresh in Dec-Feb to avoid disturbing slackwaters during main fish larval rearing phase. This recommendation may be ignored if water quality deteriorates in dry years. In those circumstances several small freshes (50-75 ML/day may be released to flush pools. More frequent events are OK after February in any year and may help facilitate Platypus dispersal. The summer fresh should be no greater than the maximum flow in the previous winter/spring to reduce risk of blackwater.	**2** **2.1** **2.2** **3**	**General:** The average summer fresh will provide flow through the second flow path on the right hand side of the island at Doakes Reserve, but will not wet the higher second flow path at English's Bridge. Flush fine silt and sediment from submerged wood and other hard surfaces. **Fish**: Promote local movement adult fish to access alternative habitats. The autumn freshes will be particularly important for facilitating dispersal of juvenile fish including species with 'opportunistic' and 'equilibrium' life history strategies. **Vegetation:** Inundate the lower banks and low benches to wet the soil and promote establishment, growth and survival of fringing emergent macrophytes such as Phragmites, reeds and sedges. **Macroinvertebrates:** Wash organic matter into stream to drive aquatic food webs. Wet submerged wood and flush fine silt and old biofilms to promote new biofilm growth and increase macroinvertebrate productivity **Platypus:** Facilitate downstream dispersal of juvenile Platypus in Apr-May to colonise other habitats in the Murray River.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Winter low flow	50-200 ML/day Aim for 100 ML/day in average flow years	6 months Jun-Nov	Vary the magnitude of flow within the prescribed range throughout Jun-Nov to match the natural flow regime. Ramp the flow up slowly from June to deliver the highest magnitude in Jul-Sep, then gradually drop flow through Oct-Nov.	<u>Ave:</u> Target average low flow of 100 ML/day in average years. <u>Dry</u>: In dry years the low flow can be closer to 50 ML/day for most of the season. <u>Wet:</u> In wet years or in years when flow needs to be transferred downstream the flow can be closer to 200 ML/day for most of the season Need to avoid sudden and frequent fluctuations in low flow magnitude.	**2** **2.1** **2.2** **2.3** **4**	**General:** The average winter low flow will provide flow through the second flow path on the right hand side of the island at Doakes Reserve, but will not wet the higher second flow path at English's Bridge. Keep submerged wood and other hard surfaces clear of fine silt and sediment **Fish:** Allow localised fish movement throughout the reach. The peak movement period is August to November as water temperature increases. **Vegetation:** Prevent terrestrial plants colonising the lower sections of the river bank and low benches in the channel. Maintain soil water in the river bank to water established River Red Gum and woody shrubs such as Bottlebrush and Tea Tree. Water and help establish littoral vegetation such as *Bolboschoenus* spp. **Platypus:** Facilitate long distance movement by male Platypus especially during the Aug-Oct breeding season. Provide foraging opportunities across a wide range of habitats for females to develop fat reserves prior to breeding. **Macroinvertebrates:** Once water temperatures increase (generally September-Nov) the depth provided by winter low flows will inundate a wide variety and large abundance of habitats that will support high macroinvertebrate productivity. **Water quality:** Flow is sufficient to prevent pools stratifying.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Winter small fresh	1000-1800 ML/day	1-2 days at peak Note – this event may need a duration of 7 days to facilitate fish movement in downstream reaches	2 per year (1 in Jul-Aug & 1 in Sep-Oct) in average to wet years. Not expected in very dry years.	The timing of the second flow should vary each year. It may be delivered in November in some years, but should not be delivered in November often or in consecutive years to avoid flushing slackwater habitats that may support developing fish larvae. If operational constraints are overcome, the small fresh will be replaced by a large fresh in some years. Important to deliver events in consecutive years because first event intended to trigger River Red Gum recruitment and second year intended to help new recruits from first year become established. It will be optimal to provide higher end of this event to facilitate at least two recruitment cycles per decade. If that is not possible then provide two events in two consecutive years at least once per decade and other events as needed to ensure no more than 4 years and preferably no more than 3 years without a watering event to maintain established trees. This maintaining flow is only needed once in a year and can be delivered at any time of year.	**1** **2** **2.1** **2.2** **3** **4** **5**	**General:** Redistribute fine sediment on benches and bars in the bottom of the channel and scoured aged biofilms from hard surfaces included submerged wood. **Water quality:** Flush accumulated leaf litter from bank and low benches to reduce risk of blackwater events during managed flow releases in summer. **Vegetation:** Wets the bank to help maintain soil moisture for established River Red Gum and woody shrubs such as Bottlebrush and Tea Tree. First winter event will have little effect on vegetation, Sep-Oct event is in growing season and will help riparian species become established low on the bank and limit colonisation by terrestrial plant species. These flows will also help scour established macrophytes from the middle of the channel and therefore maintain a clear flow path. **Fish:** Facilitate fish movement throughout whole reach and if artificial barriers are removed could allow fish to move to and from other reaches including the Murray River, which is important to maintain existing populations and support recolonisation by species that are presumed lost from the reach. Fresh in Sep-Oct may trigger Periodic spawners such as Golden Perch and Silver Perch to either spawn or move to the Murray River to spawn. **Platypus:** Fresh prior to egg-laying (ideally Aug) encourages females to select a nesting burrow higher up the bank to reduce risk of high flow later in the year flooding the burrow when juveniles are present. **Macroinvertebrates:** Flushing organic matter into the stream in winter and spring will allow it to be conditioned for consumption and breakdown by bacteria and invertebrates when water temperature increases and hence support the riverine foodweb.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Winter large fresh	1800-2000 ML/day	2-3 days at peak Note – this event may need a duration of 7 days to facilitate fish movement in downstream reaches	2 events per year in 2 consecutive years twice per decade. First event each year in Jul-Aug (preferably Aug) to wet the bank and benches, second event each year in Sep-Nov to stimulate RRG recruitment. Try to avoid delivering the event in November too often as it may flush developing fish larvae and juveniles from slackwater habitats. These events replace the small winter fresh when delivered.	Unlikely that these events can be delivered regularly, so recommendation is to wait for a natural event. If infrastructure constraints are overcome this event would be beneficial following a natural event to help any new River Red Gum and other riparian plants that recruited during the natural event get established. Important to deliver events in consecutive years because first event intended to trigger River Red Gum recruitment and second year intended to help new recruits from first year become established. It will be optimal to provide two recruitment cycles per decade. If that is not possible then provide two events in two consecutive years at least once per decade and other events as needed to ensure no more than 4 years and preferably no more than 3 years without a watering event to maintain established trees. This maintaining flow is only needed once in a year and can be delivered at any time of year.	**1** **2** **2.1** **2.2** **3** **4** **5**	**General:** This flow is large enough to inundate benches and secondary flow paths in the lower part of the channel. Redistribute fine sediment on benches and bars in the bottom of the channel and scoured aged biofilms from hard surfaces included submerged wood. **Water quality:** Flush accumulated leaf litter from bank and low benches to reduce risk of blackwater events during managed flow releases in summer. **Vegetation:** Primary aim of these higher flows is to promote RRG recruitment on benches in the channel. The event in Jul-Aug is too early to trigger recruitment, but it wets the soil to condition it for the Sep-Nov event, which is intended to trigger recruitment. These flows will also help scour established macrophytes from the middle of the channel and therefore maintain a clear flow path. **Fish:** Facilitate fish movement throughout whole reach and if artificial barriers are removed could allow fish to move to and from other reaches including the Murray River, which is important to maintain existing populations and support recolonisation by species that are presumed lost from the reach. Fresh in Sep-Oct may trigger Periodic spawners such as Golden Perch and Silver Perch to either spawn or move to the Murray River to spawn. **Platypus:** Fresh prior to egg-laying (ideally Aug) encourages females to select a nesting burrow higher up the bank to reduce risk of high flow later in the year flooding the burrow when juveniles are present. **Macroinvertebrates:** Flushing organic matter into the stream in winter and spring will allow it to be conditioned for consumption and breakdown by bacteria and invertebrates when water temperature increases and hence support the riverine foodweb.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Bankfull flow	**Reach 2:** 10,000 - 12,000 ML/day or maximum that can be delivered without causing flooding in downstream reaches **Reach 3 & 4:** 8,000 ML/day or maximum that can be delivered without causing flooding in downstream reaches	1-2 days at peak	Only need to deliver in the year after a natural bankfull or overbank flow event. Can be delivered at any time of year	Unlikely that these events can be delivered regularly, so recommendation is to wait for a natural event. If infrastructure constraints are overcome this event would be beneficial following a natural event to help any new River Red Gum and other riparian plants that recruited during the natural event get established.	**1** **2** **3** **5**	**Vegetation:** The main objective of this event is to help any riparian plants (especially River Red Gum) that established in the natural event get established so that they can withstand prolonged periods without inundation in subsequent years. These events will also help to scour vegetation from the middle of the channel and therefore maintain an open clear flow path. **Geomorphology:** Bankfull flows are channel forming. They will scour sediment from pools to maintain their volume and depth and replenish benches and bars within the channel. **Fish:** Bankfull flows that drown out artificial barriers will allow fish to disperse between reaches and if delivered in Sep-October are likely to trigger Golden Perch and Silver Perch to spawn and/or migrate.
Overbank flows	**Reach 2:** Greater than 10,000 ML/day **Reach 3 & 4:** Greater than 12,000 ML/day	As natural	As natural	Cannot deliver or control overbank flows	**1** **5**	**Geomorphology:** Overbanks flows are channel forming. They will scour sediment from pools to maintain their volume and depth and replenish benches and bars within the channel. They will also help maintain floodplain habitats, move sediment between the stream and the floodplain and wash organic material from the floodplain into the stream. **Vegetation:** The main objective of this event is to help any riparian plants (especially River Red Gum) that established in the natural event get established so that they can withstand prolonged periods without inundation in subsequent years.

6.4. Ten year water regime and hydrological objectives

Historically river systems have been managed according to annual flow recommendations. However, to achieve long term objectives flow regimes need ot be adaptable and variable from one year to the next. To meet the ‘long-term’ requirements of the Campaspe River EWMP, a ten year flow regime been established considering the following factors and is shown in Table 17:

- the recommended number of watering events over a ten year period; and
- the tolerable intervals between events (condition tolerances)

It should be noted that the ten year watering regime is assuming water availability and will need to be adaptively managed and be based on outcomes achieved in the previous year. Table 16 shows the detail of the flow recommendations within the watering regime including the ecological objectives supported by the different flow components.

6.4.1. Campaspe River ten year water regime

Table 17: Ten year water regime for the Campaspe River (assuming water availability)

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Focus objectives	Establish instream /emergent vegetation	Establish instream /emergent vegetation Successful native fish recruitment	River Red Gum Recruitment	Follow up watering for River Red Gum recruitment	Maintain instream /emergent vegetation	Maintain instream /emergent vegetation Successful native fish recruitment	River Red Gum Recruitment	River Red Gum recruitment	Maintain instream /emergent vegetation	Maintain instream /emergent vegetation
	Successful native fish recruitment	Successful native fish recruitment		Successful native fish recruitment	Successful native fish recruitment	Successful native fish recruitment		Successful native fish recruitment	Successful native fish recruitment	Successful native fish recruitment
Summer Low Flow	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Summer Fresh										
Dec/Jan	✓	✓		✓	✓	✓	✓		✓	✓
Feb			✓					✓		
March – May	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Winter Low Flow	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Small Winter Fresh										
July-Aug	✓	✓	✓	✓	✓	✓	✓		✓	✓
Sept-Oct	✓	✓		✓	✓	✓		✓	✓	✓
Nov			✓				✓			

Large Winter Fresh/Bankfull/Overbank	Review once achievable[8]	Review once achievable	Review once achievable	Review once achievable	Review once achievable	Review once achievable	Review once achievable	Review once achievable	Review once achievable	Review once achievable

[8] The outlet tower on Lake Eppalock release capacity is 1850 ML/day, therefore managed releases of large winter fresh, bankfull and overbank flow components are not able to be achieved.

7. Risk Assessment

A qualitative risk assessment has been undertaken to assign the level of risk of threats to achieving the objectives as well as risks related to the delivery of environmental water through the implementation of this EWMP. The relationship between likelihood (probability of occurrence) and the severity (severity of the impact) provide the basis for evaluating the level of risk (Table 18).

Table 18: Risk Matrix

		Severity		
		Major	Moderate	Minor
Likelihood	Probable	High	High	Moderate
	Possible	High	Moderate	Low
	Improbable	Moderate	Low	Low

The results from the Campaspe River risk assessment are presented in Table 19. Management measures relevant for the moderate to high level risks are recommended and the residual risk is then recalculated using the same risk matrix. Please note that short-term operational risks (e.g. environmental releases causes flooding of private land) are assessed as part of the development of the Campaspe System Seasonal Watering Proposal.

Table 19: Risk assessment and management measures (R= risk; RR = residual risk)

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
Threats to achieving ecological objectives								

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
1	Artificial instream structures (i.e. the Lake Eppalock dam wall, Barnadown Gauging Station Weir, the Campaspe Weir and the Campaspe Siphon)	*Water Quality* Lake Eppalock has a multi-level offtake tower that releases water from below the surface. This contributes to cold water pollution. Cold water pollution is likely to impact aquatic biota for example cold water changes macroinvertebrate community structure, slows growth rates, lowers rates of productivity and some fish may not spawn if temperatures are too low. Hypoxic water can also be released from Lake Eppalock. Thermal stratification resulting in low dissolved oxygen levels have been experienced in the lake. A cone valve exists that potentially reoxygenates releases, however hypoxic conditions have occurred in the 2012-13 season immediately downstream of Lake Eppalock when releases from the outlet tower are lower than eight metres.	2 2.1	Probable	Major		Cold water and hypoxic water releases can be slightly ameliorated if the highest level offtake was used, however an upgrade of the Lake Eppalock Structure to facilitate taking water from the surface water of Eppalock would provide the most effective management measure. Residual risk calculated on a full upgrade reducing the likelihood to improbable (see Section 8). This management measure has not been costed, and funding will need to be secured to achieve these management measures.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
2		*Longitudinal Connectivity* Instream barriers restrict: • downstream movement of plant propagules and the source of seeds or plant fragments required for the recolonisation of areas denuded by recent floods. • downstream movement of carbon and nutrient inputs especially coarse and fine particulate organic matter because leaf litter inputs are generally highest in headwater reaches. • upstream and downstream movement by fish between the reaches, causing issues such as genetic isolation and restricting spawning opportunities for migratory spawners such as Golden Perch and Silver Perch. • movement by Platypus that are then exposed to higher risk of predation if forced to travel overland to move between reaches. • recolonisation between river reaches when populations are affected by some sort of disturbance (O'Brien et al. 2006).	2 2.2 2.3 3 4	Probable	Major		Campaspe Weir and Campaspe Siphon will need to be upgraded for fish passage. Residual risk calculated on full passage upgrades reducing the likelihood to improbable (see Section 8). Funding will need to be secured to achieve these management measures.	
3		*Geomorphology* The structures are likely to be sediment traps that prevent large flows from carrying sufficient sediment loads to refresh benches bars etc. This is particularly true for sections of the river immediately downstream of these dams or weirs. A consequence of this may be restricted recolonisation of benches by vegetation if the upper loose/friable layers have been stripped away and only a hard clay layer may remain.	1 2.2 2.3	Possible	Minor		The sediment trapping nature of the Lake Eppalock dam wall is not likely to change. Campaspe Weir is no longer required for irrigation diversions, and is estimated to have a lifespan of 15-20 years remaining. Management options include fully removing the weir or upgrading the structure. An upgrade of the structure would still reduce sediment movement downstream. As discussed in Section 1.1, Barnadown Gauging Station is drowned out at higher flows. Further monitoring is required to determine the flow at which the Campaspe Siphon is drowned out. Residual risk stays the same.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
4	Stocking of native fish species such as Murray Cod and Golden Perch	Hatchery stocking can mask broader problems with fish abundance and richness (Jacobs 2014b). Current stocking programs target Golden Perch and Murray Cod in the Campaspe (DEPI 2013e). The actual severity of the threat to native fish communities is uncertain so moderate was selected.	2	Probable	Moderate		Residual risk is calculated on removal of stocking program reducing likelihood to possible (stocked fish could move into the Campaspe River from elsewhere). Further research is required to fully understand the risk prior to implementation.	
5	Recreational fishing	Recreational fishing can reduce numbers of target species, which can be a problem if the river is reduced to pools, such as during a drought (Jacobs 2014b). Anglers do not discriminate between stocked and naturally recruited fish (as this is not possible). Severity of the threat to native fish communities is uncertain.	2	Probable	Moderate		Implement a catch and release education program for native fish, while promoting catch and keep for introduced species such as Redfin Perch. Residual risk is calculated based on assumed likelihood that reduced to possible. Involving local angler groups in a fish monitoring program could be a tool for education.	
6	Grazing pressures	The Campaspe River features mostly continuous native tree canopy, however this primarily comprises large old trees. 14% of the Campaspe River is currently fenced. Grazing by domesticated, feral and/or native herbivores (e.g. cattle, sheep, rabbits, kangaroos and wallabies) may be prevent establishment of emergent vegetation on benches and recruitment of understorey and overstory species within the riparian zone. This may be caused by direct grazing pressure (most likely) or sediment pugging (less likely). Severe grazing pressure may also impact submerged aquatic vegetation via direct herbivory and physical disturbance.	1 2.2 2.3	Probable	Major		Fencing and stock exclusion have demonstrable benefits to riparian vegetation. Fencing of riparian zone and including stock exclusion or modified grazing regime in Riparian Management Agreements with landholders is currently being undertaken in the Caring for the Campaspe Project which will fence a further 15% of the Campaspe River riparian zone by 2016 – this includes upstream reaches. Implementing Rabbit control measures (not funded). Residual risk assumes that funding of the Caring for the Campaspe Phase 2 is secured. The likelihood is possible and the scale of severity is reduced to moderate.	
7	Introduced species - Common Carp	High abundance of Common Carp limits the establishment and subsequent maintenance of in-stream (submerged) vegetation with flow on affects to the entire food web (Jacobs 2014b). Carp also feed at lower trophic levels in the food web along with macroinvertebrates and small bodied fish, yet they are long lived and grow very large, effectively locking up large amounts of carbon that would flow up the food web and support higher trophic levels in natural systems (Jacobs 2014b).	1 4	Possible	Moderate		There is yet to be a broadscale successful method for controlling Common Carp biomass. This is a knowledge gap across the Murray-Darling Basin. Further it is suspected that the proposed flow regime may continue to provide favourable conditions for Common Carp as the species is successful under a number of niches.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
8	Introduced species - Foxes	Predation on Platypus and other aquatic fauna such as freshwater turtles – aquatic fauna that can leave the water are vulnerable to predation when travelling through very shallow water or across dry land (Jacobs 2014b).	4	Possible	Moderate		Managing this risk relates to improving riparian cover and longitudinal aquatic connectivity as well as fox control programs. Residual risk is assessed assuming full implementation of these measures reducing likelihood to improbable	
9	Introduced species – Gambusia/ Redfin	Eastern Gambusia have been linked to the decline in distribution and/or abundance of small bodied fish such as Murray-Darling Rainbowfish, Olive Perchlet and Purple Spotted Gudgeon through competition for food and habitat. Research has also indicated that larger predatory fish species such as Murray Cod and Golden Perch actively avoid Eastern Gambusia as a prey item (Macdonald & Tonkin 2008). Redfin Perch is a predatory fish and preys on small bodied fish (Jacobs 2014b).	2	Probable	Major		Research indicates that traps that exploit Eastern Gambusia's attraction to light and heat may maximize capture of eastern Gambusia while having a minimal impact on native fish (Macdonald & Tonkin 2008). Residual risk is assessed assuming that Eastern Gambusia numbers are controlled within the Campaspe, but that recolonisation from the Murray River is possible but that the spatial severity (i.e. recolonisation is managed) is moderate	
10	Extended high water levels between September and February	Depending on the magnitude and duration of flows, flooding can substantially reduce Platypus reproductive success from the time that females incubate eggs (starting in September) through at least the end of February. A lactating female blocks the tunnel leading to her nesting chamber with consolidated soil 'pugs' to help protect her offspring from drowning if water levels rise for a short period. However, this measure will be ineffective if flood waters persistently remain above the level of the nesting chamber.	4	Possible	Moderate		Freshes scheduled in spring or summer should be coupled to a preceding event of similar or greater magnitude in August, i.e. around the time that breeding females are choosing nursery burrow sites, to encourage females to locate nesting chambers above the maximum height of the subsequent fresh. Resdiual risk is assessed assuming likelihood of burrows being flooded as improbable	
Threats related to the delivery of environmental water								
11	Winter high fresh drowning juvenile Platypus	Winter high fresh could inundate burrow entrance					Deliver winter high fresh in August to trigger female to select or construct nursery burrows higher in the river bank. Residual risk assumes implementation of management action	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
	Buildup of leaf little being mobilised by summer fresh	Blackwater event - Blackwater events generally occur when ephemeral streams with high loads of accumulated leaf litter are inundated or when high flow events wash large amounts of leaf litter into the river from the adjacent bank, benches and floodplain. Microbes rapidly consume the available carbon and it is their respiration that severely depletes oxygen levels in the water column. Microbial activity is higher in warm temperatures and is also governed by the amount of available organic material (Jacobs, 2014a).	2 2.1 3 4	Improbab le			The three factors that determine the likelihood and severity of a blackwater event are the magnitude of the high flow or re-wetting event, the timing of that event and the amount of accumulated organic material (Jacobs, 2014a). Management option is to deliver a summer fresh at the same magnitude as the previous winter low flow therefore the summer fresh will entrain only litter that has built up since the winter low flow was ceased. Residual risk assumes that the management action will reduce the special extent of the risk, reducing the severity to minor. Further research is required to understand the leaf loading threshold on the river bank where blackwater would be possible.	

8. Environmental Water Delivery Infrastructure

8.1. Constraints

The following section outlines the constraints to delivering environmental water in the Campaspe River.

8.1.1. Infrastructure constraints

Lake Eppalock outlet capacity

The recommended winter bankfull and overbank flows to the Campaspe River downstream of Eppalock, which range from 8,000 to 12,000 ML/day, are constrained by the available outlet capacity of Lake Eppalock. At less than full supply level, Eppalock outlet capacity is 1,850 ML/day. The capacity of Lake Eppalock outlet works could be increased to 12,000 ML/day. The cost of doing this is estimated at $AUD 25 million (SKM 2006d).

8.1.2. Operational constraints

Constraints in achieving bank full downstream of Eppalock

Reach 2 - Bankfull flow: to achieve 8,000 ML/day at Rochester, the flow rate required at Barnadown is 9,600 ML/day. This assumes 30% flow contribution from Mt Pleasant Creek at Barnadown which is close to the bankfull capacity in Reach 2 (10,000 ML/day). If it was attempted to achieve this flow from Lake Eppalock, a much higher flow rate would be required to allow for flow attenuation, which could result in overbank flows in some locations along Reach 2 (SKM 2012b).

Reach 3 - Environmental flow recommendations in Campaspe River Reach 3 are delivered via the Campaspe Weir, however the following recommendations would enhance the delivery of the desired flow regime:

1. Campaspe Weir investigations undertaken by GMW have recommended a remediation option to strengthen the Campaspe Weir and extend its life for a further 20 years. Any works undertaken will need to consider environmental water uses both upstream and downstream of the weir and provide fish passage.
2. To provide the winter bankfull flow component to Campaspe River Reach 3 there is a constraint at the Lake Eppalock outlet capacity at less than FSL (maximum 1,850 ML/day). Recommendations to modify Eppalock releases and piggyback on high tributary inflows have been made (SKM 2006d) for consideration by the Environmental Water Manager.

Reach 4 - There are three main issues that constrain the delivery of bankfull flows to Reach 4 by means of an in-stream release:

1. Longitudinal variations in channel capacity mean that the bankfull requirements of Reach 4 cannot be achieved without overbank flows in Reach 3. These overbank flows are likely to flood private property.
2. To provide the winter bankfull flow component to Reach 4 the same constraint at the Lake Eppalock outlet capacity as described for Reach 3 applies. Furthermore, the revised bankfull requirements of Reach 4 cannot be solely achieved from a Lake Eppalock release. As the maximum release rate from Lake Eppalock is 1,850 ML/day, a flow rate of 10,000 ML/day can only be achieved in Reach 3 if there is significant tributary contribution, or this release is made in conjunction with a high flow event (SKM 2012b).

   As the maximum that can be achieved in Reach 4 from in-stream flows without flooding Reach 3 is around 6,400 ML/day (Section 8.2), this leaves about 2,600 ML/day being required from the WWC. While this flow rate is within the conveyance capability of the WWC (up to 3,500 ML/day), the capability to release such a volume from the WWC into the Campaspe River is limited by outlet capacity (estimated at 2,300 ML/day), the irrigation requirements at that time, and could be affected by high flows in the Campaspe (SKM 2006c). This needs to be investigated in more detail.

8.2. Infrastructure recommendations

Lake Eppalock capacity

See Section 8.1.1.

Lake Eppalock release mechanism

Cold water pollution from Lake Eppalock could be managed by adjusting the water release level. This may be feasible given that Lake Eppalock already has a multi-level offtake tower; however Occupational Health and Safety (OHS) issues exist when changing the outlet level.

The installation of a thermal curtain on the tower could be a solution to mitigate the OHS risk and which would only allow the ambient surface water to enter the offtake for release (Lugg and Copeland 2014). Further work is required to cost this option.

Campaspe Weir

The Campaspe Weir was constructed to provide enough head in the river to divert water for irrigation by gravity. The estimated remaining life of the infrastructure is about 20 years (Chris Solum pers. comm [Goulburn Murray Water], July 2012). The Campaspe Weir pool is no longer required for irrigation due to the closure of the irrigation district. However, as experienced with the Echuca gauge weir, the community values the weir pool and the area is used recreationally for camping, recreational fishing, canoeing and swimming. Further, over time natural sediment build up, and active gravel reinforcement of the weir, could potentially threaten the downstream reaches. The options are to completely remove the weir, or modify it to include fish passage within the next ten to 20 years.

Campaspe Siphon

Downstream of the Campaspe Siphon, part of the recommended winter bankfull and overbank flow could also be delivered from the Waranga Western Channel. However, this is constrained by outfall capacity (1,470 to 2,300 ML/day), and off-season maintenance requirements. This needs to be investigated in more detail.

The Campaspe Siphon can be overtopped at flows greater than 1500 ML/day. Fish passage would facilitate connectivity at lower flows would enable fish movement between Reach 3 and Reach 4.

8.3. Complementary actions

Implementation of the above watering regime for the Campaspe River will generate benefits to the environmental values of the river. Some objectives require complementary actions to be realised. These are directly related to the risk section, i.e. risk of not achieving objectives (Table 20).

Table 20: Complementary actions to enhance the outcomes of environmental water

Activity	Rationale
Thermal curtain on Lake Eppalock outlet tower	Cold water pollution impacts native fish through creating conditions unsuitable for spawning.
Fish passage on Campaspe Weir and Campaspe Siphon	Upgrading these instream barriers would facilitate fish passage between the whole EWMP area, enhancing native fish genetic interaction, allowing fish to have access to a greater variety of habitat, and would facilitate colonisation after a severe disturbance.
Fencing	Livestock have direct access to the Campaspe River. This damages native vegetation and inhibits the recruitment of native vegetation including River Red Gum trees. Additional fencing will be required once the Caring for Campaspe Project is finalised.
Rabbit control	Rabbits are potentially grazing vegetation and inhibiting the recruitment of understorey species. Rabbit control measures include warren fumigation and education interactive activities such as rabbit buster.
Fox control	Foxes are likely to predate Platypus when the animals are in shallow water or moving across land. Fox control measures include baiting and interactive fox drives.
Carp control	Common Carp dominate the system; they have the largest biomass of all fish in the Campaspe. A truly effective carp control measure is yet to be devised, however carp screens on fishways and education interactive activities such as “catch a carp” may help.

9. Demonstrating Outcomes

Monitoring is required to demonstrate that watering is achieving long term environmental outcomes. Monitoring is also a critical component of the adaptive management of Campaspe River.

Two types of monitoring are recommended to assess the effectiveness of the proposed water regime on objectives and to facilitate adaptive management:

- Long-term condition monitoring
- Intervention monitoring

Currently the principle monitoring program for the release of environmental water on the Campaspe River is the VEFMAP program. The State is has recently reviewed the VEFMAP program which will inform the next phase of environmental watering monitoring is uncertain. Appendix x details the findings of the review.

The North Central CMA and VEWH held a workshop on 9 October 2014 to develop a monitoring program for the Campaspe River EWMP. The monitoring program below is specifically related to demonstrating achievement of the short and long-term objectives of the Campaspe River EWMP.

9.1. Long-term condition monitoring

Long-term condition monitoring will provide information on whether the watering regime (and other factors) is causing a change in, or maintaining, the overall condition of the river (trend over time).

Current long-term condition monitoring

Funding has been confirmed under the VEFMAP program for fish surveys for the next two years (2015, 2016) and vegetation surveys in 2016, however funding for monitoring beyond this time is unconfirmed.

Required long-term condition monitoring

The long-term condition monitoring requirements that will demonstrate changes in condition over time specifically focusing on demonstrating the long-term outcomes of the Campaspe River EWMP is shown in Table 21.

Table 21: Required long-term condition monitoring for the Campaspe River

Objective	Method	When
1. Maintain Increase River Red Gum 2.2 Increase extent/maintain emergent littoral vegetation 2.3 Increase extent/maintain aquatic plants	Comprehensive vegetation condition surveys, including tree health, EVC condition, species presence, weediness and evidence of recruitment.	Years 2, 6, 10
2. Fish (Increase abundance and appropriate age classes)	Large bodied fish - targeted electrofishing fish surveys	Ideally annual No more than 2 years between surveys
	Small bodied fish - small mesh gauge fyke nets	Ideally annual No more than 1 year between surveys
3. Fish (new species presumed lost)	Intensive fish survey	Ideally annual but no more than 2 years
2.1 Macroinvertebrates – functional groups	Method such as the Rapid Bioassessment protocol – surveys undertaken by QA/QC trained and funded Waterwatch, analysis undertaken by biologist	Twice yearly
2.1 Macroinvertebrate biomass	Best available science	TBD
3. Platypus	Qualitative surveys – community based (Waterwatch) – analysis by biologist	Year 5, 10.
2.4 Water Quality	Continuous physicochemical monitoring	Continuous
5. Connectivity	Measuring discharge/level	Continuous

1.1. Intervention monitoring

Intervention monitoring will assess the responses of key environmental values to the changes in the water regime (intervention) and the achievement of ecological objectives e.g. to increase the extent of instream and emergent vegetation. Intervention monitoring may include monitoring of water quality, vegetation and biota (i.e. native fish).

Monitoring the response to a watering event will be important to provide feedback on how the system is responding and whether any amendments need to be made to the operational management or determine if any risk management actions need to be enacted.

Current intervention monitoring

The North Central CMA conducts an ongoing environmental flow water resource planning program for the Campaspe River, which is undertaken as part of the implementation of the Seasonal Watering Proposal. Each year environmental flows are released based on an assessment of the monitoring data as well as the water availability.

The internal CMA monitoring program is relatively limited and does not adequately cover the suite of ecological objectives and their response to flows. Current monitoring sites are identified in Figure 10 and Figure 11. Appendix 7 provides more information on the current monitoring sites and photo points.

Required intervention monitoring

Further intervention monitoring is required so that the CMA is able to adaptively manage the river over the next ten years to ensure that the delivery of environmental water is achieving objectives. The proposed intervention monitoring program and the objective that is being monitored is shown in Table 22.

Table 22: Required intervention monitoring for the implementation of the Campaspe EWMP

Objective	Monitoring question	When	Event	Method
Increase extent and maintain instream aquatic vegetation and emergent littoral macrophytes	Is instream and emergent vegetation responding to flows?	Year 1 and 2[9]	Summer fresh	Vegetation surveys– survey sites should include areas along the river that have been fenced and an agreement with landholder to exclude stock has been reached as well as sites with grazing pressure.
Maintain adult River Red Gum trees and facilitate successful recruitment	Are River Red Gum trees recruiting after November winter fresh	Year 3 and 4[10]	Large winter fresh (November event) Follow up large winter fresh event	Photopoints
Increase population size (with an appropriate age structure) of native fish	Are native fish spawning in slackwater in the Campaspe River?	Until we know	Summer low flow Also after winter fresh if in November or Summer Fresh if in Dec/Jan	Larvae sampling of slackwater – detail TBD
Facilitate recolonisation by native species that are presumed lost from the river	Are fish moving from the Murray river across the Echuca fishway and Campaspe Siphon when drowned out?	Year 1 and follow up Year 5	All events (Fishway) Large Winter Fresh (Siphon)	Options could be netted surveys at fishway or investment in acoustic fish transponder and tagging project – detail dependent on budget and TBD
Risk				
Drowning Platypus burrows during November winter fresh	Is the August winter fresh encouraging Platypus to place their breeding burrows higher in the bank?	(whenever November fresh is intended)	After August fresh	Survey height of burrow entrances relative to mAHD
Stratification of deep pools (Reach 3 and Reach 4)	Is summer low flow mixing saline pools (>20 ML/day) or creating a freshwater lens	Each year	Summer low flow	Salinity probes at different depths in saline pools
Blackwater risk of managed summer events?	Are dissolved oxygen levels maintained at acceptable concentrations during summer fresh?	Each year	Summer fresh	Continuous dissolved oxygen

[9] Instream and emergent vegetation intervention monitoring will need to occur in the first two years as a minimum, additional instream and emergent vegetation intervention monitoring will be required if response isn't as expected.

[10] Assumption that ten year flow regime proposed in this EWMP is followed. The actual timing will be dependent on adaptive management.

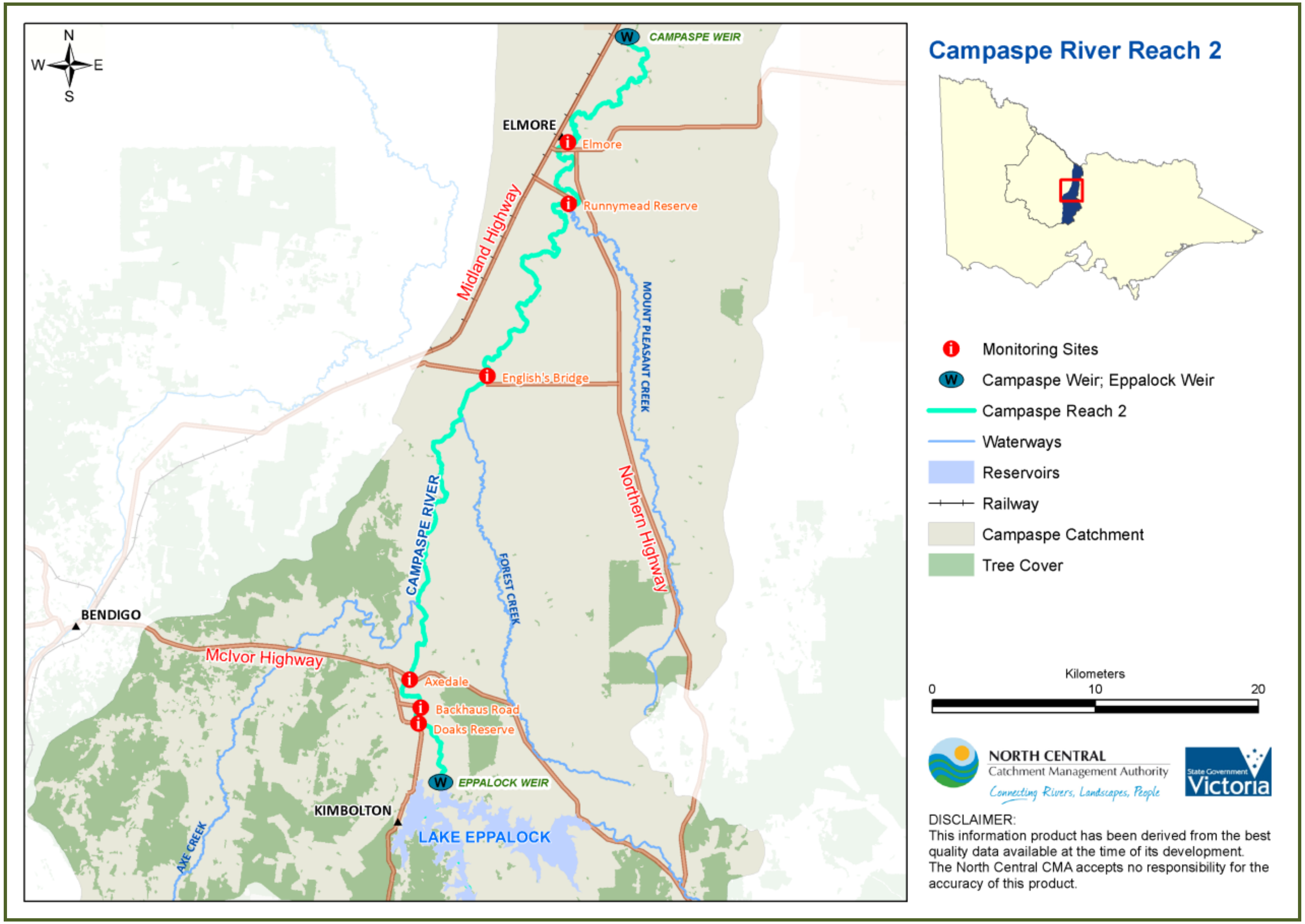

Figure 10: Campaspe River monitoring sites Reach 2

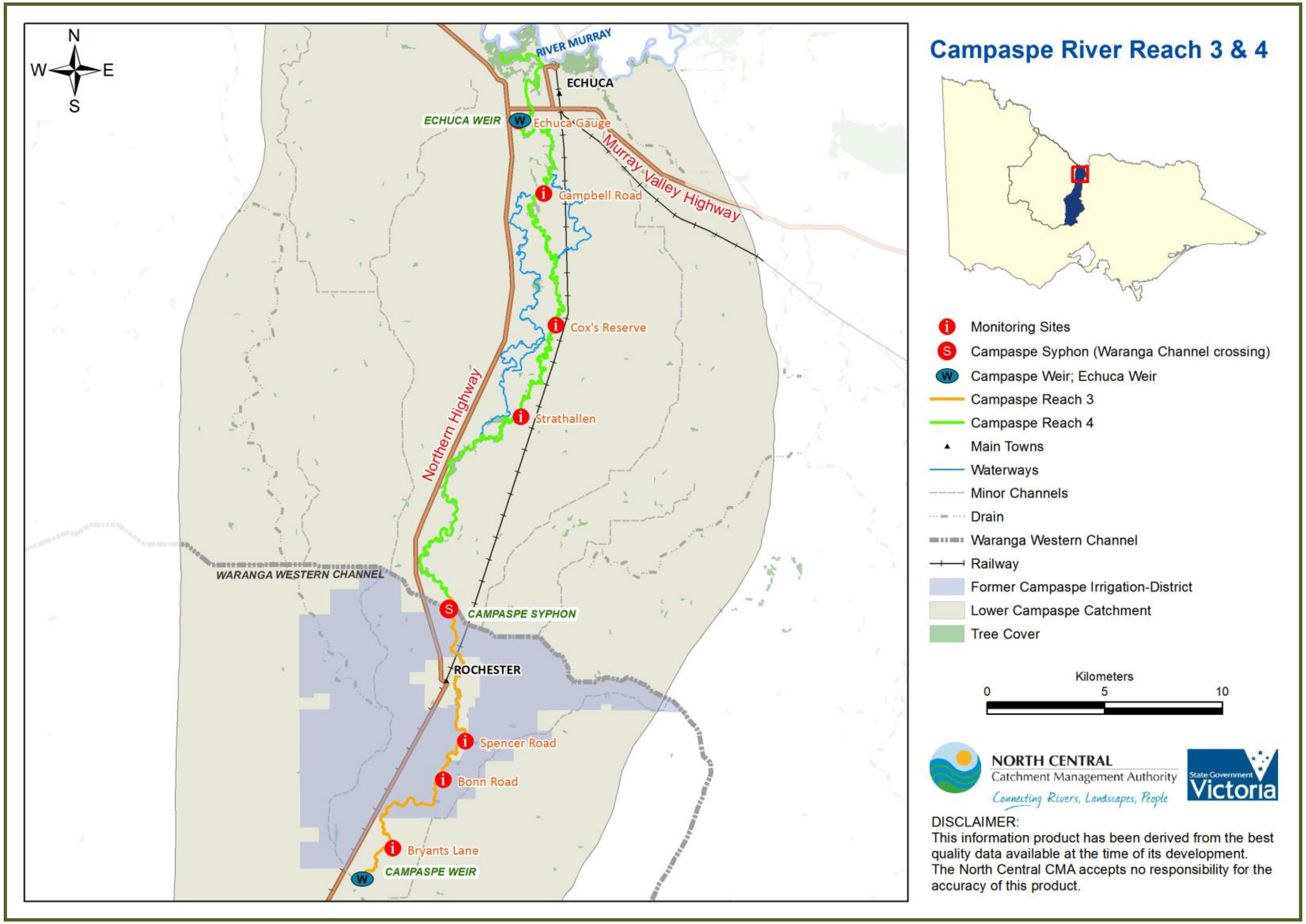

Figure 11: Campaspe River monitoring sites Reach 3 and 4

2. Knowledge Gaps and Recommendations

The Campaspe River EWMP has been developed using the best available information. However, a number of information and knowledge gaps exist which may impact on recommendations and/or information presented in the EWMP. These are summarised below with priority status in Table 23.

Table 23: Knowledge gaps and recommendations

Knowledge Gap	Objective/ Risk	Recommendation	Who	Priority
Objectives				
To ensure maximum native fish recruitment determine the most appropriate month (November to February) to deliver a fresh event?	Objective 2	An honours or PhD research project could monitor recruitment response after delivering freshes at different times.	CMA/Research body	High
To facilitate connectivity between reach 3 and reach 4 determine flow rate required to drown out the Campaspe Siphon	Objective 5	Monitoring discharge at the Siphon during high floe events, particularly when piggy-backing tributary unregulated flows, and undertake photo monitoring	CMA	As required
Risks				
Determine factors influencing native fish abundance e.g. exotic fish pressures, stocking, recreation fishing pressure, cold water	Objective 2 Risks 1, 4, 5, 7, 9	An intensive study into fish population dynamics (size, age classes, qualitative surveys of anglers etc)	CMA/Research body	High
Quantum of leaf litter loading and extent entrained on river banks over which point a blackwater event is a real risk	Risk 12	An honours or PhD study to design project	CMA/Research body	Low

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4. Abbreviations and Acronyms

AVIRA	Aquatic Value Identification and Risk Assessment
BE	Bulk Entitlement
Bonn	The Convention on the Conservation of Migratory Species of Wild Animals (also known as the Bonn Convention or CMS)
CAMBA	China-Australia Migratory Bird Agreement
CEWAG	Campaspe Environmental Water Advisory Group
CEWH	Commonwealth Environmental Water Holder
CMA	Catchment Management Authority
CID	Campaspe Irrigation District
DEPI	Department of Environment and Primary Industries
DPI	Department of Primary Industries (Now an amalgamation DEPI in 2013)
DSE	Department of Sustainability and Environment (Now DEPI in 2013)
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
EVC	Ecological Vegetation Class
EWMP	Environmental Water Management Plan
FFG	*Flora and Fauna Guarantee Act 1988* (Vic)
GL	Gigalitre (one billion litres)
GIS	Geographical Information System
GMW	Goulburn Murray Water
HRWS	High Reliability Water Share
ISC	Index of Stream Condition
IVT	Inter Valley Transfer
JAMBA	Japan-Australia Migratory Bird Agreement
LRWS	Low Reliability Water Share
LTCE	Long Term Cap Equivalent
MDBA	Murray-Darling Basin Authority (formerly Murray-Darling Basin Commission, MDBC)
ML	Megalitre (one million litres)
ML/d	Megalitres per day
North Central RWS	North Central Regional Waterway Strategy
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RWS	Regional Waterway Strategy
SRA	Sustainable River Audit
SWP	Seasonal Watering Proposal
TLM	The Living Murray Initiative
VEFMAP	Victorian Environmental Flows Monitoring and Assessment Program
VEWH	Victorian Environmental Water Holder
VWMS	Victorian Waterway Management Strategy
VWQN	Victorian Water Quality Network
WSPA	Water Supply Protection Area

Appendix 1 – Campaspe River EWMP Consultation

Table A1: Campaspe technical and stakeholder workshop attendees (18 July 2014)

Name	Organisation	Expertise/Role
2006 Campaspe River FLOWS study Environmental Flows Technical Panel		
Dr Andrew Sharpe	Jacobs SKM	Aquatic Ecologist
Dr Peter Sandercock	Jacobs SKM	Geomorphology
Dr Paul Boon	Dodo Environmental	Vegetation
Dr Paul Humphries	Charles Sturt University	Fish
Agency Staff		
Andrea Keleher	Department of Environment and Primary Industries	Program Manager - Healthy Landscapes Environment and Natural Resources
Chris Solum	Goulburn Murray Water Connections Project	Project Manager - Environmental
Andrew Shields	Goulburn Murray Water	Manager River Operations
Michelle Maher	North Central CMA	Co -author of Campaspe EWMP
Darren White	North Central CMA	Campaspe River Environmental Flow Delivery
Louissa Rogers	North Central CMA	Project Manager - Co –author of Campaspe EWMP
Angela Gladman	North Central CMA	Project Manager – Caring for Campaspe Project
Cass Davis	North Central CMA	Regional Waterwatch Coordinator
Emer Campbell	North Central CMA	Executive Manager Murray Campaspe Avon Richardson Catchments
Bree Bisset	North Central CMA	Project Manager - EWMP Project - observer

Table A2: FLOWS review workshop (7 and 8 August 2014)

Name	Organisation	Expertise/Role
Dr Andrew Sharpe	Jacobs SKM	Aquatic Ecologist
Dr Paul Boon	Dodo Environmental	Vegetation
Dr Paul Humphries	Charles Sturt University	Fish
Dr Melody Serena	Australian Platypus Conservancy	Platypus
Caitlin Davis	VEWH	Statewide Environmental Water Delivery
Michelle Maher	North Central CMA	Co -author of Campaspe EWMP
Louissa Rogers	North Central CMA	Project Manager - Co -author of Campaspe EWMP
Darren White	North Central CMA	Campaspe River Environmental Water Delivery
Bree Bisset	North Central CMA	Project Manager - EWMP Project - observer

Table A3: Campaspe EWAG membership

Name	Organisation
Community	
Wal Sommerville	Community representative
John McKinstry	Community representative
Veronica and John Groat	Community/ Strathallan Landcare
Geoff Elliott	Community
Ted Gretrix	North Central CMA Natural Resource Management Committee member
Colin Smith	North Central CMA Natural Resource Management Committee member
James Williams	North Central CMA Board member
Peter Williams	North Central CMA Natural Resource Management Committee member
Stakeholders	
Kerry Webber	CEWH
Lauren Davy	CEWH
Caitlin Davis	VEWH
Andrea Keleher	DEPI
Deb Dash	GMW
Andrew Shields	GMW
Lynley Straunch	GMW
Ed Thomas	GMW
Darren White	North Central CMA
Peter Sandercock	SKM – technical expertise

Appendix 2 – Watering history for Reach 2 and Reach 4 (2002-2014)

Flow Component		Season											
		2002 - 2003	2003 - 2004	2004 - 2005	2005 - 2006	2006 - 2007	2007 - 2008	2008 - 2009	2009 - 2010	2010 - 2011	2011 - 2012	2012 - 2013	2013- 2014
Reach 2													
Summer	Base flows												
	Freshes												
Winter	Low flow												
	High flow												
	Bank-full												
	Overbank flow												
Reach 4													
Summer	Base flows									*	*		
	Freshes												
Winter	Low flows												
	High flows												
	Bank-full												

KEY

No significant part of the flow component provided naturally or through managed flows	Flow component partially provided	Environmental flow component has been completely provided

*Flow exceeded the summer base flow target due to high natural flows in the reach during wet year.

Appendix 3 - Fauna Species List

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG status	Vic Status	FFG community
Fish								
Native								
Australian Smelt	*Retropinna semoni*	*	*	*				
Bony Herring	*Nematalosa erebi*			*				
Carp Gudgeon	*Hypseleotris compressa*	*	*	*				Y
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*			*		L	DD	Y
Flat-headed Galaxias	*Galaxias rostratus*			*		I	VU	Y
Flat-headed Gudgeon	*Philypnodon grandiceps*	*	*	*				Y
Golden Perch	*Macquaria ambigua*	*	*	*			VU	Y
Macquarie Perch	*Macquaria australasica*	*			EN	L	EN	Y
Murray Cod	*Maccullochella peelii*	*	*	*	VU	L	EN	Y
Murray Rainbowfish	*Melanotaenia fluviatilis*			*				Y
Silver Perch	*Bidyanus bidyanus*			*		L	CR	Y
Trout Cod	*Maccullochella macquariensis*			*	EN	L	CR	Y
Western Carp Gudgeon	*Hypseleotris klunzingeri*		*	*				Y
Exotic								
Brown Trout	*Salmo trutta*	*						
Common Carp	*Cyprinus carpio*	*	*	*				
Eastern Mosquito-fish	*Gambusia holbrooki*	*	*	*				
Goldfish	*Carassius auratus*	*	*	*				
Oriental Weatherloach	*Misgurnus anguillicaudatus*			*				
Rainbow Trout	*Oncorhynchus mykiss*	*						
Redfin Perch	*Perca fluviatilis*	*	*	*				
Tench	*Tinca tinca*	*						

Common Name	Scientific Name	R 2	R 3	R 4	EPBC Status	FFG status	Vic Stat us	Treat y
Birds								
Water dependent								
Australasian Grebe	*Tachybaptus novaehollandiae*	*						
Australasian Shoveler	*Anas rhynchotis*	*					VU	
Australian Pelican	*Pelecanus conspicillatus*	*						
Australian Shelduck	*Tadorna tadornoides*	*						
Australian White Ibis	*Threskiornis molucca*	*						
Australian Wood Duck	*Chenonetta jubata*	*	*	*				
Black Swan	*Cygnus atratus*	*						
Black-fronted Dotterel	*Elseyornis melanops*	*						
Buff-banded Rail	*Gallirallus philippensis*	*						
Clamorous Reed Warbler	*Acrocephalus stentoreus*	*						
Darter	*Anhinga novaehollandiae*	*						
Dusky Moorhen	*Gallinula tenebrosa*	*	*					
Eastern Great Egret	*Ardea modesta*	*				L	VU	C/J
Eurasian Coot	*Fulica atra*	*						
Great Cormorant	*Phalacrocorax carbo*	*		*				
Grey Teal	*Anas gracilis*	*						
Hardhead	*Aythya australis*	*					VU	

Common Name	Scientific Name	R 2	R 3	R 4	EPBC Status	FFG status	Vic Status	Treaty
Little Black Cormorant	*Phalacrocorax sulcirostris*	*						
Little Grassbird	*Megalurus gramineus*	*						
Little Pied Cormorant	*Phalacrocorax melanoleucos*	*		*				
Musk Duck	*Biziura lobata*	*					VU	
Nankeen Night Heron	*Nycticorax caledonicus hillii*	*					NT	
Pacific Black Duck	*Anas superciliosa*	*	*	*				
Pied Cormorant	*Phalacrocorax varius*	*					NT	
Purple Swamphen	*Porphyrio porphyrio*	*						
Royal Spoonbill	*Platalea regia*	*					VU	
Silver Gull	*Chroicocephalus novaehollandiae*	*						
Straw-necked Ibis	*Threskiornis spinicollis*	*						
Swamp Harrier	*Circus approximans*	*						
White-faced Heron	*Egretta novaehollandiae*	*						
White-necked Heron	*Ardea pacifica*	*						
Yellow-billed Spoonbill	*Platalea flavipes*	*						
Terrestrial								
Australian Hobby	*Falco longipennis*	*						
Australian King-Parrot	*Alisterus scapularis*	*						
Australian Magpie	*Gymnorhina tibicen*	*	*	*				
Australian Raven	*Corvus coronoides*	*	*	*				
Barking Owl	*Ninox connivens*	*				L	EN	
Black Kite	*Milvus migrans*	*						
Black-chinned Honeyeater	*Melithreptus gularis*	*					NT	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	*	*	*				
Black-shouldered Kite	*Elanus axillaris*	*						
Blue-faced Honeyeater	*Entomyzon cyanotis*	*	*					
Blue-winged Parrot	*Neophema chrysostoma*	*						
Brown Goshawk	*Accipiter fasciatus*	*	*					
Brown Treecreeper	*Climacteris picumnus*	*	*	*			NT	
Brown-headed Honeyeater	*Melithreptus brevirostris*	*						
Cockatiel	*Nymphicus hollandicus*	*	*					
Collared Sparrowhawk	*Accipiter cirrhocephalus*	*						
Common Blackbird *	*Turdus merula*	*	*	*				
Common Bronzewing	*Phaps chalcoptera*	*						
Common Myna *	*Acridotheres tristis*	*						
Common Starling *	*Sturnus vulgaris*	*	*	*				
Crested Pigeon	*Ocyphaps lophotes*	*	*					
Crested Shrike-tit	*Falcunculus frontatus*	*						
Crimson Rosella	*Platycercus elegans*	*		*				
Diamond Firetail	Stagonopleura guttata	*	*			L	VU	
Dollarbird	*Eurystomus orientalis*	*						
Dusky Woodswallow	*Artamus cyanopterus*	*	*	*				
Eastern Rosella	*Platycercus eximius*	*	*	*				
European Goldfinch *	*Carduelis carduelis*	*						
Flame Robin	*Petroica phoenicea*	*						
Fork-tailed Swift	*Apus pacificus*	*						C/J
Fuscous Honeyeater	*Lichenostomus fuscus*	*						
Galah	*Cacatua roseicapilla*	*	*	*				
Golden Whistler	*Pachycephala pectoralis*	*						
Grey Butcherbird	*Cracticus torquatus*	*						
Grey Fantail	*Rhipidura albiscarpa*	*						
Grey Shrike-thrush	*Colluricincla harmonica*	*	*	*				
Grey-crowned Babbler	*Pomatostomus temporalis*	*				L	EN	

Common Name	Scientific Name	R 2	R 3	R 4	EPBC Status	FFG status	Vic Status	Treaty
	temporalis							
Hooded Robin	Melanodryas cucullata cucullata	*	*			L	NT	
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	*						
House Sparrow *	*Passer domesticus*	*		*				
Laughing Kookaburra	*Dacelo novaeguineae*	*	*	*				
Little Corella	*Cacatua sanguinea*	*		*				
Little Friarbird	*Philemon citreogularis*	*	*					
Little Lorikeet	*Glossopsitta pusilla*	*						
Little Raven	*Corvus mellori*	*		*				
Long-billed Corella	*Cacatua tenuirostris*	*	*	*				
Magpie-lark	*Grallina cyanoleuca*	*	*	*				
Masked Lapwing	*Vanellus miles*	*						
Musk Lorikeet	*Glossopsitta concinna*	*	*					
Noisy Friarbird	*Philemon corniculatus*	*						
Noisy Miner	*Manorina melanocephala*	*		*				
Olive-backed Oriole	*Oriolus sagittatus*	*	*					
Pallid Cuckoo	*Cuculus pallidus*	*						
Peaceful Dove	*Geopelia striata*	*	*					
Peregrine Falcon	*Falco peregrinus*	*						
Pied Currawong	*Strepera graculina*		*	*				
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*	*						
Rainbow Bee-eater	*Merops ornatus*	*	*					
Red Wattlebird	*Anthochaera carunculata*	*	*					
Red-rumped Parrot	*Psephotus haematonotus*	*	*					
Regent Honeyeater	*Anthochaera phrygia*	*			EN	L	CR	
Restless Flycatcher	*Myiagra inquieta*	*						
Rock Dove *	*Columba livia*	*						
Rufous Songlark	*Cincloramphus mathewsi*	*						
Rufous Whistler	*Pachycephala rufiventris*			*				
Sacred Kingfisher	*Todiramphus sanctus*	*	*					
Southern Boobook	*Ninox novaeseelandiae*	*						
Spotted Pardalote	*Pardalotus punctatus*	*						
Spotted Turtle-Dove *	*Streptopelia chinensis*		*					
Striated Pardalote	*Pardalotus striatus*	*	*	*				
Striated Thornbill	*Acanthiza lineata*			*				
Sulphur-crested Cockatoo	*Cacatua galerita*	*	*	*				
Superb Fairy-wren	*Malurus cyaneus*	*		*				
Swift Parrot	*Lathamus discolor*	*			EN	L	EN	
Tawny Frogmouth	*Podargus strigoides*	*						
Tree Martin	*Hirundo nigricans*	*						
Varied Sittella	*Daphoenositta chrysoptera*	*						
Wedge-tailed Eagle	*Aquila audax*	*						
Welcome Swallow	*Hirundo neoxena*	*	*	*				
Whistling Kite	*Haliastur sphenurus*	*	*					
White-bellied Cuckoo-shrike	*Coracina papuensis*	*						
White-browed Scrubwren	*Sericornis frontalis*	*						
White-browed Woodswallow	*Artamus superciliosus*	*						
White-naped Honeyeater	*Melithreptus lunatus*	*						
White-plumed	*Lichenostomus penicillatus*	*	*	*				

Common Name	Scientific Name	R 2	R 3	R 4	EPBC Status	FFG status	Vic Status	Treaty
Honeyeater								
White-throated Treecreeper	*Cormobates leucophaeus*			*				
White-winged Chough	*Corcorax melanorhamphos*	*						
White-winged Triller	*Lalage sueurii*	*						
Willie Wagtail	*Rhipidura leucophrys*	*	*	*				
Yellow Thornbill	*Acanthiza nana*			*				
Yellow-faced Honeyeater	*Lichenostomus chrysops*	*						
Zebra Finch	*Taeniopygia guttata*	*						

Common Name	Scientific Name	R2	R3	R4	EPBC status	FFG status	DEPI Status	Last record
Amphibians								
Plains Froglet	*Crinia parinsignifera*	*						2006
Common Froglet	*Crinia signifera*	*	*					2006
Southern Bullfrog	*Limnodynastes dumerilii*	*						2006
Reptiles								
Water dependent								
Eastern Long-necked turtle	*Chelodina longicollis*	*						1992
Terrestrial								
Bougainville's Skink	*Lerista bougainvillii*	*						2006
Boulenger's Skink	*Morethia boulengeri*	*						1965
Eastern Brown Snake	*Pseudonaja textilis*	*						1992
Olive Legless Lizard	*Delma inornata*	*						2006
Mammals								
Native, water dependent								
Platypus	*Ornithorhynchus anatinus*	*	*	*				2007
Native, terrestrial								
Bat - Unidentified	Ord. Chiroptera	*						2006
Black Wallaby	*Wallabia bicolor*	*						1984
Common Brushtail Possum	*Trichosurus vulpecula*	*						1992
Common Ringtail Possum	*Pseudocheirus peregrinus*	*						1985
Squirrel Glider	*Petaurus norfolcensis*			*		L	EN	
Exotic, terrestrial								
European Hare	*Lepus europeaus*	*	*					1992
European Rabbit	*Oryctolagus cuniculus*	*						2006
House Mouse	*Mus musculus*	*						1979

Appendix 4 – Flora Species List

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG Status	Vic Status
Native, water dependent							
Australian Sweet-grass	*Glyceria australis*			*			
Austral Trefoil	*Lotus australis var. australis*	*					k
Blunt-leaf Pomaderris	*Pomaderris helianthemifolia subsp. minor*	*					r
Broad-leaf Cumbungi	*Typha orientalis*	*	*				
Broom Rush	*Juncus sarophorus*	*	*				
Common Reed	*Phragmites australis*		*	*			
Common Spike-sedge	*Eleocharis acuta*		*				
Curly Pondweed	*Potamogeton crispus*		*				
Eel Grass	*Vallisneria americana var. americana*		*				
Fen Sedge	*Carex gaudichaudiana*		*				
Floating Pondweed	*Potamogeton tricarinatus s.l.*	*	*				
Lesser Joyweed	*Alternanthera denticulata s.l.*		*				
Narrow-leaf Cumbungi	*Typha domingensis*		*	*			
Pacific Azolla	*Azolla filiculoides*	*	*				
Pale Flax-lily	*Dianella sp. aff. longifolia (Riverina)*			*			v
Perennial Blown-grass	*Lachnagrostis perennis spp. agg.*		*	*			k
Poong'ort	*Carex tereticaulis*	*	*				
Robust Water-milfoil	*Myriophyllum papillosum*		*				
Sand Rush	*Juncus psammophilus*	*					r
Small Loosestrife	*Lythrum hyssopifolia*		*	*			
Tall Sedge	*Carex appressa*	*	*				
Water Ribbons	*Triglochin procera s.l.*	*	*				
Native, terrestrial							
Bent/Blown Grass	*Agrostis s.l. spp.*			*			
Berry Saltbush	*Atriplex semibaccata*		*	*			
Blackwood	*Acacia melanoxylon*		*	*			
Bluebell	*Wahlenbergia spp.*			*			
Bristly Wallaby-grass	*Austrodanthonia setacea*	*	*	*			
Brome	*Bromus spp.*			*			
Brush Wire-grass	*Aristida behriana*	*					
Buloke	*Allocasuarina luehmannii*		*			L	
Burr Daisy	*Calotis spp.*			*			
Common Blown-grass	*Lachnagrostis filiformis s.l.*	*	*				
Common Tussock-grass	*Poa labillardierei*		*	*			
Common Wallaby-grass	*Austrodanthonia*	*					

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG Status	Vic Status
	caespitosa						
Cotton Fireweed	*Senecio quadridentatus*			*			
Creeping Knotweed	*Persicaria prostrata*	*	*	*			
Finger Rush	*Juncus subsecundus*	*	*				
Grassland Wood-sorrel	*Oxalis perennans*	*	*	*			
Grey Box	*Eucalyptus microcarpa*		*				
Grey Tussock-grass	*Poa sieberiana*		*				
Grey Willow-herb	*Epilobium billardierianum subsp. cinereum*	*					
Hairy Willow-herb	*Epilobium hirtigerum*	*	*				
Heron's Bill	*Erodium spp.*	*					
Hogweed	*Polygonum spp.*			*			
Hollow Rush	*Juncus amabilis*	*	*	*			
Jersey Cudweed	*Pseudognaphalium luteoalbum*			*			
Joyweed	*Alternanthera spp.*			*			
Kangaroo Grass	*Themeda triandra*		*	*			
Lightwood	*Acacia implexa*		*	*			
Mat Grass	*Hemarthria uncinata var. uncinata*		*	*			
Panic	*Panicum spp.*		*	*			
Raspwort	*Haloragis spp.*			*			
Red-leg Grass	*Bothriochloa macra*		*	*			
River Bluebell	*Wahlenbergia fluminalis*		*				
River Bottlebrush	*Callistemon sieberi*		*	*			
River Red-gum	*Eucalyptus camaldulensis*	*	*	*			
Rough Spear-grass	*Austrostipa scabra subsp. falcata*		*	*			
Slender Dock	*Rumex brownii*	*	*	*			
Slender Wallaby-grass	*Austrodanthonia racemosa var. racemosa*		*	*			
Small St John's Wort	*Hypericum gramineum*	*					
Southern Swainson-pea	*Swainsona behriana*	*					r
Sow Thistle	*Sonchus spp.*			*			
Spear Grass	*Austrostipa spp.*	*	*				
Sprawling Bluebell	*Wahlenbergia gracilis*			*			
Spurred Spear-grass	*Austrostipa gibbosa*		*	*			
Swamp Club-sedge	*Isolepis inundata*			*			
Sweet Bursaria	*Bursaria spinosa*		*				
Tall Fireweed	*Senecio runcinifolius*			*			
Thread Rush	*Juncus filicaulis*	*					
Tussock Grass	*Poa spp.*			*			
Variable Crane's-bill	*Geranium sp. 2*		*				
Variable Sida	*Sida corrugata*		*	*			

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG Status	Vic Status
Variable Willow-herb	*Epilobium billardierianum*	*					
Varied Raspwort	*Haloragis heterophylla*		*				
Velvet Daisy-bush	*Olearia pannosa subsp. cardiophylla*	*				L	v
Wallaby Grass	*Austrodanthonia spp.*		*				
Warrego Summer-grass	*Paspalidium jubiflorum*		*	*			
Weeping Grass	*Microlaena stipoides var. stipoides*		*	*			
Windmill Grass	*Chloris truncata*	*	*				
Wingless Bluebush	*Maireana enchylaenoides*		*	*			
Wiry Dock	*Rumex dumosus*	*					
Wood Sorrel	*Oxalis spp.*		*	*			
Exotic							
African Box-thorn	*Lycium ferocissimum*	*					
Annual Beard-grass	*Polypogon monspeliensis*		*	*			
Annual Veldt-grass	*Ehrharta longiflora*			*			
Arabian Grass	*Schismus spp.*	*					
Artichoke Thistle	*Cynara cardunculus*	*					
Aster-weed	*Aster subulatus*		*				
Barley-grass	*Hordeum leporinum*	*					
Bearded Oat	*Avena barbata*	*					
Black Nightshade	*Solanum nigrum sensu Willis (1972)*			*			
Bridal Creeper	*Asparagus asparagoides*		*				
Burr Medic	*Medicago polymorpha*	*					
Cape Weed	*Arctotheca calendula*	*		*			
Caustic Weed	*Chamaesyce spp.*			*			
Chicory	*Cichorium intybus*		*				
Chilean Needle-grass	*Nassella neesiana*	*					
Cluster Clover	*Trifolium glomeratum*	*					
Clustered Dock	*Rumex conglomeratus*		*				
Cocksfoot	*Dactylis glomerata*		*				
Common Peppercress	*Lepidium africanum*		*	*			
Common Sow-thistle	*Sonchus oleraceus*		*	*			
Common Verbena	*Verbena officinalis s.s.*		*				
Coolah Grass	*Panicum coloratum*		*				
Couch	*Cynodon dactylon var. dactylon*	*	*	*			
Crack Willow	*Salix fragilis*		*				
Creeping Knapweed	*Rhaponticum repens*			*			
Curled Dock	*Rumex crispus*	*	*				
Desmazeria	*Tribolium acutiflorum s.l.*	*	*	*			
Divided Sedge	*Carex divisa*		*	*			

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG Status	Vic Status
Drain Flat-sedge	*Cyperus eragrostis*	*	*				
False Brome	*Brachypodium distachyon*		*	*			
Fennel	*Foeniculum vulgare*	*					
Fiddle Dock	*Rumex pulcher subsp. pulcher*	*					
Flatweed	*Hypochaeris radicata*	*					
Fog-fruit	*Phyla canescens*			*			
Golden Thistle	*Scolymus hispanicus*	*					
Great Brome	*Bromus diandrus*	*	*	*			
Hastate Orache	*Atriplex prostrata*		*				
Hemlock	*Conium maculatum*		*				
Hoary Cress	*Lepidium draba*		*				
Hop Clover	*Trifolium campestre var. campestre*	*					
Horehound	*Marrubium vulgare*	*		*			
Jointed Rush	*Juncus articulatus*		*				
Knotted Barley-grass	*Hordeum secalinum*			*			
Mallow	*Malva spp.*			*			
Medic	*Medicago spp.*		*	*			
Mediterranean Brome	*Bromus lanceolatus*		*	*			
Montpellier Broom	*Genista monspessulana*		*				
Narrow-leaf Clover	*Trifolium angustifolium var. angustifolium*	*	*				
Noogoora Burr species aggregate	*Xanthium strumarium spp. agg.*		*				
Oat	*Avena spp.*		*				
Olive	*Olea europaea*		*				
Onion Grass	*Romulea rosea*	*	*	*			
Ox-tongue	*Helminthotheca echioides*	*		*			
Panic Veldt-grass	*Ehrharta erecta var. erecta*	*					
Paspalum	*Paspalum dilatatum*	*	*	*			
Paterson's Curse	*Echium plantagineum*	*	*	*			
Pepper Tree	*Schinus molle*	*	*				
Perennial Rye-grass	*Lolium perenne var. perenne*		*	*			
Prairie Grass	*Bromus catharticus*	*					
Prickly Lettuce	*Lactuca serriola*		*	*			
Prostrate Knotweed	*Polygonum aviculare s.l.*	*	*	*			
Rat's-tail Fescue	*Vulpia myuros*	*					
Red Brome	*Bromus rubens*		*	*			
Ribwort	*Plantago lanceolata*	*	*	*			
Rough Sow-thistle	*Sonchus asper s.l.*	*					
Sea Barley-grass	*Hordeum marinum*		*	*			
Sharp Rush	*Juncus acutus subsp. acutus*		*				

Common Name	Scientific Name	R2	R3	R4	EPBC Status	FFG Status	Vic Status
Slender Centaury	*Centaurium tenuiflorum*		*				
Slender Thistle	*Carduus pycnocephalus*			*			
Small-flower Mallow	*Malva parviflora*	*					
Soft Brome	*Bromus hordeaceus subsp. hordeaceus*	*	*	*			
Soursob	*Oxalis pes-caprae*		*	*			
Spear Thistle	*Cirsium vulgare*		*	*			
Squirrel-tail Fescue	*Vulpia bromoides*	*	*	*			
Sweet Briar	*Rosa rubiginosa*		*				
Sweet Melilot	*Melilotus indicus*	*					
Toowoomba Canary-grass	*Phalaris aquatica*	*	*	*			
Verbena	*Verbena spp.*			*			
Water Couch	*Paspalum distichum*	*	*	*			
Wild Oat	*Avena fatua*		*	*			
Willow	*Salix spp.*	*	*				
Wimmera Rye-grass	*Lolium rigidum*	*	*	*			
Yorkshire Fog	*Holcus lanatus*		*				

Appendix 5 – Criteria and assessment indicators for the Campaspe River's ecosystem function

Item	Criteria	Meets criteria	Description for the Campaspe
Criterion 1: The ecosystem function supports the creation and maintenance of vital habitats and populations			
1	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides vital habitat including:		
	(a) a refugium for native water-dependent biota during dry periods and drought; or	✓	The Millennium Drought highlighted that the deep pools in the Campaspe River, particularly in Reach 2, were critical for the survival of water dependent species. For example no fish species that were recorded in the late nineties and early 2000s were lost from the river during the drought.
	(b) pathways for the dispersal, migration and movement of native water-dependent biota; or	✓	The Campaspe River has been identified as an important source of dispersing Platypus population for the Murray River (Melody Serena *pers.* comm. [Australian Platypus Conservancy], 7 August 2014). The construction of the fishway at Echuca Weir has also opened 45 kilometres of Campaspe River for movement of native fish between the Murray River and the Campaspe.
	(c) a diversity of important feeding, breeding and nursery sites for native water-dependent biota; or	✓	The Campaspe River currently has extensive and complex instream woody habitat within the river channel. This provides a substrate for biofilm growth and food and habitat for macroinvertebrates and small fish. It also has many slackwater habitats across a range of low flow magnitudes that are critical habitat for fish larvae. The river channel is confined with steep banks with large River Red Gum trees, this bank habitat is optimum habitat for Platypus breeding burrows (Jacobs, 2014a)
	(d) a diversity of aquatic environments including pools, rifle and run environments; or	✓	The Campaspe River has a high diversity of aquatic environments. Each reach has a series of run/riffle pool sequences, a significant number of deep pools exist throughout the river, particularly in Reach 2. The channel morphology comprises a variety of beaches, benches, depressions, secondary channels and flood runners that become engaged at a range of flow magnitudes.
	(e) a vital habitat that is essential for preventing the decline of native water-dependent biota.	✓	The Campaspe River and its riparian zone provide habitat for a significant number of threatened flora and fauna species. For all native fish species providing a diversity of flows at appropriate times of the year, is likely to enhance the fish assemblage in the Campaspe River. This would include flows large enough to drown-out the Campaspe Siphon and allow fish movement upstream and downstream.

Item	Criteria	Meets criteria	Description for the Campaspe
Criterion 2: The ecosystem function supports the transportation and dilution of nutrients, organic matter and sediment			
2	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides for the transportation and dilution of nutrients, organic matter and sediment, including:		
	(a) pathways for the dispersal and movement of organic and inorganic sediment, delivery to downstream reaches and to the ocean, and to and from the floodplain; or	✓	The Campaspe River is a lowland river and a tributary to the Murray River dispersing nutrients, organic matter and sediment to the Murray River and its floodplain (e.g. the Gunbower Forest downstream of Echuca).
	(b) the dilution of carbon and nutrients from the floodplain to the river systems.	✓	Delivering high flows in the cool months will flush accumulated leaf litter from banks and benches, diluting carbon and nutrients from the floodplain in the cooler months. This also will reduce the amount of organic material that is likely to be washed into the river by summer environmental flow releases, which will reduce the risk of blackwater events.
Criterion 3: The ecosystem function provides connections along a watercourse (longitudinal connections)			
3	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides connections along a watercourse or to the ocean, including longitudinal connections:		
	(a) for dispersal and re-colonisation of native water-dependent communities; or	✓	With the removal of the Echuca gauging weir the potential exists to increase the richness of fish species throughout the Campaspe from the Murray. Species that have been recorded in the Murray River downstream of the Murray/Campaspe confluence that have not recently been recorded in the river include Bony Herring (*Nematalosa erebi*) and Unspecked Hardyhead (*Craterocephalus stercusmuscarum fulvus*).
	(b) for migration to fulfil requirements of life history stages; or	✓	Migratory species, Golden Perch and Silver Perch, have been recorded in the Campaspe River , although instream barriers within the river are likely to prevent migration within the channel, migration may occur between the Reach 4 and the Murray River.
	(c) For in-stream primary production.	✓	The Campaspe River has an extensive coverage of instream woody habitat throughout the entire river. Higher flows will flush silt and biofilms from the surface of the wood transporting it downstream to other habitat areas (Jacobs, 2014a).
Criterion 4: The ecosystem function provides connections across floodplains, adjacent wetlands and billabongs (lateral connections)			
4	**Assessment indicator:** An ecosystem function requires environmental watering to sustain it if it provides connections across floodplains, adjacent wetlands and billabongs, including:		
	(a) lateral connections for foraging, migration and re-colonisation of native water-dependent species and communities; or	✓	There is very limited opportunity for floodplain inundation in the Campaspe River catchment; however a number of secondary channels, billabongs and floodrunners provide additional habitat for foraging when engaged.

Item	Criteria	Meets criteria	Description for the Campaspe
	(b) lateral connections for off-stream primary production.	✓	Because the Campaspe so rarely overbank floods, the riparian zone is the principal lateral extent of the river and the principal way that the adjacent land connects to the river, and vice versa. The riparian zone has a relatively intact riparian canopy which is a source of carbon to the river.

Appendix 6 – Ecological Objectives for the Campaspe River (Jacobs 2014a) and hydrological requirements

Hydrological requirements describe the water regimes required for achieving ecological objectives (DNRE 2002). All values identified have components of their life-cycle or process that are dependent on particular water regimes for success e.g. native fish require certain timing, duration and frequency of flooding to successfully breed and maintain their population.

Objective (habitat, flora, fauna, process)	Justification (e.g. intrinsic value or link to other value)	Hydrological requirements
M1 Macroinvertebrates **Reaches 2, 3 and 4** Maintain/increase diversity and productivity of macroinvertebrates and macroinvertebrate functional feeding groups to drive productive and dynamic food webs. * *Knowledge *gap –the target quantum for relative biomass or productivity of different functional feeding groups or the current levels of those is not known.*	Macroinvertebrates are a critically important component of the food web: • They extract carbon from leaf litter and primary producers such as diatoms, algae and macrophytes available to higher order consumers such as fish and Platypus. • Different functional groups serve different ecological functions; e.g. shredders convert fallen leaves to coarse and fine particulate organic matter that can be consumed by other biota and allows material to more readily move downstream; filter feeders can affect nutrient spiralling rates by sieving food from the water column.	Flows should permanently inundate some wood and periodically inundate other wood as wetting and drying will be important to drive biofilm production. Water levels should fluctuate so rapidly that they strand macroinvertebrates or force them below the photic zone. Moreover, turbidity should not be too high to allow primary producers to grow on snags. Flows should be high enough to connect all channel habitats, but not too high such that they limit the quality and quantity of slackwater habitats. Low flows should be provided to allow submerged and emergent macrophytes to become established, but high flows may also be needed to periodically scour vegetation. There should be sufficient flow to flush fine sediment or prevent fine sediment from smothering hard substrates that macroinvertebrates use for food or habitat (Jacobs 2014a)
W1 Water quality **Reaches 2, 3 and 4** Minimise risk of blackwater events associated with managed flow releases in summer	• Blackwater events can lead to fish kills and severe stress to other aquatic fauna. • Blackwater events are natural, but we do not want managed flows to trigger an event. • High flows in cool months to clear organic loads will reduce the likelihood of blackwater events during summer.	The best way to reduce that risk is to deliver one or more flow events in winter or spring that are at least as large as the biggest managed flows that will be delivered in summer or autumn. Delivering high flows in the cool months will flush accumulated leaf litter from banks and benches and therefore reduce the amount of organic material that is likely to be washed into the river by summer environmental flow releases (Jacobs 2014a)
W2 Water quality **Reaches 3 and 4** Control salinity and stratification in deep pools	• High salinity and low dissolved oxygen concentrations are a threat to aquatic biota. • Minimum flows are needed to prevent pools stratifying or during dry periods to at least maintain a lens (0.5-1.0 m) of freshwater (<3000 EC) across saline pools during summer. • Freshes can periodically mix stratified pools.	Flows greater than 35 ML/day are needed to mix stratified pools in dry years when the water table is low and flows greater than possibly 70-100 ML/day may be needed if water tables are higher. There is likely to be a lag between catchment rainfall and water table levels, so it may be necessary to continue to deliver higher to mix stratified pools in the first few years of a dry period and lower flows may be adequate to

Objective (habitat, flora, fauna, process)	Justification (e.g. intrinsic value or link to other value)	Hydrological requirements
		mix stratified pools in the first few years after a prolonged drought is broken (Jacobs 2014a).
G1 Geomorphology **Reaches 2, 3 and 4** Maintain channel form, deposit sediment on benches and scour pools to maintain their depth	Channel form and habitat heterogeneity are critical to providing habitat and food for aquatic and riparian flora and fauna. For example the deep pools through Reach 2 provide a critical drought (and potentially flood) refuge for aquatic fauna and flora.	Winter fresh/bankfull/overbank (Jacobs 2014a)
G2 Geomorphology **Reaches 2, 3 and 4** Maintain floodplain topography	Overbank flows cannot be delivered through environmental flows, but will occur naturally and will help maintain floodplain habitats such as wetlands by scouring surfaces and delivering silt to replenish soils on the floodplain.	Overbank (Jacobs 2014a)
G3 Geomorphology **Reaches 2, 3 and 4** Flush accumulated silt and sediment from substrates including rocks, submerged wood and macrophytes	Regular flows that flush silt and fine sediment from hard surfaces will increase their suitability for macroinvertebrates and biofilm production and lead to an overall increase in biological productivity and diversity.	Summer and winter fresh/bankfull/overbank (Jacobs 2014a)
F1 Fish **Reaches 2, 3 and 4** Increase population size (with an appropriate age structure) of native fish with periodic, equilibrium and opportunistic life history strategies[11] that have been recently recorded in each reach e.g.: Reach 2: Golden Perch, Murray Cod, Australian Smelt. Reach 3: Golden Perch, Murray Cod, and Murray Rainbowfish. Reach 4: Golden Perch, Murray Cod, Carp Gudgeon.	These species would have historically been abundant in each reach	<u>Opportunistic low flow specialists</u> (e.g. Carp Gudgeons, Murray Rainbowfish) – period of time between November and February (ideally) when slackwater habitat is maximised and undisturbed by freshes. <u>Opportunistic generalists</u> (e.g. Flathead Gudgeons, Australian Smelt) – minimal flow requirements, although dispersal can be facilitated by connectivity between habitats. However, for species that could recolonise the Campaspe River, such as Southern Pygmy Perch, floodplain inundation can enhance dispersal and recruitment. <u>Periodic</u> (e.g. Golden Perch, Silver Perch) – although there is much uncertainty, these species may benefit from substantial rises in flow around their normal spawning time (likely between October and March), which would allow wide dispersal of eggs and larvae, should spawning take place. <u>Equilibrium sedentary</u> (e.g. River Blackfish, Freshwater Catfish) – minimal flow requirements, although conditions of nests during spawning may be enhanced by some water movement. <u>Equilibrium movers</u> (e.g. Murray Cod, Trout Cod) – flow requirements are mostly related to the prevention of

[11] See Jacobs, 2014a for description of life history strategies.

Objective (habitat, flora, fauna, process)	Justification (e.g. intrinsic value or link to other value)	Hydrological requirements
		washing out of nests during the incubation and early life stages (likely between early October and early December), and a requirement for some flow so that the larvae leaving the nest can disperse. For all species, irrespective of life history strategy, providing a diversity of flows at appropriate times of the year, is likely to enhance the fish assemblage in the Campaspe River.
F2 Fish **Reaches 2, 3 and 4** Facilitate recolonisation by native species that have been presumed lost e.g.: Reach 2: Trout Cod, River Blackfish and Macquarie Perch. Reach 3: Trout Cod, River Blackfish and Macquarie Perch. Reach 4: Silver Perch, Bony Herring.	These species would have historically been abundant in the river. • Reach 2 and 3: The ability to achieve this objective will depend on opportunities for fish passage past the Campaspe Weir and Campaspe Siphon that will allow fish to move upstream into the reach from the Murray and Reaches 3 and 4. Reach 3 may be drowned out at flows greater than 1500 ML/day. • Reach 4: the recent replacement of the Echuca flow gauge weir with a rock ramp fishway should allow more species to recolonise this reach.	Flow cues at the convergence of the Campaspe with the Murray (e.g. running a fresh for seven days) (P. Humphries pers. comm. [Charles Sturt University], 8 August 2014)
V1 Vegetation **Reaches 2, 3 and 4** Re-establish instream aquatic plants e.g. *Triglochin* spp.	Instream plants were common throughout the river prior to the 2011/12 floods, but are now rare. They are an important component of the stream ecosystem and provide habitat, sediment stability and support food webs.	Submerged angiosperms require annual flooding, typically of 50–100 cm, for prolonged periods (Jacobs 2014a)
V2 Vegetation **Reaches 2, 3 and 4** Promote growth of emergent littoral macrophytes (e.g. Phragmites, rushes, reeds and sedges) on benches and edges of channel, but limit their encroachment into the middle of the channel	Fringing emergent plants were common throughout the reach prior to the 2011/12 floods, but are now rare. They are an important component of the stream ecosystem and provide habitat, sediment and bank stability and support food webs.	Reeds – widest hydrological niches of all riparian plants, and typically grows best under fluctuating water levels, in water up to 2 m deep. Adults can withstand prolonged inundation (if some vegetative material remains aerial), but also prolonged dry periods (Jacobs 2014a) Rushes and Sedges - but typically require annual inundation for 2–4 months over spring to summer in water up to ~ 30 cm deep. Some taxa are advantaged by inundation in late winter or early spring (e.g. Bolboschoenus fluviatilis) whereas others (e.g. Eleocharis spacelata) will mainly benefit from flooding in late spring or early summer when temperatures are warmer; other taxa require near-permanent inundation (e.g. Typha spp.) and some more terrestrial conditions (e.g. Poa spp.). The ecological consequence of these various hydrological requirements in the rushes and sedges is that mosaics

Objective (habitat, flora, fauna, process)	Justification (e.g. intrinsic value or link to other value)	Hydrological requirements
		of vegetation can be expected, in time and in space, according to wetting and drying regimes (Jacobs 2014a)
V3 Vegetation **Reaches 2, 3 and 4** Maintain adult River Red Gum trees and facilitate recruitment of juveniles into the population	River Red Gum trees provide carbon to fuel food webs, shade, instream woody habitat (snags) to the river and habitat for fauna.	*EVC 56* - Elevation and rainfall are relatively low and soils are fertile alluviums subject to periodic flooding and inundation (DSE 2004a) *River Red Gum – recruitment* (Roberts & Marston 2011). Timing: flooding required in Spring as late as possible to provide warm moist conditions for germination. Follow up flooding required to recharge soil moisture in the same year or the following year. Depth: 20 – 30 cm Duration: 4 – 6 weeks *River Red Gum – maintenance* Frequency – one in every 2 – 4 years for woodlands Depth: Not critical Timing: not critical but more growth if spring/summer
P1 Platypus **Reaches 2 and 3** Maintain/increase resident breeding population by facilitating successful recruitment at least every second year and promote safe dispersal by juveniles.	The Campaspe River is an important source of juvenile Platypus to facilitate recolonisation of the Murray River and strengthen the Gunbower population. This reach supports resident breeding populations, but they are likely to have declined during the drought.	Flow requirements will align closely with those for macro-invertebrates, given that successful breeding by Platypus depends on their having access to an ample food supply. In addition: Flows should be high enough throughout the year to minimise the likelihood that resident animals and their offspring are killed by predators (particularly foxes). Freshes scheduled in spring or summer should be coupled to a preceding event of similar or greater magnitude in August, i.e. around the time that breeding females are choosing nursery burrow sites, to encourage females to locate nesting chambers above the maximum height of the subsequent fresh. The duration of substantial freshes scheduled in spring or summer should be limited insofar as possible to the minimum length of time needed to carry out their designated environmental function (Jacobs 2014a)
P2 Platypus **Reach 4** Maintain existing resident population and facilitate safe dispersal by juveniles from this reach and upstream reaches to the Murray River.	The Campaspe River is an important source of juvenile Platypus to facilitate recolonisation of the Murray River and strengthen the Gunbower population. Upstream reaches support strong breeding populations of Platypus; there may be some resident populations in this reach.	Flows should be high enough throughout the year to provide a continuous aquatic corridor for safe passage by dispersing juveniles in late autumn and early winter (Jacobs 2014a)

Appendix 7 – Campaspe River Monitoring Sites

Table 7.1: Campaspe River monitoring site information

River Reach	Site location	Features / Rationale	Monitoring Technique
Reach 2: Lake Eppalock to Campaspe Weir	**1.** Doakes Reserve	• Upstream of Axe Creek • Shallow-medium depth • Cumbungi & Woody habitat around island area • Identified as environmental flows monitoring site for state program	• Continuous probe (DO, EC and temperature) • North Central CMA photo point and water quality monitoring
	2. Axedale	• Downstream of Axe Creek • Large deep pool • Good drought refuge	• North Central CMA photo point and water quality monitoring
	3. Backhaus Road	• Existing monitoring site	• Continuous probe (DO, EC and temperature) •
	4. English's Bridge	• Existing monitoring site	• North Central CMA photo point and water quality monitoring
	5. Runnymead Reserve	• Existing monitoring site	• North Central CMA photo point and water quality monitoring
	6. Elmore	• Existing monitoring site • Deep pool - backed up from the Campaspe Weir • Important refuge for fish	• North Central CMA photo point and water quality monitoring
Reach 3: Campaspe Weir - Siphon	**7.** d/s Campaspe Weir	• Existing monitoring site	• North Central CMA photo point and water quality monitoring
	8. Burnewang-Bonn Road	• Existing monitoring site • Deep pool (2.4m) • Identified in "Saline Pools Investigation" project • Good drought refuge	• Continuous probe (VEFMAP) • North Central CMA photo point and water quality monitoring
	9. Reserve on east side river - Rochester town flood gauge	• Existing monitoring site	• North Central CMA photo point and water quality monitoring
	10. Reserve on east side river - Rochester town flood gauge	• Existing monitoring site	• North Central CMA photo point and water quality monitoring
	11. Rochester Rail Bridge	• Existing monitoring site • Deep pool - backed up from siphon • Cross reference data for continuous monitoring probe	• North Central CMA photo point and water quality monitoring VWQMN data (406202C)
Reach 4: Siphon - Echuca Weir	**1.** Strathallen Bridge	• Existing monitoring site • E-flows site	• North Central CMA photo point and water quality monitoring
	2. Fehring Lane	• Deep pool (1.9m) • Identified in "Saline Pools Investigation" project • Good drought habitat	• Continuous probe (VEFMAP)
	3. U/s Echuca Weir	• Existing monitoring site	• North Central CMA photo point and water quality monitoring

Table 7.2: Photopoint monitoring (primary sites)

Reach 2	
	
Doakes Reserve	Axedale
	
Russell's Bridge	Backhaus Road
	
English's Bridge	Avonmore Bridge

Reach 3	
	
Bonn Road	
Reach 4	
	
Strathallen (upstream)	Strathallen (downstream)
	
Cox's Reserve (upstream)	Cox's Reserve (downstream)

	
Campbell Road	Echuca Gauging weir

DEPI has commission the University of Melbourne to undertake an analysis of VEFMAP results to determine the effectiveness of environmental flows from 2011 to 2014. The results presented below are quoted from the report (Miller et al. 2014). The VEFMAP analysis indicated that:

- Prolonged inundation reduces encroachment of unwanted vegetation that may choke a river channel. Long inundation periods are more effective at reducing encroachment than multiple short duration inundations, regardless of season. The importance of long duration events confirms that these flows, rather than short increases in flow following heavy rainfall, are the most important type of flow for controlling terrestrial vegetation encroachment.
- Native vegetation on river banks responds positively to short duration (approximately 5-10 days) wetting events especially if they occur in winter and spring. There is little added benefit with longer wetting events, potentially reducing the amount of environmental water that needs to be invested in such ecological responses.

The analysis also found that VEFMAP results:

- were insufficient to draw any conclusions concerning flow-ecology relationships for fish that are less mobile, such as River Blackfish and Flathead Gudgeons. Results from the statistical analysis were also very difficult to interpret, given high levels of uncertainty in the forecasts. However, they suggest that the delivery of a high flow event during the spawning season would result in greater subsequent abundance, a conclusion that runs counter to our initial conceptual model.
- were difficult to interpret, with high levels of uncertainty, for fish that are more mobile such as Pygmy Perch and Carp Gudgeon. Although the results do suggests that high flows of long duration after spawning, and the absence of exotic redfin perch, would result in greater abundance. They also provide no evidence of any effect of spring water temperature on spawning success, despite this being a widely held belief. All three results are consistent with a systematic review of the literature.
- were unable to detect any effects of short-term changes in flow regime on macroinvertebrate assemblages of Victorian lowland rivers. This is perhaps not surprising, because, despite widespread use in monitoring, Rapid Bioassessment (RBA) methods are not designed to detect effects of specific stressors, despite widespread use in monitoring. The Rheophily Index (RI) used in this analysis was the most robust way of analysing such data, but was unable to detect any changes in macroinvertebrate assemblages in response to short-term changes in flow regime. If macroinvertebrates are to remain an endpoint in environmental flows monitoring, new approaches to monitoring are required. Specifically, monitoring methods must be designed specifically to capture invertebrate responses to flow variation.