North Central CMA Region Environmental Water Management Plan for the Birch's (Bullarook) Creek System

EWMP Area: Birch's Creek downstream of Newlyn Reservoir to Creswick Creek

NORTH CENTRAL
Catchment Management Authority
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Department of Environment, Land, Water & Planning

Document History and Status

Version	Date Issued	Prepared By	Reviewed By	Date Approved
1	25/2/2015	Phil Slessar, Peter Sandercock, Simon Treadwell, Melody Serena, Damian Cook,	Rohan Hogan	3/3/2015
2	6/3/2015	Phil Slessar,	Louissa Rogers	10/3/2015
3	13/3/2015	Phil Slessar	Rohan Hogan	18/3/2015
4	20/3/2015	Phil Slessar	Emer Campbell, Brad Drust	14/4/2015
5	14/4/2015	Phil Slessar	DELWP	18/5/2015
6	3/6/2015	Phil Slessar	BEWAG members	FINAL

Distribution

Version	Date	Quantity	Issued To
1	25/2/2015	1	Rohan Hogan
2	6/3/2015	1	Louissa Rogers
3	13/3/2015	1	Rohan Hogan
4	20/3/2015	2	Emer Campbell, Brad Drust
5	14/4/2015	1	DELWP
6	3/6/2015	Multiple	BEWAG members
7	30/6/2015	1	DELWP

Document Management

Printed:	
Last saved:	3 June 2015
File name:	Birch's Creek EWMP V4
Authors:	Philip Slessar
Name of organisation:	North Central CMA
Name of document:	Birch's Creek EWMP V4
Document version:	6
SharePoint link:	\\sharepoint\DavWWWRoot\nrmops\Operations\MD_Basin_Plan_-_EWMP_-_2013-16\Birch's Creek EWMP V4.docx

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© North Central Catchment Management Authority 2015 Front cover photo: Birch's Creek at Nelson's Bridge looking downstream

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

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Please cite this document as: North Central CMA (2015). *Birch's Creek Environmental Water Management Plan*, North Central Catchment Management Authority, Huntly.

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Executive summary

The Birch's (Bullarook) Creek Environmental Water Management Plan (EWMP) sets out long-term objectives for the priority environmental values of Birch's Creek downstream of Newlyn Reservoir to its confluence with Creswick Creek. The EWMP is an important part of the Victorian Environmental Water Planning Framework, providing a five to ten year management approach, based on scientific information and stakeholder consultation. The Birch's Creek EWMP will be used by the North Central Catchment Management Authority (CMA), Department of Environment, Land, Water and Planning (DELWP) and the Victorian Environmental Water Holder (VEWH) for both short and longer-term environmental water planning.

This EWMP is focused on environmental water management so that Birch's Creek can continue to provide environmental, social, cultural and economic values for all users.

The main sections featured in the EWMP are presented below including a summary of the information that will be used to facilitate appropriate environmental water management in Birch's Creek into the future.

Hydrology and system operations

Flow in Birch's Creek is regulated by the operation of Newlyn Reservoir. As a result of regulation, current flows in Birch's Creek are characterised by longer periods of low flow and shorter periods of high flow compared to natural, and this represents a key threat to water-dependant flora and fauna. Flows in Birch's Creek also influence flows in Tullaroop Creek upstream of Tullaroop Reservoir, and contribute to maintaining water dependent flora and fauna and contributing to the dispersal of aquatic species to the rest of the system.

Water dependent values

Birch's Creek is an upper catchment tributary of the Loddon River, and is connected to the Murray River via the Loddon River and Tullaroop Creek. It provides habitat for native fish including River Blackfish and a number of small bodied native species such as Australian Smelt and Obscure Galaxias. The creek also provides important in-stream habitat for aquatic fauna including Platypus and Water Rats.

Ecological condition and threats

Birch's Creek is currently in relatively poor condition. Its native fish population, in particular River Blackfish, have shown signs of decline in upper parts of the creek. Riparian vegetation is significantly impacted by willows and other woody weeds and in some areas the riparian zone is cleared.

Management objectives

A long-term management goal has been defined for Birch's Creek:

Birch's Creek long term management goals:

- To establish resilient breeding populations of Platypus and small to medium bodied native fish including River Blackfish and provide opportunities for these animals to disperse to Creswick and Tullaroop Creeks.
- To maintain and increase a diverse mosaic of in-stream, fringing and riparian native vegetation communities.

The ecological objectives and hydrological objectives that sit under the long-term management goal for Birch's Creek were assessed in 2005 (SKM 2005b and 2005c) and have been reviewed and refined during the development of this EWMP. These objectives prescribe the environmental watering regime for Birch's Creek.

Managing risks to achieving objectives

The threats to achieving the ecological objectives that are external to environmental water have been identified in this EWMP. These include for example instream barriers to fish movement and grazing of riparian vegetation. The risks of providing environmental water are also assessed in the Risk Management section.

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 installation of a gauge in the lower reach of Birch's Creek.

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 Birch's Creek EWMP. Birch's Creek EWMP recommends a suite of intervention and long-term monitoring activities that will meet the monitoring requirements such as vegetation surveys to assess changes in vegetation resulting from flows, fish surveys to track the blackfish population as well as determine populations of small bodied fish, .

Consultation

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

Knowledge Gaps

The management actions in Birch's Creek EWMP are based on the best available information. Knowledge gaps have been identified during the development of the EWMP, particularly around groundwater – surface water interactions and cold water pollution during releases from Newlyn Reservoir.

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 Birch's (Bullarook) Creek EWMP

The information contained in the Birch's (Bullarook) Creek 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 and organisations in preparing this EWMP:

- Andrea Keleher Department of Environment, Water, Land and Planning (DELWP)
- Mark Toomey, Victorian Environmental Water Holder (VEWH)
- Kerry Webber Commonwealth Environmental Water Holder (CEWH)
- Ed Thomas, Peter Watson, Andrew Shields (Goulburn Murray Water)
- Norm Suckling, Geoff May, Robert Wilson (Birch's Creek Environmental Water Advisory Group)
- Ron Cosgrave, Richard Carter (North Central CMA Natural Resource Management Committee)
- Damian Cook (Rakali Ecological Consulting), Melody Serena (Australian Platypus Conservancy), Simon Treadwell, Peter Sandercock (Jacobs SKM), (Environmental Flows Technical Panel)
- Rohan Hogan, Phil Slessar, Louissa Rogers, Peter McRostie (North Central CMA).

1. Introduction

Management of environmental water is planned and implemented through the environmental watering framework. Figure 1 illustrates the strategies, scientific reports and operational documents required for environmental water management in Victoria (Department of Environment and Primary Industries [DEPI] 2013). 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 Birch's (Bullarook) Creek the North Central Waterway Strategy long term resource condition targets are:

- Improve the condition of Birch's Creek (ISC Reach 21) from poor to good (based on Index of Stream Condition (ISC)) by 2050.
- Improvement of one in the ISC streamside zone sub-index along Birch's Creek by 2021.
- Maintain and improve Blackfish (*Gadopsis marmoratus*) populations within Birch's Creek by 2022.

These targets are reflected in the overall management goals and objectives described by this EWMP (section 6).

The North Central CMA is being funded through the Department of Environment, Land, Water and Planning (DELWP) 'Victorian Basin Plan Environmental Water Management Plan (EWMP) Program' to prepare an Environmental Water Management Plan (EWMP) for Birch's (Bullarook) Creek. Once completed, annual seasonal watering proposals for Birch's Creek will be informed by the EWMP.

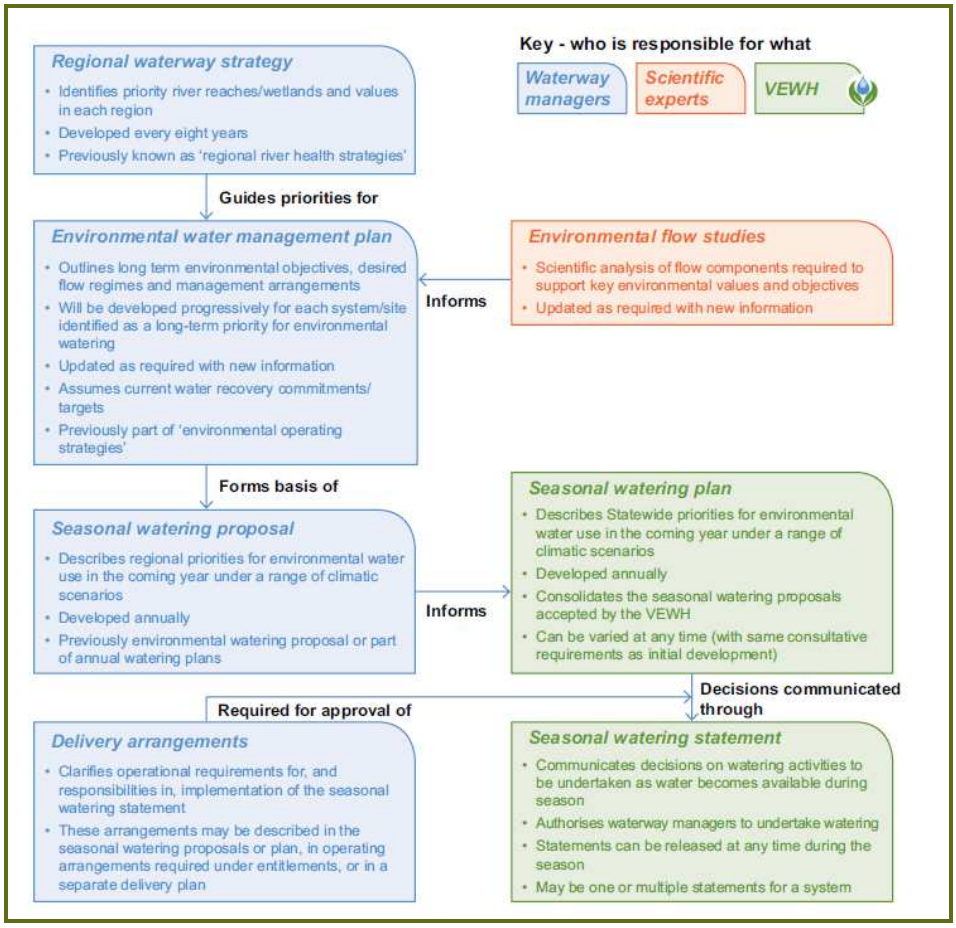


Figure 1: Planning framework for decisions about environmental water management in Victoria.

1.1. Purpose and scope of the Birch's (Bullarook) Creek Environmental Water Management Plan

The Birch's (Bullarook) Creek EWMP is a ten year management plan that describes the ecological values present, long-term goal for the creek and priority ecological objectives including a 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 DELWP, the Victorian Environmental Water Holder (VEWH) and the Commonwealth Environmental Water Holder (CEWH) 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 creek system
- provide a vehicle for community consultation, including for the long-term objectives and water requirements of the creek system
- 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 reaches of Birch's (Bullarook) Creek downstream of Newlyn Reservoir to its confluence with Creswick Creek (Figure 2). Hepburn Race, which carries irrigation water and enters Birch's Creek near Smeaton, is not included. The reach below the Creswick Creek confluence (Tullaroop Creek above Tullaroop Reservoir) is considered in the context of carrying water from Birch's Creek to Tullaroop Reservoir.

1.2. Development process

The Birch's (Bullarook) Creek EWMP has been developed in collaboration with stakeholders including DELWP, VEWH and Goulburn Murray Water (GMW). Community input has been garnered through the Birch's Creek Environmental Water Advisory Group (EWAG). A number of tasks were undertaken to develop the EWMP including:

- **Scoping and collating information:** technical work, monitoring and research that have been undertaken on the creek to date.
- **Technical review of ecological objectives and flow recommendations:** a technical panel (the Environmental Flows Technical Panel (EFTP) were convened to review the ecological objectives identified in the 'Environmental Assessment for the Birch's (sic) Creek Catchment' (SKM 2005a) based on monitoring results and up-to-date scientific understandings on flow requirements of flora and fauna.
- The outputs of these 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. The water dependent values (fauna, vegetation communities and flora) are presented by reach. Terrestrial species that are dependent on the vegetation within the riparian zone due to large-scale clearing of woodland habitat throughout the catchment 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 state-wide Index of Stream Condition, is discussed. 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 are based on the water dependent values recorded in the creek, the current condition and the condition trajectory. The objectives are also aligned with the broader environmental outcomes proposed in the Basin Plan 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 Birch's Creek are based on monitoring data, community concerns and best-available river health scientific knowledge as provided by the EFTP.

  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.

  Management actions to mitigate the risks are recommended (and included as Complementary Actions).

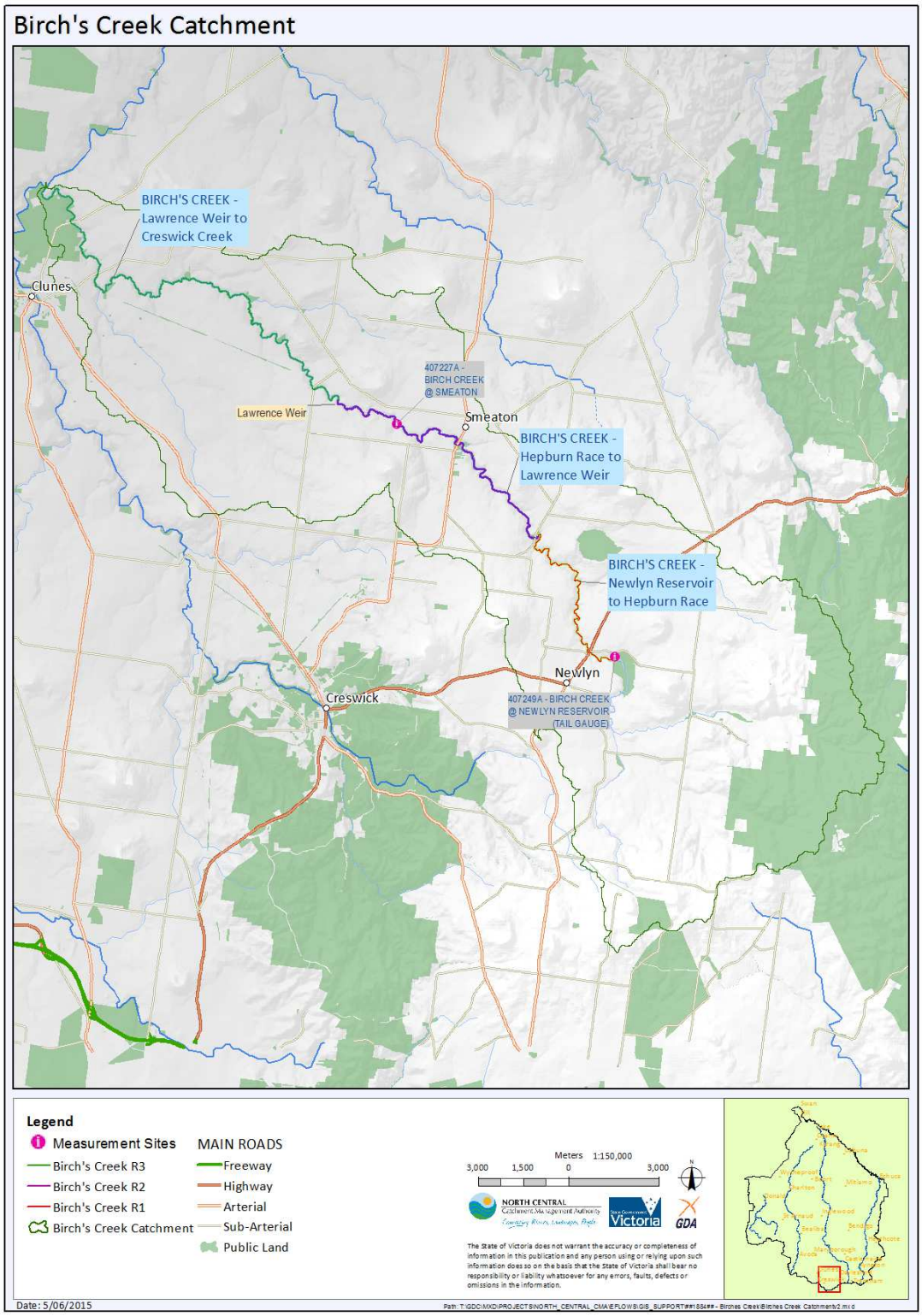
  Residual risk assumes that management actions are fully implemented.

- **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.

Figure 2: Birch's Creek location map showing flow reaches and major features



2. Site overview

2.1. Site location

Birch's Creek is a tributary of the Loddon River rising on the northern slopes of the Great Dividing Range and drains a catchment area of 707km^2 (North Central CMA 2014b). The Newlyn Reservoir is the upper limit of the environmental flows management area, and Creswick Creek, which joins Birch's Creek approximately 3km north of Clunes, marks the downstream limit. Distance from Newlyn Reservoir to Creswick Creek is approximately 40 km.

Downstream of the Creswick Creek confluence the creek becomes Tullaroop Creek, which flows into Tullaroop Reservoir near Carisbrook. A separate EWMP has been developed for Tullaroop Creek as part of the Loddon River system EWMP.

Birch's Creek receives major tributary inputs from Rocky Lead, Langdons, Lawrence and Tourello Creeks (Figure 2).

Two storages built in the 1870s regulate stream flow for irrigation and urban supply. Newlyn Reservoir (total capacity = 3030 ML) is located on Birch's Creek upstream of the township of Newlyn, while Hepburn Lagoon (total capacity = 3,080 ML) is an off-stream storage located on Langdons Creek and connected to Birch's Creek via the Hepburn Race. As outlined in Section , environmental water can only be delivered from Newlyn Reservoir.

Downstream of the storages, the catchment is extensively cleared and the creek meanders through a generally incised basaltic valley with a mostly confined floodplain. The dominant land-uses are broadacre agriculture, dairying and mixed enterprise including cropping. Potatoes are a major crop in the catchment.

2.2. Catchment setting

Climate

Rainfall is generally higher in winter with most run off occurring between May and November. August is, on average, the wettest month with average rainfall just over 80mm at Blampied (Bureau of Meteorology [BOM] 2015)

During the period of record (1968 – 2014) there were two years of very high rainfall (1127.5mm in 1973 and 1018.2 in 2010) and annual totals declined significantly from 1992 to 2009. Figure 3 and Figure 4 show annual rainfall totals and monthly averages respectively for the period from 1969 to 2014 at Blampied recording station.

Average monthly temperatures (Figure 5) show the hottest months as December to February and the coldest maximum temperatures generally occur in July and August.

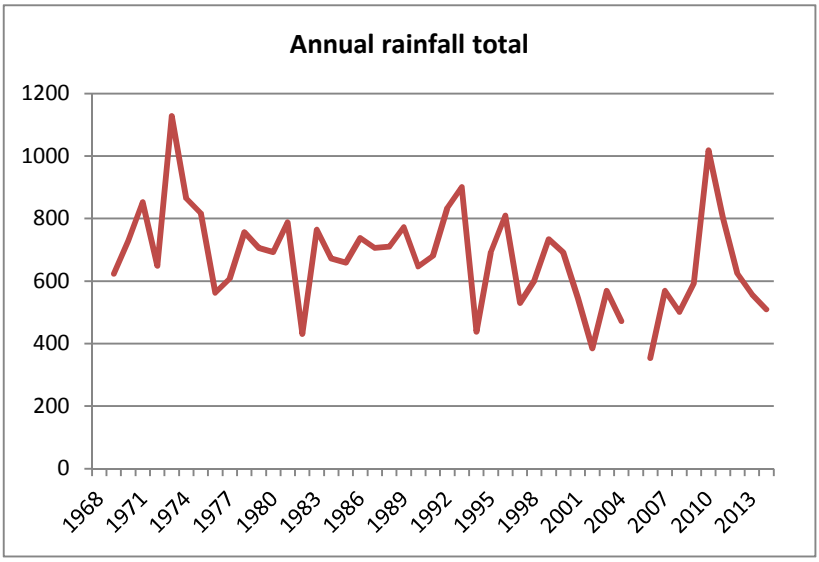


Figure 3: Annual rainfall totals (mm) for Blampied gauge 1969-Present

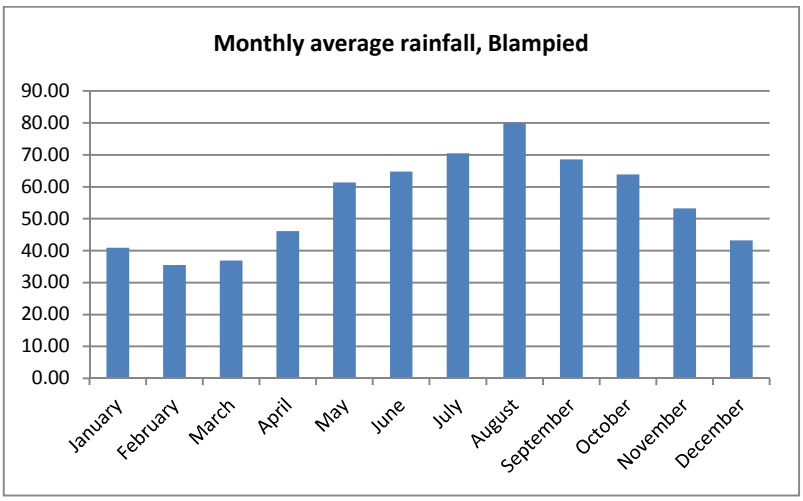


Figure 4: Average monthly rainfall (mm) for Blampied gauge, 1969-Present

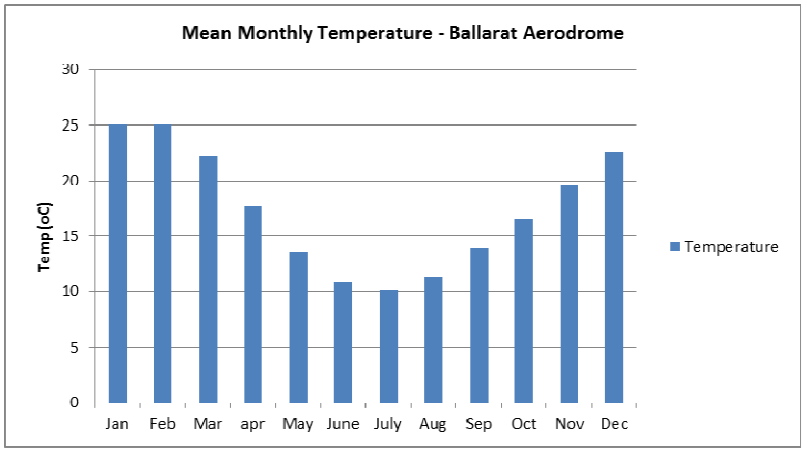


Figure 5: Mean monthly temperature at Ballarat Aerodrome, 1908 - Current

Geology

The primary geological units in the Birch's Creek catchment include the Newer Volcanic basalt and the underlying Calivil Formation alluvium. There are several basalt flows that comprise the Newer Volcanics in this area, reaching thicknesses of up to 250 m. Between each basalt flow is a weathered clay layer, however this is not an effective aquitard (Kirshbaum, 2014).

The Newer Volcanics overlay the Calivil Formation alluvium which occurs as 'deep leads' (named for their deposition in ancient paleodrainages). In this area the deep lead is referred to as the 'Berry Lead' and is relatively thin underlying the Birch's Creek. Groundwater provides a moderate proportion of base flow in Birch's Creek (see Section).

Hydrophysical characteristics

Birch's Creek receives water from tributary inflows, springs, groundwater intersection with surface water. A small volume of excess irrigation water enters Birch's Creek at Hepburn Race, and remnant irrigation water from reaches 1 and 2 also provide some flow to Reach 3 (Watson, P, 2013, personal communication, [GMW Customer Service Officer Diversions West] April). An oat mill at Smeaton also discharges water to the creek under an Environment Protection Authority (EPA) licence.

The Birch's Creek flow study (Site Paper) (SKM 2005b) divided the Birch's Creek below Newlyn Reservoir into 3 reaches. A description of each reach follows.

Reach 1: Reach 1 extends from the outlet of Newlyn Reservoir to the Hepburn Race, a distance of approximately 7.5 km (Figure 2). It is characterised by gently undulating basaltic hills and a moderately incised channel. The township of Newlyn is within this reach. Thick Willow (*Salix spp.*) root mats have modified the natural channel form through sedimentation of sections of the reach and bifurcation of the channel. Naturally the creek would have had a cobble and bedrock substrate, and this is still visible in some sections of the reach (SKM 2005b, McGuckin 2015).

Reach 2: Hepburn Race to Lawrence Weir is a distance of approximately 10.5 km and includes the township of Smeaton (Figure 2). It is also characterised by an incised channel and confined floodplain through most of its length.

The natural substrate has been impacted by sedimentation, a result of extensive clearing of the catchment and riparian zone but some bedrock and cobble substrate is still visible in this reach (McGuckin 2015). concludes that the clay layers are

Reach 3: Lawrence Weir to the confluence with Creswick Creek is a distance of approximately 20 km and is the target reach for environmental flow management (SKM 2005b) (Figure 2). Much of the channel flows through a deeply incised basalt valley with a confined floodplain.

The 2005 flow study (SKM 2005b) included the reach between Birch's Creek/Creswick Creek confluence and Tullaroop Reservoir. It has not been included in this document because flows exiting Reach 3 combine with Creswick Creek water to progress down Tullaroop Creek. There is no means to control flows in this reach with the exception of flows out of Birch's Creek. The reach is however recognised as important for connectivity between upper Loddon tributaries and the mid-lower Loddon River

Figure 6 is a longitudinal profile of the creek below Newlyn Reservoir, showing reach delineations and hydrological features.

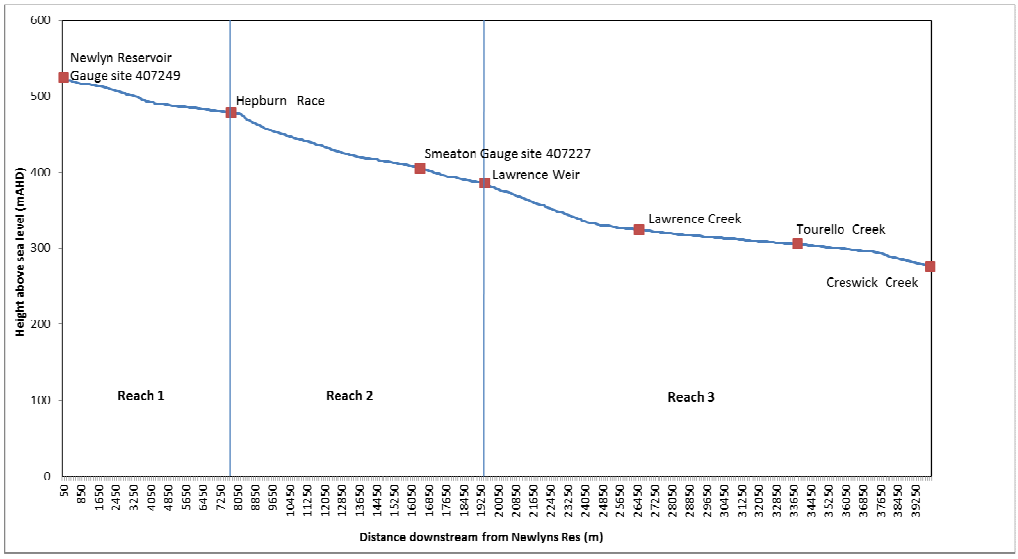


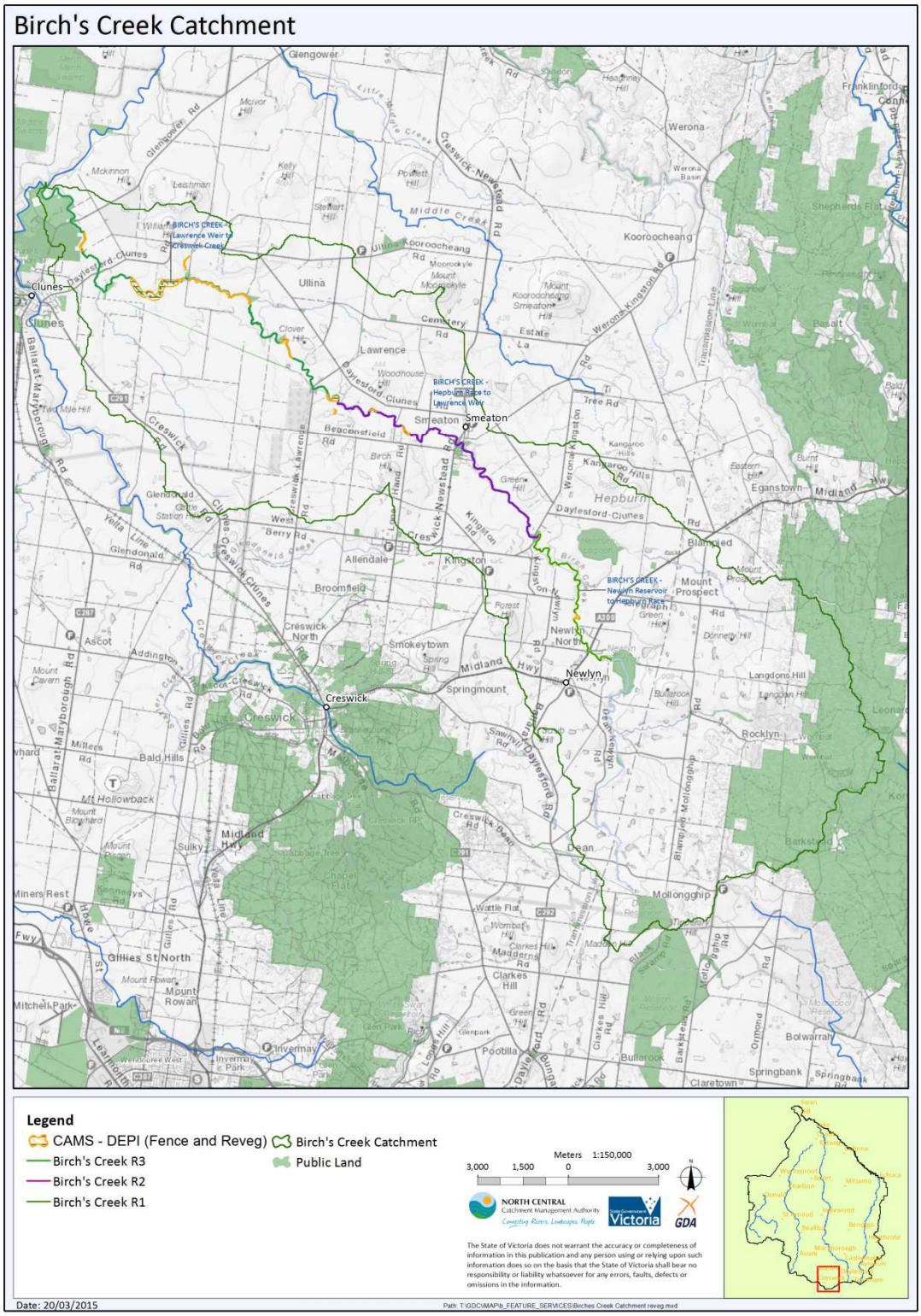
Figure 6: Profile of Birch's Creek below Newlyn Reservoir showing major hydrological features

2.3. Land status and management

Birch's (Bullarook) Creek flows through agricultural land, with towns including Newlyn, Smeaton and Clunes within the catchment. A majority of the riparian zone is freehold land, with only small discreet areas identified as Crown Land. These include the Andersons Mill precinct (managed by Parks Victoria) and an area at Lord Clyde Rd (managed by DELWP) (Figure 7).

North Central CMA has undertaken projects on private property along the creek that include Willow removal, revegetation and fencing. The area around Nelson's Bridge in Reach 3 underwent habitat reinstatement for River Blackfish in 2001 (Department of Natural Resources [DNR] 2002).

Figure 7: Fencing and revegetation activities in Birch's Creek



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 Birch's Creek.

Table 1: Roles and responsibilities for environmental water in Birch's Creek (DEPI 2013; VEWH 2014a)

Agency/group	Responsibilities/involvement
Department of Environment, Land, Water and Planning (DELWP)	Manage the water allocation and entitlements framework. Develop state policy on water resource management and waterway management approved by the Minister for Environment, Climate Change and Water. Develop state policy for the management of environmental water in regulated and unregulated systems. Act on behalf of the Minister for Environment, Climate Change and Water 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. Authorize 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	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.
North Central Catchment Management 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) and 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 maximize environmental outcomes. Operate water supply infrastructure such as dams and irrigation distribution systems to deliver environmental and irrigation water. Ensure the provision of passing flows and compliance with management of diversion limits in unregulated and groundwater systems.
Central Highlands Water (CHW)	Urban water supply authority. Manage consumptive water for townships in the Birch's Creek catchment (eg Clunes, Newlyn).
Parks Victoria	Land Manager. Implement the relevant components of EWMPs. 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.
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.
Birch's Creek Environmental Water Advisory Group (BEWAG)	The Birch's Creek 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 creek. 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

There are two potential sources of water for Birch's Creek:

- Environmental entitlement
- Passing flows.

Each of these are described below.

Environmental Entitlement

The right to environmental water in the Birch's (Bullarook) Creek was defined in 2009 through the *Environmental Entitlement (Birch's Creek – Bullarook System) 2009*. This currently provides the only source of environmental water in the creek, a volume of 100 ML High-reliability water share (HRWS) per year. There are two types of water shares in Victoria which are classed by their reliability:

- High-reliability water share (HRWS) is a legally recognized, secure entitlement to a defined share of water.
- Low reliability water shares (LRWS) are still legally recognized water shares but have a relatively low reliability of supply.

Allocations are made to high-reliability water shares before low-reliability water shares (DEPI 2014b). Currently there is no LRWS entitlement for the environment in Birch's Creek.

Conditions on the environmental entitlement are:

- Allocated when seasonal HRWS determination is 20% or greater on 1st December each year. If allocations are not 20% on 1 December, the Water Holder is entitled to an equitable share of avail;able resources
- Does not carry over. Account resets on 1 December each year
- Entitlement spills from 1 July to 30 November
- Only available for delivery from Newlyn Reservoir

Passing flows

Passing flows are also prescribed for Birch's Creek in the Environmental Entitlement (EE) (Government of Victoria 2009). For all reaches, passing flows carry an 'or natural' clause. This means that the prescribed rates are a maximum rate, but if inflows to Newlyn Reservoir are lower than the prescribed rate then the lower flow rate becomes the passing flow. In the Birch's Creek system, GMW generally maintains a minimum flow of 2ML/d during periods of no inflow (Watson, P, 2013, personal communication [GMW Customer Service Officer Diversions West], April).

Passing flow rates and timing are outlined in Table 2

Table 2: Passing flow rates for Birch's Creek

Reach	Passing flow rates (ML/day)	
	Summer (Dec-May)	Winter (Jun-Nov)
1	3	10
2	5	10
3	8	15

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 Birch's Creek. 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 Murray-Darling Basin Plan).

Strategies, programs and projects relevant to the Birch's Creek 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 2013).
- 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. The North Central Waterway Strategy has identified Birch's Creek as a priority waterway and has outlined the work required to improve its health over time including fencing, off stream watering, weed control and delivery of environmental water.

3. Hydrology and system operations

3.1. River hydrology

Birch's Creek receives water from tributary inflows, springs and groundwater intersection with surface water. A small volume of excess irrigation water enters Birch's Creek at Hepburn Race, and remnant irrigation water from reaches 1 and 2 also provide some flow to Reach 3 (Watson, P, 2013, personal communication, [GMW Customer Service Officer Diversions West] April). An oat mill at Smeaton also discharges water to the creek under an Environment Protection Authority (EPA) licence.

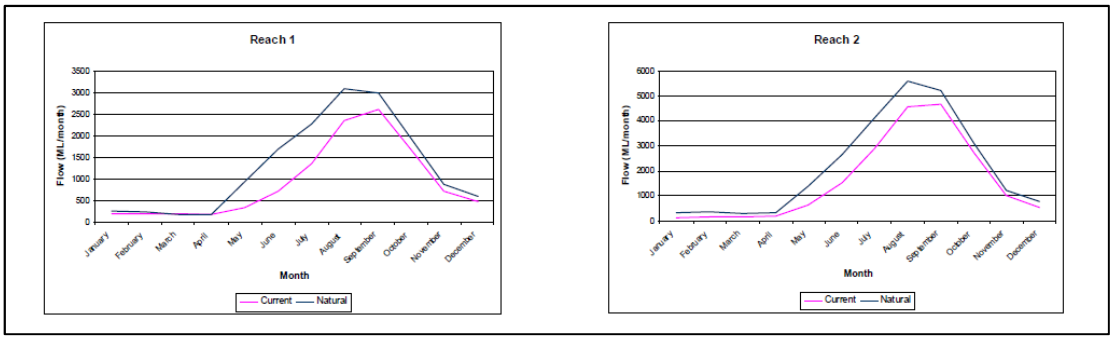
Prior to European settlement, flows were seasonally variable with the majority of flow occurring during the winter and spring. Since regulation spills do not occur as frequently or for as long as natural high flows in the winter-spring period (Figure 8). This is the case for all reaches, where the current high flows (which represent spill) on average commence later, finish earlier, and are of lower volume than natural. This is probably also a reflection of the fact that there has been a significant decrease in the inflows to Newlyn Reservoir because of the proliferation of farm dams in the upper catchment that intercept run off before it reaches Newlyn Reservoir.

Because of the relatively small capacity of Newlyn Reservoir Birch's Creek is somewhat different from larger systems such as the Campaspe and Loddon which have high storage capacity and much lower probability of spilling in any one year.

For Newlyn Reservoir, spill occurs in most years in winter-spring, but naturally freshes would have occurred as a result od summer storms. In the current situation irrigation provides the main source of water in Reaches 1 and 2 during summer, and spills in summer/autumn are much less common.

From around 1997 to late 2010, Victoria experienced the Millennium Drought, a severe and extended drought that impacted a large area of the state. During this period Birch's Creek dried to a series of small pools, suffering considerable flow stress and putting pressure on populations of River Blackfish and platypus (Cosgrave, R, 2013, personal communication [Landholder], April). Newlyn Reservoir dried to below operable levels, and water allocations were 0% in much of the period between 2005/6 and 2009/10 (GMW 2015a).

In 2010-11 widespread heavy rains across northern Victoria resulted in two periods of very high flow (September 2010 and January 2011) including overbank flows in Birch's Creek, commencing its recovery from the drought. Newlyn Reservoir has either spilled or undergone pre-release during winter in the years since 2010-11.



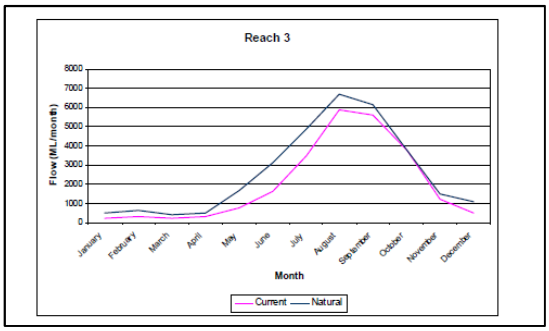


Figure 8: Hydrographs showing natural vs current flow (Source SKM, 2005b)

3.2. Groundwater hydrology and management

Groundwater in this area is fresh due to rapid recharge to the basalt aquifer from rainfall, mainly directed through the multiple volcanic cones in the area.

Groundwater flow is from the underlying Calivil Formation to the overlying basalt aquifer. The upward hydraulic gradient is interpreted to have led to mixing of the groundwater in some places and in particular this is noted to have occurred where faults are known to be present, and the chemical signature of the basalt aquifer is present in the overlying formation (Kirschbaum 2014).

Groundwater quality for 11 bores that reside along Birch's Creek indicate groundwater salinity (measured by electrical conductivity (EC)) ranges from 319-1520 uS/cm, which is relatively fresh. Groundwater EC was found to increase with distance downstream in the basalt aquifer. This is a common phenomenon and is generally attributed to evapotranspiration processes influencing groundwater quality along the groundwater flow path.

Groundwater-surface water interaction

The Loddon Highlands Water Supply Protection Area Consultative Committee (LHWSPACC) was established to develop a management plan for groundwater in the upper Loddon Catchment. The plan (LHWSPACC 2012) identified Birch's Creek as one of the areas in the Loddon Highlands with the greatest potential for impacts to creeks from groundwater pumping.

Detailed work has been undertaken in this catchment to investigate the contributions of groundwater to surface water. Work undertaken by Kirshbaum (2014), Hagerty (2006) and Parsons Brinckerhoff (2011) has been drawn upon here, but the complexity of ground-surface water interactions in the Birch's Creek catchment means that further work is required to gain a clearer picture of the interactions.

Groundwater inflow to Birch's Creek is likely to be greater in winter during periods of high watertable. Parsons Brinckerhoff (2011) found that even when groundwater levels are significantly reduced in summer, the creek remains gaining or near-neutral during these periods.

Key findings of previous studies were:

- Reach 1: the groundwater-surface interactions are inconclusive, however it is suspected to have a role in surface flow
- Reach 2 and 3: groundwater is estimated to contribute to 15% of surface flow.

3.3. System operations – history of use

Discharge in Birch's Creek is measured at 2 established gauging stations (Table 3).

Table 3: Victorian Water Quality Monitoring Network flow gauging stations

Gauging Station ID	Reach No.	Location	Period of Record
407249	1	Birch's Creek at Newlyn Reservoir	June 2006 to current
407227	2	Birch's Creek at Smeaton	March 1961 to current

There is no gauging station in Reach 3.

3.3.1. Water management and delivery

Birch's and Lawrence Creeks were impounded by Newlyn Reservoir and Hepburn Lagoon respectively in 1871. Stored water was used to supply Anderson's Mill, Clunes and Spring Hill. Both storages were upgraded and enlarged in the early 1960s and now supply mainly irrigation and stock and domestic supplies (GMW 2015b). Town water supplies are now, on the whole, derived from groundwater sources, but Central Highlands Water retain an entitlement of a maximum 500 ML in Newlyn.

Lawrence Weir regulated flows for the Clunes town water supply, but this is now mostly supplied from groundwater, and Lawrence Weir is essentially a redundant structure that is a barrier to fish movement (SKM 2005c).

Water is extracted for irrigation in reach 1 and directly from the Hepburn Race. A small number of users take water from reach 2 and a single allocation in reach 3 is rarely used. Domestic and Stock licences and a commercial licence are also current in the system. The irrigation season generally runs

from December to March, with total HRWS allocations approximately 870 ML (Watson, P, 2013, personal communication, [GMW Customer Service Officer Diversions West], April).

Table 4 shows the average usage and licence volume for direct diversions from the Birch's Creek system. This includes direct diversions from Newlyn Reservoir and Hepburn's Lagoon/Race. The remaining water held in storage is needed to operate the system. This includes potential losses from evaporation (which can be in the order of 1,500 ML/year) and the volume needed to run the creek, which can also be about 1,500 ML/year (Shields, A, 2015, personal communication, [GMW Manager, River Operations], March).

Table 4: Licensed volume of diversions in Birch's Creek (SKM 2005c)

Reach	Licensed volume (ML/yr)	Average usage (ML/yr)
1	322.6	499.2
2	43.1	67.7
3	40.4	0.0
Hepburn Lagoon/Race (direct)	147.0	173.9
Newlyn Res (direct)	139.5	129.2
Total	692.6	869.0

Farm Dams

Winterfill licences and farm dams occur throughout the catchment, and upstream of Newlyn Reservoir the volume of water required to fill small catchment dams impacts on inflows into Newlyn Reservoir. Downstream of Newlyn Reservoir a total of 2,174 ML are captured in farm dams (Table 5).

Table 5: Winterfill licence and farm dam volumes (SKM 2005c)

Reach	Winterfill (ML/yr)	Volume of farm dams (ML)
Reach 1	73.2	481.6
Reach 2 (incl Hepburn Race)	0	799.0
Reach 3	26.0	640.5
Reach 4	0	253.3
Total	99.2	2174.4

Water is released from Newlyn Reservoir to supply irrigation customers in reaches 1 and 2, while Hepburn Lagoon water is diverted by customers along the Hepburn Race. The total volume of water available for allocation and the total volume used in 2012/13 are shown in Table 6 (after SKM 2005c).

Table 6: Summary of total water resources available for allocation and total water use in 2012/13

Water source	Total water resource (ML)	Total use (ML)
Surface water	1,739	976
Groundwater [1]	7307.7	1547.6
Recycled water	NA	NA

3.3.2. Groundwater usage

Most groundwater is extracted from the Newer Volcanic basalt. It is found at shallower depths, has a greater thickness and groundwater salinity is generally lower compared to the Calivil Formation aquifer.

During the Millennium Drought groundwater use was far greater than surface water use, but since the drought broke groundwater usage has returned to pre-drought levels. Available metered data indicates that usage has generally been around 30 to 40% of total entitlement. Groundwater use has generally been higher in dry periods and correlates with reduced surface water availability. Restrictions on extractions were in place between 2007/08 and 2009/10, but high rainfall and flooding in 2010/11 resulted in little groundwater usage (Loddon Highlands Water Supply Protection Area Consultative Committee [LHWSPACC] 2012). Table 7 shows the Management zones of the Loddon Highlands Water Supply Protection Area (LHWSPA), the number of licences and annual licence

[1] Combined figures for Newlyn, Blampied and Ullina zones of the Loddon Highlands WSPA

volume. This information is derived from a plan developed by GMW to manage groundwater in the Loddon Highlands (LHWSPACC 2012)

Table 7: Number of LHWSPA licence holders and licence volume in June 2012 (LHWSPACC 2012)

Management Zone	Number of licences	Licence volume (GL/year)
Mollongghip	3	0.3
Blampied*	22	1.3
Newlyn*	28	3.1
Ullina*	19	2.4
Ascot	68	7.0
Waubra	35	4.7
Talbot	14	1.3
TOTAL	191	20.1

* Management zone within Birch's Creek catchment

3.3.3. Environmental watering

Until the inception of the BE in 2009 there was no formal arrangement for environmental water. GMW delivered minimum passing flow, which during the peak of the Millennium Drought was only 1 ML/day. A small volume of 4 ML/day for three days was released in 2008 to provide critical habitat needs for River Blackfish.

Since 2009 environmental water has been released twice, once in May 2012 and in April-May 2015. These were summer/autumn freshes at a rate of 15 ML/d (2012) and 27 ML/day. This was focussed on freshening water quality and improving habitat conditions after the summer period.

The small volume of entitlement and the restrictions around its use limit the capacity to deliver a broad suite of flows using environmental reserve. In all but the driest years Newlyn spills in winter-spring, providing higher flows and freshes during the winter. Summer overflows from Newlyn are uncommon.

4. Values

4.1. Water dependent environmental values

4.1.1. Listings

Federal and State environmental legislation and international agreements form the basis for the conservation of biodiversity for Birch's Creek. The relevant agreements and acts are identified in Table 8.

Table 8: Legislation, agreements, convention and listings relevant to the site, or species recorded in Birch's Creek

Legislation, Agreement or Convention	Jurisdiction	Listed
Japan Australia Migratory Birds Agreement (JAMBA)	International	x
China Australia Migratory Birds Agreement (CAMBA)	International	x
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	✓

4.1.2. Fauna

The Birch's Creek catchment supports a number of threatened or endangered species of terrestrial and aquatic fauna, although only one is water dependent species, the Growling Grass Frog (*Litoria raniformis*). It is listed as threatened under the Flora and Fauna Guarantee Act (1988).

Waterbirds

Many species of water birds have been recorded in the Birch's Creek system, in particular at Newlyn Reservoir. These include grebe, ibis, duck, heron and pelican species (Appendix 3) Table 9 shows threatened birds recorded at Birch's Creek.

Table 9: Important faunal species of Birch's Creek (DELWP 2015a)

Common Name	Scientific Name	EPBC status	FFG status	Vic Status	Last record
Growling Grass Frog	*Litoria raniformis*	**Vu**	**L**	**TH**	**22/11/2000**
Golden Perch	*Macquaria ambigua*		L	NT	**1/03/1995**
Freckled Duck	*Stictonetta naevosa*		**L**	**EN**	**15/07/2006**
Blue-billed Duck	*Oxyura australis*		**L**	**EN**	**15/07/2006**
Australasian Shoveler	*Anas rhynchotis*			VU	**15/07/2006**
Hardhead	*Aythya australis*			VU	**15/07/2006**
Musk Duck	*Biziura lobata*			VU	**15/07/2006**
Pied Cormorant	*Phalacrocorax varius*			NT	**24/02/1990**
Royal Spoonbill	*Platalea regia*			NT	**17/03/1989**

Fish

Fish species present in Birch's Creek including River Blackfish which are not threatened but are considered regionally significant (North Central CMA 2014b) and small bodied natives, Australian Smelt (*Retropinna semoni*), Flat-headed Gudgeon (*Philypnodon grandiceps*) and Obscure galaxias (*Galaxias oliros*).

Historically blackfish were distributed throughout the length of the creek and regularly fished by recreational anglers (Cosgrave, R, 2015, personal communication, [Landholder], February). The introduction of species such as redfin, brown and rainbow trout have impacted on populations of Blackfish in the creek.

Golden Perch (*Macquaria ambigua*) have historically been caught in Birch's Creek, but recent fish surveys have found no evidence that they persist in the creek.

Mammals

Birch's Creek is home to a breeding population of Platypus (*Ornithorhynchus anatinus*). While they were significantly impacted by drought and flood, platypus appear to have returned to the lower part of the creek. During the 2014 fish survey, 7 platypus were captured as bycatch (McGuckin 2015).

A male platypus was captured at Nelsons Bridge, two females and a male were captured at Jorgensen's Bridge, and one female and a male were captured at Foley Road (just u/s of the Creswick Creek confluence) (McGuckin 2015). This indicates that platypus are well established in the lower part of the creek.

4.1.3. Vegetation communities and flora

Birch's Creek is located in the Victorian Volcanic Plain Bioregion. The vegetation communities of Birch's Creek are restricted within a narrow riparian zone in an area that has been substantially cleared and/or infested with exotic species. Following EFTP field visits some modification of the EVC identification was made.

Table 10 describes the EVCs and their conservation status. Table 11 shows the water dependent flora species recorded in Birch's Creek.

Table 10: Conservation status of current EVCs of Birch's Creek

Bioregion	EVC Name	EVC #	Bioregional Conservation Status	Reach	Area (Ha)
Victorian Volcanic Plain	Swampy Riparian Woodland	83	Endangered	1,2	
	Creekline grassy woodland	68	Endangered	3	
Source: DELWP 2015a; VEAC 2008					

Table 11: Significant water dependant flora species recorded at Birch's Creek (DELWP 2015a)

Common Name	Scientific Name	Reach	EPBC status	FFG status	Vic Status
Annual Buttercup	*Ranunculus sessiliflorus var. pilulifer*			**L**	Poorly known
Purple Blown-grass	*Lachnagrostis punicea subsp. punicea*			**L**	Rare
Pale Swamp Everlasting	*Coronidium gunnianum*			**L**	Vulnerable
Australian Anchor Plant	*Discaria pubescens*			L	Rare
River red gum	*Eucalyptus camandulensis*			**X**	

4.2. 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 Birch's Creek 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. instream woody habitat (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 riparian trees such as Red Gum and Manna Gum. 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.
- 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. Birch's Creek is an upstream tributary of the Loddon River. It is important for the dispersal of fish into Tullaroop Creek and the Loddon River for genetic exchange.

4.3. 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.

4.3.1. Cultural Heritage

Aboriginal cultural heritage

The area that includes Birch's Creek is Dja Dja Wurrung country. Areas of aboriginal cultural sensitivity include all waterways and riparian zones in the catchment (DPC 2015)

European cultural heritage

The Birch's Creek catchment was settled after the discovery of gold in the 1850s. Anderson's Mill, constructed in 1861, was used to mill wheat and oats, but closed in 1959 as profitability declined (North Central CMA 2006)

Lawrence Weir is also considered an historic site. Infrastructure involved in the early delivery of water to the township of Clunes can still be seen in the vicinity of the weir (Wilson, R, 2015, personal communication, [Landholder], February).

4.3.2. Recreation

Birch's Creek is used for recreational fishing and passive activities such as walking and picnicking. The reservoir at Newlyn is also used for recreational fishing, and is regularly stocked with brown trout. For example, 2,000 brown trout were released into Newlyn Reservoir in October 2013.

Passive enjoyment of the creek and its biota is commonly cited as an important value. This includes activities such as picnicking, walking and sitting by the creek.

4.3.3. Tourism

Anderson's Mill, located on the banks of the creek at Smeaton, is the main tourist site in the catchment. It is visited because of its historic significance. In addition to Anderson's Mill, Hepburn Lagoon is a popular site for fishing, and a trout farm in the vicinity of Kooroocheang also attracts visitors to the area. The Volcanic Plains bioregion with its many scoria cones and unique landscape is also a significant tourist attraction.

4.4. Economic Values

The primary economic activity in the Birch's Creek area is agriculture. Farming includes potato cropping, grain and dairying. Creek water (via Newlyn Reservoir) is used to irrigate crops, particularly in the area around Newlyn.

4.5. Conceptualisation of the Site

The conceptual understanding of the ecology and ecological functions of Birch's Creek is shown in Figure 9

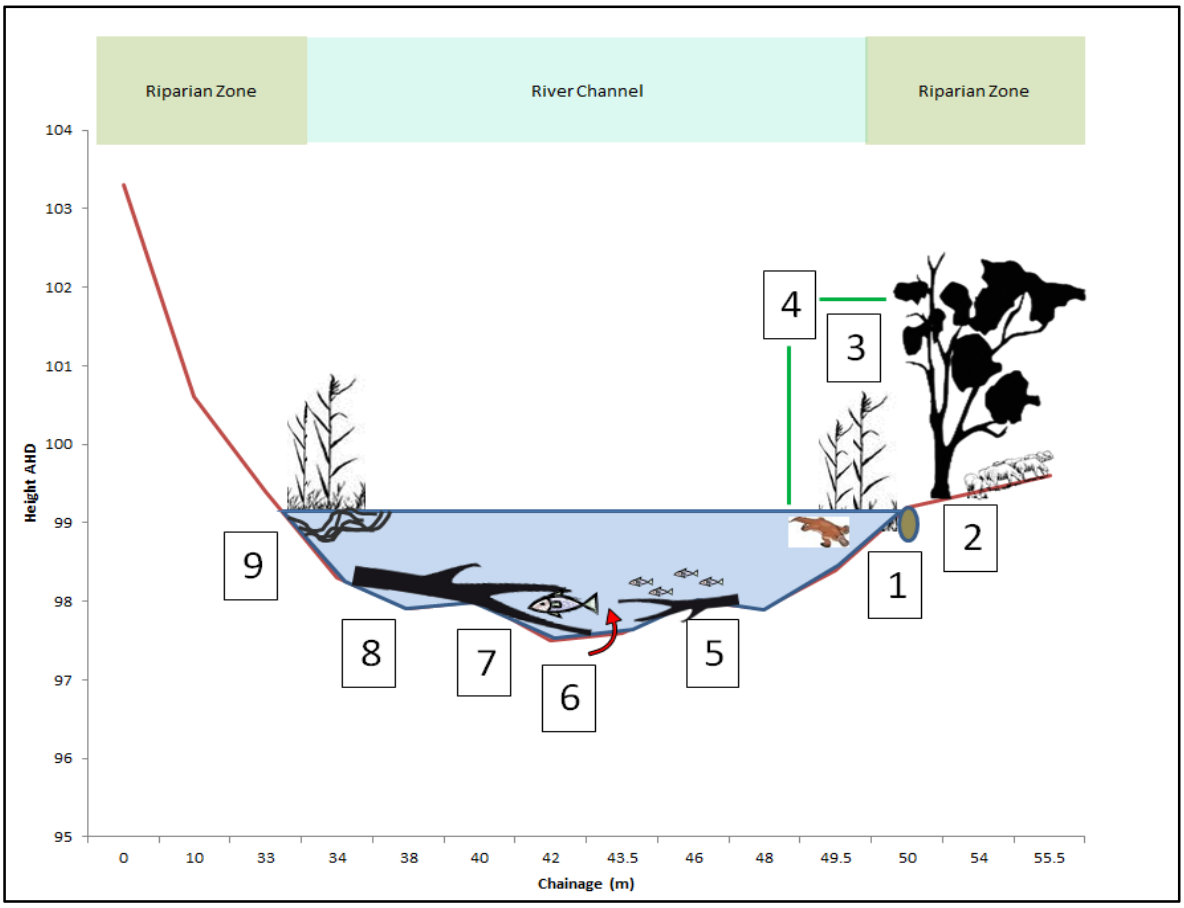


Figure 9: Cross section (Reach 3) indicating conceptual understanding of Birch's Creek ecology.

1. High flows in August are expected to cue Platypus to establish breeding burrows higher on the bank (Reach 3).
2. The riparian zone is restricted to a very narrow margin along the creek and is abutted by agricultural land. Stock has access to the creek at many sites along its length.
3. Emergent vegetation provides shelter for macroinvertebrates, frogs and small fish when inundated. Both instream and emergent vegetation are sources of carbon that drives productivity.
4. Large trees in the riparian zone contribute large wood to the creek. Shade helps to reduce the risk of algal blooms.
5. Instream woody habitat provides shelter, biofilms, zooplankton, macroinvertebrates, fish and platypus larder.
6. Groundwater contributes to creek flows in all reaches
7. Pools provide important habitat, particularly for River Blackfish and Platypus. They are critical for refuge during periods of low to no flow.
8. River Blackfish use hollows in Instream woody habitat for breeding.
9. Instream vegetation includes stands of submerged taxa, such as *Triglochin spp.* 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.

4.6. Significance

Birch's Creek supports regionally significant water dependent species such as River Blackfish and Platypus populations. The creek also supports threatened aquatic herbs. During dry conditions drought refuge in the form of deep pools persists in Reaches 2 and 3.

The site has historically supported EPBC listed Growling Grass Frog.

5. Ecological Condition and Threats

5.1. Context

Following the Millennium Drought, rainfall conditions significantly improved in the 2010 Winter/Spring period resulting in natural high river flows. In January 2011 significant flooding occurred in Birch's Creek catchment providing extensive overbank flows.

During the drought, Birch's Creek dried to a series of small pools putting pressure on fish and platypus populations. The drought caused reductions in the abundance of native fish along the creek. River Blackfish are now restricted to the lower 10 km of the creek, and fish and platypus populations are recovering. Threats such as introduced flora and fauna, land clearing, livestock access and grazing of river banks, have further degraded the condition of Birch's Creek (SKM 2005c).

5.2. Current Condition

Previous condition assessments

The Sustainable River Audit is conducted by the Murray-Darling Basin Authority as a standard condition assessment across the basin. It has been conducted for the periods 2004-2007 (MDBA, 2008) and 2008-2010 (Murray-Darling Basin Authority [MDBA] 2012). Birch's Creek is located in the slopes zone of the Loddon catchment for these ratings. This data have been used to compare ratings and trajectories for Birch's Creek (Table 12).

The slopes zone rates poorly for a number of criteria, although it needs to be recognised that this work was conducted during the latter part of the millennium drought, when many smaller creeks and rivers were either dry or reduced to unconnected pools. In Birch's Creek, an improvement in the score for Hydrology may be related to the improved rainfall/inflow conditions in 2010 compared to the earlier assessment.

Table 12: MDBA Sustainable River Audit indices ratings for the 'Slopes' zone of the Loddon River catchment.

Theme	SRA 1	SRA 2	Trajectory
Ecosystem health	Very poor	Very Poor	Same
Fish	Extremely poor	Extremely poor	Same
Macroinvertebrate condition	Poor	Moderate	Improved
Riverine Vegetation Theme	NA	Extremely poor	NA
Physical form	NA	Moderate	NA
Hydrology	Moderate - Good	Good	Improved

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[2]. Assessments were undertaken in 1999, 2004 and 2010 (DEPI 2013). 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. The results of the three assessments against the ISC reaches (aligned with FLOWS reaches) are shown in Table 13.

Table 13 shows that the majority of stream indices has declined, with an overall decline in condition.

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

Table 13: 1999, 2004 and 2011 Index of Stream Condition sub - indices scores and trajectories for Birch's Creek (ISC Reach 21, all e-flow reaches)

	Year of survey			Trajectory
	1999	2004	2010	
Sub-index				
Physical Form	6	2	6	0
Stream-side zone	3	2	4	+
Hydrology	7	1	3	-
Water Quality	NA	NA	NA	NA
Aquatic Life	8	NA	7	-
Total Score	26	8	22	-
Condition	M	VP	P	
Trajectory			-	

The Vegetation SRA score from the Millennium Drought and the three ISC Streamside Zone Scores indicate that vegetation along Birch's Creek has been in very poor condition and that the condition of the riparian zone increases progressively downstream.

In the upper reaches willow infestation is extensive, native vegetation has been cleared and pasture species provide the only groundcover. The clearing of the riparian zone as well as the spread of willows means that the opportunity for the natural replenishment of IWH is reduced. Willows also alter the instream habitat by blanketing substrate and undercut banks, thereby decreasing the amount of habitat available to aquatic biota. The dominance of willows in Birch's Creek is likely to hamper any restoration of the aquatic fauna of Birch's Creek, even if suitable flows are provided (SKM 2005c). Some willow removal works have been undertaken along Birch's Creek in the time since the previous FLOWS study was completed, but further work is still required. For example, 20km of willow control in Birch's Creek has been identified in the works program identified in the North Central Waterway Strategy (North Central CMA 2014a). Willows have been mapped in the catchment and the extent of willow infestation can be seen in Figure 10.

A reduction in flow may lead to a reduction in the amount of instream habitat available to fish and macroinvertebrates. It can also favour the presence and distribution of water tolerant weed species and reduce the recruitment of riparian species such as River Red Gum. Prolonged very low flow over the summer period for irrigation releases decrease the variability in the natural flow regime and reduce the amount of complex habitat available to macroinvertebrates and native fish (SKM 2005c).

Birch's Creek downstream of Newlyn Reservoir may also be affected by cold water releases (Ryan et al. 2001). Cold water releases can inhibit spawning of native fish, and if these releases of cold water are regular and persistent, breeding of native fish may not occur (SKM 2005c).

The fish populations of Birch's Creek are effectively isolated due to Newlyn Reservoir and Hepburn Lagoon at the top of the catchment and Tullaroop Reservoir at the bottom of the catchment. Lawrence Weir is a major barrier to fish movement in the middle reaches. Under low flow conditions, rock riffles and vehicle waterway crossings may also be barriers to fish movement (SKM 2005c).

Deterioration in the condition of Birch's Creek compared to 1999 can be considered a consequence of the extended drought (at its peak in 2004-5) and flooding. Recovery of fish, macroinvertebrate and in-stream vegetation has taking place since the height of the drought, showing a more positive trajectory in the ISC scores between 2004 and 2010.

Riparian vegetation

Agriculture, mining and urban development have drastically altered the distribution, condition and structure of riparian vegetation. A major change to the riparian vegetation since European settlement has been the introduction of a suite of exotic species (SKM 2005c). Exotic species now dominate the riparian zone and typically consist of Blackberry (*Rubus fruticosus*), willow (*Salix spp*) and hawthorn (*Crataegus monogyna*). Field observations indicate that all three reaches of Birch's Creek are dominated by exotic vegetation and there is evidence of exotic regeneration throughout.

Figure 10: Mapped area of willows in the Birch's Creek riparian zone and areas of willow removal

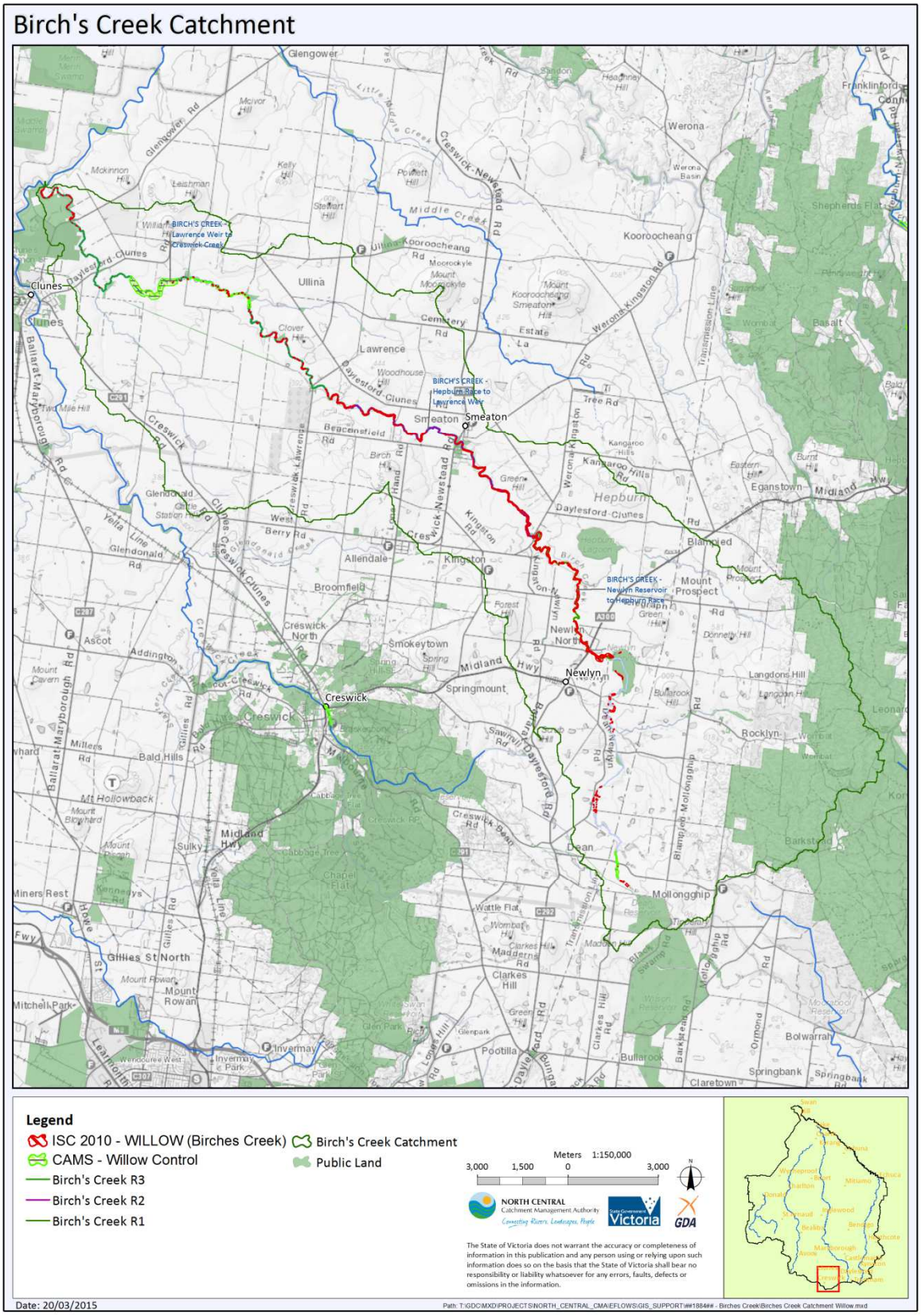


Figure 10 shows the extent of willows in the riparian zone as well as where along the creek willow removal has taken place. From this map it is clear that willows are a significant problem in the creek

and are particularly dense upstream of Smeaton. Willow rootmats invade shallow patches of the waterway by blocking spaces in between rocks leading to a loss of valuable habitat for many invertebrates and small fish (SKM 2005c). They also interfere with flows, forcing water to seek alternative flow paths resulting in channel bifurcation and erosion (SKM 2005c). The ability of willows to propagate from fragments is an ongoing threat to ecological values in the creek.

Downstream of Smeaton, willows are less prolific. However low vegetation coverage means that the channel is less shaded and there is an increase in biofilms and algae. Fewer trees also mean that there are lower inputs of large wood and organic matter. Instream woody habitat is essential for macroinvertebrates and fish (SKM 2005c).

Fish

Exotic species include tench (*Tinca tinca*), rainbow trout (*Oncorhynchus mykiss*) and eastern gambusia (*Gambusia holbrooki*). Brown trout were not found in 2014 and only small numbers of rainbow trout were caught. Tench were common downstream of Tourello Estate (Reach 3) while neither redfin nor carp were caught in the 2014 survey (McGuckin 2015).

Habitat

Habitat quality in Birch's Creek is variable along its length. Reaches 1 and 2 have poor instream habitat, with only small sections of large wood and shading. Riparian vegetation is in poor condition along much of the creek's length, with willows dominant. A lack of instream woody habitat is evident along the creek, partially due to the lack of mature eucalypts that drop limbs into the creek (Cook, D, 2015, personal communication, [Consultant, Rakali Ecological Consultants], February).

In 2001 habitat reinstatement works were undertaken in a section of the creek at Nelson's Bridge (crossing of the Daylesford-Clunes Road). Instream woody habitat (IWH) was reinstated and breeding tubes for River Blackfish were introduced. Plate 1 and Plate 3 show the condition of the creek at the reinstatement site immediately after works in 2001 and again in 2014.

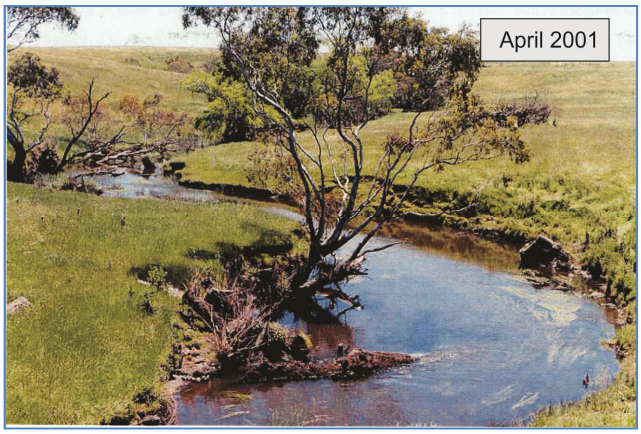


Plate 2: Nelson's Bridge looking downstream, April 2001

Plate 3: Nelson's Bridge looking downstream, November 2014

Water quality

Water temperature and dissolved oxygen represent a threat to aquatic biota in Birch's Creek. Persistent low flow rates or periods of cease-to-flow can result in declining oxygen levels, particularly in pools that have not been flushed during the summer period (eg in Reach 3). This is a problem for native fish and macroinvertebrates that rely on dissolved oxygen for respiration. In the worst case, low dissolved oxygen can result in blackwater.

Cold water releases from Newlyn Reservoir may impact on metabolic rates and breeding cues for fish. There is currently little information as to the temperature of Newlyn releases or whether cold water persists for any distance downstream.

5.3. Condition Trajectory - Do nothing

Birch's Creek was significantly stressed during the Millennium Drought, with pools reducing in size and drying out, and fish and platypus populations decimated. The creek is now recovering.

Since the drought and subsequent floods in 2010-11, a gradual recolonisation of the creek by Blackfish and Platypus has occurred, but populations are now restricted mainly to the lower part of the creek (McGuckin 2015). Riparian vegetation remains in poor condition, being dominated by Willows, and this leads to erosion and channel bifurcation, minimal replenishment of IWH, and a reduction in habitat opportunities for fish and macroinvertebrates.

If environmental water is not delivered to Birch's Creek:

- There is a very real risk that without low flows and freshes the abundance and diversity of instream and fringing vegetation will significantly decline.
- The native fish population will decline due to:
    - Increased predation of young-of-year by introduced species as movement is limited to pools where small fish are more vulnerable to predation.
    - Potential loss of fish during periods of very low flow due to low dissolved oxygen levels in remnant pools.
- The platypus population will decline due to starvation, increased stress levels and predation, particularly if animals have to travel across dry land to access disconnected remnant pools (Grant & Bishop 1998).

6 Management Objectives

6.1 Management Goal

The long term management goal for the Birch's Creek 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, and seeks to address the condition and condition trajectory.

Birch's Creek long term management goals:

- To establish resilient breeding populations of Platypus and small to medium bodied native fish including River Blackfish and provide opportunities for these animals to disperse to Creswick and Tullaroop Creeks.
- To maintain and increase a diverse mosaic of in-stream, fringing and riparian native vegetation.

6.2 Ecological Objectives

The ecological objectives established under the Birch's Creek Environmental FLOWS assessments (SKM 2005b; SKM 2005c; SKM 2005d) have been reviewed by the EFTP.

The ecological objectives shown in Table 14 are to be achieved through the provision of environmental water over the next ten years.

Table 14: Ecological objectives for Birch's Creek

Objective	Justification
Primary Objectives	
P1: Increase abundance and diversity of native fish such as River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt.	Four small-bodied native fish species have been recorded in Birch's Creek – River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt. River Blackfish and Mountain Galaxias populations in Birch's Creek are of regional significance. The Millennium Drought caused reductions in the abundance of native fish along Birch's Creek. Recent surveys indicate that River Blackfish are restricted to the lower 10 km of Birch's Creek (Reach 3). None of these fish are migratory or require specific components of the flow regime to trigger spawning. However, their ability to move within a reach and between pool habitats is an important consideration in providing refuge and opportunity to access habitats during periods of low flow.
P2: Provide conditions that consistently support widespread successful breeding by Platypus to increase population resilience to future drought and floods and to provide surplus juveniles that can disperse to Creswick Creek and Tullaroop Creek.	Anecdotal reports indicate that Birch's Creek supported a breeding population of Platypus; numbers declined significantly during the Millennium Drought and the population is now considered to be in a recovery phase. The objective for Birch's Creek will be to return the population to its pre-drought density, especially in Reach 3, which is likely to function as an important drought refuge for aquatic fauna.

Objective	Justification
Secondary Objectives	
S1: Maintain and increase overall abundance, diversity and productivity of macroinvertebrates and macroinvertebrate functional feeding groups to drive productive and dynamic food webs.	Macroinvertebrates are a critically important component of the food web. They make 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. Birch's Creek from Newyln Reservoir to Hepburn Race (Reach 1) is dominated by Willows and this is likely to have a detrimental influence on macroinvertebrates. Willow removal and habitat improvement will need to be addressed to assist achieving the ecological objectives. The section of Birch's Creek downstream from Hepburn Race (Reach 2 and 3) generally features a good variety of macroinvertebrate habitats and therefore the objective will be to maintain the macroinvertebrate community.
S2: Provide habitat and flow conditions that will allow River Blackfish to re-establish in Reaches 1 & 2.	River Blackfish prior to the later stages of the Millennium Drought were recorded throughout Birch's Creek. Their current distribution is now limited to Reach 3. River Blackfish have a very low dispersal capability and translocation will likely be required to re-establish populations in the upper reaches of Birch's Creek (Reach 1 and 2). In addition to management of flows, additional complementary management actions are needed to improve habitat conditions (i.e. resnagging, willow removal and riparian restoration).
S3: Maintain water quality that is able to support aquatic biota and ecological processes. Specifically: • Limit nutrient concentrations to prevent excessive algal growth and blooms. • Maintain dissolved oxygen levels above 2 mg/L in dry periods. • Prevent water temperature declining below 16^0C during late Spring/Early Summer.	Minimum flows are required during low flow periods to prevent water quality deteriorating to critical levels for fish and macroinvertebrates. Birch's Creek downstream of Newlyn Reservoir may be affected by cold water releases; however there are no temperature gauges downstream of the reservoir. Temperatures need to be at least 16^0C during late Spring/Early Summer to stimulate spawning of River Blackfish.
S4: Maintain (Reach 3) and improve (Reaches 1 & 2) diversity and abundance of instream aquatics such as *Triglochin procerum, Myriophyllum verrucosum, Potamogeton crispus, P. ochreatus* and *Vallisneria americana*.	Instream vegetation is an important component of the stream ecosystem and provides habitat, sediment stability and support of foodwebs Diversity and abundance of native instream plants is high in the lower section (Reach 3), but is less diverse at sites in the upper section (Reach 1 and 2), which also tend to be dominated by exotic species (see below).
S5: Reduce dominance of exotic instream aquatics such as Elodea (especially in Reaches 1 and 2)	Exotic instream aquatics compete with native species and can result in dominance. Apart from physically removing exotic aquatics, higher flows will function as disturbance events and will assist in removal of exotics and provide opportunities for an increase in the abundance and diversity of native species.

S6: Maintain and improve abundance and diversity of emergent fringing vegetation such as *Bolboschoenus medianus* spp., *Phragmites australis* and *Typha domingensis* on benches and edges of channel, but limit their encroachment into the middle of the channel.	Emergent fringing vegetation is an important component of the stream ecosystem and provides habitat, bank stability and support of foodwebs. Diverse fringing plants are common in the lower section (Reach 3), but are less abundant in the upper section (Reach 1 and 2).
S7: Maintain (Reach 3) and restore (Reaches 1 & 2) adult riparian woody vegetation (e.g. Swamp Gum, Manna Gum, River Red Gum) and facilitate recruitment.	The two EVCs along Birch's Creek are EVC 83 'Swampy Riparian Woodland' (Reach 1 and 2) and EVC 68 'Creekline Grassy Woodland' (Reach 3), which have a canopy layer dominated by Manna Gums and Swamp Gums (Reach 1 and 2), River Red Gums (Reach 3) and a floristically diverse understorey. Manna Gum, Swamp Gum and River Red Gum provide carbon to fuel foodwebs, shade, instream woody habitat to the river, and provide habitat for fauna. The riparian zone is variously affected by willows and grazing by livestock. In areas where both of these are controlled, the riparian zone has a good mix of overstorey trees, shrubs and native grasses, and some weeds. At grazed sites, the shrub and understorey layers are more degraded.

6.3 Birch's Creek 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 Birch's Creek 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 in Table 15 as two seasons (summer/autumn and winter/spring) in line with the FLOWS method (DEPI 2013). 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.

6.1 Ten year water regime

Environmental flow components for Birch's Creek flows are described as annual, meaning that they should be delivered every year. The only way of achieving this outcome is by spill from Newlyn Reservoir. This is most likely to occur in winter-spring.

Table 15: Annual flow recommendations (Jacobs, 2015)

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Cease-to-flow	Not recommended					
Summer/Autumn low flow	**Reach 1:** 3 ML/Day **Reach 2:** 2-5 ML/Day **Reach 3:** 4-8 ML/Day	6 months Dec-May	Annual: Vary the magnitude of flow within the prescribed range throughout Dec-May to match the natural flow regime.	**Reach 1:** Target average low flow of 3 ML/Day in wet/average and dry years **Reach 2:** Target average low flow of 5 ML/Day in wet/average and 2-3 ML/Day in dry years **Reach 3:** Target average low flow of 8 ML/Day in wet/average and 4 ML/Day in dry years	P1, P2, S1, S2, S3, S4, S6	This flow will provide a minimum of 0.1 m flow depth in riffles for macroinvertebrates and 1 m flow depth in pools for fish. It will also expose large areas of the streambed, which serves as an important function for nutrient processing by allowing terrestrial organic matter to accumulate on the exposed channel.
Summer/Autumn fresh	**Reach 1:** 10 ML/Day **Reach 2:** 15 ML/Day **Reach 3:** 27 ML/Day	3 days	Annual: 1 to 4 per season between December and March.	Target 4 freshes in wet/average years. Expect these will occur with spills from Newlyn Reservoir. In dry years provide 1 fresh. Couple this with monitoring of DO in pools to time freshes for occasion when DO falls below 2 mg/L.	P1, P2, S1, S2, S3, S4, S6	Summer freshes will result in an expansion in riffle/run areas and raise water depths by 0.05 to 0.1 m and temporarily enhance connectivity between pools, allowing some fish movement. The recommended flows produce average water velocities between 0.2 and 0.8 m/s, which should move particle sizes greater than 0.5 mm. This suggests that freshes would be suitable for maintaining substrate conditions and sufficient to refresh water quality in pools, particularly dissolved oxygen.
Winter/Spring low flow	**Reach 1:** 5-10 ML/Day **Reach 2:** 5-10 ML/Day **Reach 3:** 10-20 ML/Day	6 months Apr-Nov	Annual: Vary the magnitude of flow within the prescribed range throughout April and November to match the natural flow regime	**Reach 1:** Target average low flow of 10 ML/Day in wet/average and 5 ML/Day in dry years **Reach 2:** Target average low flow of 10 ML/Day in wet/average and 5 ML/Day in dry years **Reach 3:** Target average low flow of 20 ML/Day in wet/average and 10 ML/Day in dry years	P1, P2, S1, S2, S3, S4, S6, S7	A sustained winter low flow will suppress encroaching vegetation that has been able to colonise the lower channel zone during summer/autumn low flows while providing ideal conditions for aquatic vegetation, particularly in mid to late Spring (October/November) when many species are entering their growing phase. These flows will also provide more habitat for fish, macroinvertebrates, frogs, platypus and water rats because more habitat features are inundated.

Flow Component	Magnitude	Duration	Frequency and timing	Condition tolerances	Ecological Objectives	How the Flow component supports the ecological objectives
Winter fresh	**Reach 1:** 30 ML/Day **Reach 2:** 30 ML/Day **Reach 3:** 65 ML/Day	5 days in wet/average years and 3 days in dry years	Annual: 1 to 4 per season between June and November	Target 4 freshes in wet/average years and at least 1 fresh in dry years. In dry year if fresh does not occur, deliver by October/November to provide opportunity for breeding of frogs	P1,P2, S1, S2, S3, S4, S6, S7	Winter freshes will provide moisture and sediment to bank and bench vegetation. Organic cycling within the stream will also be facilitated by moving organic material (both dissolved and leaves and twigs) from the benches and into the stream. Benches and smaller channels will also be inundated providing more habitat and refuges for small fish. Freshes in October/November may also provide opportunities for breeding of frogs. A fresh prior to egg-laying (ideally in early August) encourages female Platypus 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.
Winter high flow	**Reach 1:** 160 ML/Day **Reach 2:** 275 ML/Day **Reach 3:** 200 ML/Day	3 days in wet/average years	Annual: 3 per season in between June and November.	Target 3 high flows in wet/average years. In dry year would not expect these to occur.	P1,P2, S1, S2, S3, S4, S5, S6, S7	It is expected that high flows will be delivered during wet/average years when Newlyn Reservoir spills. High flows will provide more depth in pools and over benches, provide lateral connectivity between the stream and high flow channels. Winter high flows may also assist in removing exotic instream vegetation such as Elodea. The inundation of these features will provide additional habitat for fish, macroinvertebrates, frogs, platypus and water rats. Carbon cycling within the stream will also be facilitated by the movement of litter from the benches.
Bankfull flow	**Reach 1 and 2:** not recommended **Reach 3:** 1300 ML/Day	1 Day in wet/average years	Annual: 1 per season between November and June	Target 1 bankfull flow in wet/average years. In dry year would not expect these to occur.	S5, S7	A bankfull flow is recommended for Reach 3. The principal function of this flow is as an ecosystem disturbance. This flow fills the channel, inundating benches, disturbing riparian vegetation and transporting sediment. These flows will also assist in removal of instream exotic aquatics. This flow will also reach the top of the banks and assist in the regeneration of River Red Gum. Timing should ideally be from March to June to minimise possible adverse effects on Platypus and Water rat reproduction from August onwards.
Overbank flows	As natural					

6. 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) provides the basis for evaluating the level of risk (Table 16).

Table 16: Risk Matrix

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

The results from Birch's Creek risk assessment are presented in Table 17. 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 Birch's Creek System Seasonal Watering Proposal.

Table 17: 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								
1	Artificial instream structures (i.e Newyln Reservoir, Hepburn Lagoon, Lawrence Weir, smaller weirs and waterway crossings)	*Water Quality* Birch's Creek downstream of Newlyn Reservoir may be affected by cold water releases which could have a negative impact on fish populations, especially the recruitment of River Blackfish (SKM 2005c). Hepburn Lagoon has a long history of poor water quality, which could impact on water quality downstream in Birch's Creek.	P1 S3	Possible	Moderate		Measurements in Newyln Reservoir to determine if water is mixed or if seasonal stratification occurs. Continuous physiochemical monitoring in Reach 2 and 3. These management measures have not been costed, and funding would need to be secured to achieve these management measures.	
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. • movement by Platypus that are then exposed to higher risk of predation if forced to travel overland to move between reaches. • recolonisation between reaches when populations are affected by some sort of disturbance (O'Brien et al. 2006).	P1 P2	Possible	Moderate		Lawrence Weir will need to be updated to provide passage for fish and platypus. An investigation into small weirs and waterway crossings is recommended to assess whether these are a barrier and what options exist to improve fish passage. Funding will need to be secured to achieve these management measures.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
3	Stocking of exotic fish species (brown trout, rainbow trout)	Exotic species compete with native species for resources such as food and habitat and can restrict the distribution and abundance of native species (SKM 2005c). Not stocking these species would be a benefit to River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt, which are all preyed upon by brown trout and rainbow trout)	P2 S2	Probable	Moderate		Implement a ban on stocking of exotic fish species in Newlyn Reservoir (McGuckin 2015) Residual risk assumes that implementing a ban on stocking in Newlyn reservoir reduces numbers of exotic species in the creek and thus the risk of predation on native species	
4	Recreational fishing	Recreational fishing can reduce numbers of target species such as River Blackfish, which can be a problem if the river is reduced to pools, such as during a drought. 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.	P2 S2	Probable	Moderate		Implement a ban on the capture of River Blackfish from Birch's Creek until the population has recovered (McGuckin 2015). Residual risk assumes an effective ban on taking blackfish and population is adequate to recover and disperse. Likelihood reduces to possible and severity to minor	
5	Grazing pressures	Grazing by domesticated, feral and/or native herbivores (e.g. cattle, sheep, rabbits, kangaroos and wallabies) may be preventing 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.	S4 S6 S7	Probable	Major		Fencing and stock exclusion have demonstrable benefits to riparian vegetation. Fencing of riparian zone and provision of off-stream watering points are management actions listed in the North Central Waterway Strategy 2014-2022. Residual risk assumes that funding will be available to complete these management actions. The likelihood is possible and the scale of severity is reduced to minor	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
6	Introduced species - Willows	Willows are ubiquitous in the Birch's Creek system, and their presence has lead to a number of issues: • their dominance has led to decline in the abundance and diversity of native vegetation. • the channel is subject to channel bifuractions associated with thick willow mats • they alter instream habitat by blacketing substrate and undercut banks • they negatively impact on the distribution of Platypus foraging activity, due to difficulties experienced in obtaining prey concealed within the tough, fibrous root mats (Serena et. al. 2001).	P2 S1 S2 S4 S6 S7	Possible	Moderate		Stage removal of willows together with planting of native species and reintroduction of large wood is required to improve the quality of the riparian vegetation and instream habitat. Willow control works and habitat improvement works (e.g. instream woody habitat installation) are management actions listed in the North Central Waterway Strategy 2014-2022. Residual risk assumes that funding will be available to complete these management actions. The likelihood is possible and the scale of severity is reduced to minor.	
7	Introduced species – eg Foxes	Predation on Platypus and other aquatic fauna such as Water rats – aquatic fauna that can leave the water are vulnerable to predation when travelling through very shallow water or across dry land.	P2	Probable	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 unlikely.	
9	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.	P2	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. Residual risk is assessed assuming likelihood of burrows being flooded as unlikely.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
Threats related to the delivery of environmental water								
10	Winter/Spring fresh Winter high flow could inundate burrow entrance	Juvenile platypus could drown or be disconnected from their mother for too long and starve.	P2	Possible	Moderate		It is expected that high flows will be delivered during wet/average years when Newyln Reservoir spills and be preceded by a Winter Fresh in August. Delivery of a Winter Fresh in August will trigger female to select or construct nursery burrows higher in the river bank. Residual risk assumes implementation of management action.	
11	Buildup of leaf litter 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.	P1 P2 S1 S2	Improbable	Moderate		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. 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.	

	Threat	Outcome	Relevant objective	Likelihood	Severity	R	Management Measure	RR
12	Cease to flows result in stratification of pools and dissolved oxygen reduction from increased temperatures and in-situ organic matter decomposition	Blackwater event – A blackwater event could occur under circumstances where there is a long period of cease to flows. This could lead to stratification of pools and dissolved oxygen reduction from increased temperatures and in-situ organic matter decomposition.	P1 P2 S1 S2	Possible	Moderate		In dry years the target is to provide a continuous Summer/Autumn and Winter/Spring low flows. One Summer/Autumn fresh is also recommended to refresh water quality in pools, particularly dissolved oxygen. Monitoring of dissolved oxygen is recommended in pools to time freshes for occasions when dissolved oxygen falls below 2 mg/L. These management measures have not been costed, and funding would need to be secured to achieve these management measures. The residual risk remains moderate as no monitoring of dissolved oxygen in pools is in place. It is also possible that in very dry years, water is not available to deliver a Summer/Autumn fresh.	
13	Groundwater pumping decreases groundwater-surface water connectivity	Expected gains in Reaches 2 and 3 are not realised	M1 P1 S2 S1 P2 S4 S5	Possible	Moderate		Further monitoring and investigations are required to assess groundwater surface water interactions and potential impacts that pumping is having on connectivity.	

7. Environmental Water Delivery Infrastructure

7.1. Constraints

The following section outlines the constraints to delivering environmental water in Birch's Creek.

7.1.1. Infrastructure constraints

Environmental water in Birch's Creek is delivered via the outlet structure of Newlyn Reservoir. The outlet at Newlyn Reservoir is capable of delivering up to 55 ML/d (Watson, P, 2015, personal communication, [GMW Customer Service Officer Diversions West] February). This is inadequate for delivering flows such as winter freshes and other high flow components. For these flows to be delivered, the outlet structure requires an increase in capacity.

There is no flow measurement structure in Reach 3, the target environmental flow reach. GMW has stated that it does not need measurement in the reach and are not favourable to installing one. This means that there is no means of accurately determining the flow rate in reach 3, which has implications for compliance with the Bulk Entitlement and monitoring environmental flows.

During the fish survey (McGuckin, 2015) it was noted that there was an instream barrier at the Tourello Estate property in Reach 3. It is believed that this is an illegal stream crossing, and has the potential to hinder fish dispersal.

Lawrence Weir also presents a barrier to fish. While this structure is no longer used for water regulation, there are heritage issues that need to be resolved if the structure is to be removed.

7.1.2. Operational constraints

The environmental entitlement of 100 ML can only be delivered from Newlyn reservoir at a maximum rate of 55 ML/day. If water could be delivered via Hepburn Lagoon/Hepburn Race, losses due to stock and domestic extractions would be lower.

The environmental entitlement for Birch's Creek is relatively small and readily spills, so there are limitations on how the entitlement can be used. In addition, irrigation does not provide much benefit to Reach 3 as this is used in reaches 1 and 2. Large volume flow components, such as winter fresh and high flows, cannot be delivered from the environmental entitlement, and natural, spill or pre-release flows are relied on to deliver these components.

7.2. Infrastructure recommendations

The following recommendations are made with regard to infrastructure requirements:

- Install measurement device in reach 3. There is currently no compliance point in reach 3
- Remove instream barrier at Tourello Estate to allow fish passage
- Investigate feasibility of removing Lawrence Weir

8. Complementary actions

Implementation of the watering regime for Birch's Creek will generate benefits to the environmental values of the creek. Some objectives require complementary actions to be realised. These are directly related to the risk section, i.e. risk of not achieving objectives Table 18. The North Central Waterway Strategy (North Central CMA 2014a) identifies many of these activities as priorities for investment over the lifetime of the strategy.

Table 18: Complementary actions to enhance the outcomes of environmental water

Activity	Rationale
Willow management and riparian restoration	Willows exist throughout the Birch's Creek and transform the ecology of the system (e.g. simplify habitat, impact on instream vegetation and nutrient availability). Staged removal of willows together with planting of native species is required to improve the quality of the riparian vegetation and improve the structure and diversity of native vegetation in the riparian zone.
Habitat reinstatement for fish and macroinvertebrates	Large wood provides important habitat for macroinvertebrate communities, small to medium bodied native fish, platypus and water rats. Selected resnagging is recommended to improve instream habitat conditions. This needs to be undertaken in conjunction with a broader program aimed at removing willows and restoring the riparian vegetation along Birch's Creek. A restored riparian zone will provide for future recruitment of large wood into the stream. Previous resnagging in Reach 3 shows the benefits of this action. It is likely that this resnagging assisted in helping fish and platypus to find refuge in this reach during the Millennium Drought.
Assessment of Fish Barriers	Lawrence Weir provides a significant barrier to the movement of native fish in the upper reaches of Birch's Creek. Smaller weirs and waterway crossings are also present which may impact on fish movement. Further investigations are recommended to assess whether these are a barrier and what options exist to improve fish passage. The ability for River Blackfish to recolonise upstream reaches from their core population in Reach 3 is severely restricted by the presence of these instream barriers.
Maintain and increase River Blackfish populations	Blackfish dispersal is low, so translocation will likely be required to re-establish populations of River Blackfish in the upper reaches (Reach 1 and 2). A translocation plan for Blackfish should be developed but only where there is no evidence of natural dispersal after 5 years of this plan. Additional complementary management actions are needed to improve habitat conditions for River Blackfish (i.e. resnagging, willow removal, improved fish passage and riparian restoration).
Fencing & off-stream watering points	Livestock have direct access to Birch's Creek. This damages native vegetation and inhibits the recruitment of native vegetation including River Red Gum trees.
Improve planning for environmental water management	The Environmental Entitlement was gazetted in 2009 with negotiations taking place during the Millennium drought. The small entitlement for the environment limits the CMA's ability to implement recommended watering actions, meaning there is a high risk that some ecological objectives are unachievable. A re-negotiation of the Bulk/Environmental Entitlement may lead to additional water being made available to the environment to improve the outcomes from environmental watering in the creek.

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 Birch's Creek.

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

9.1. 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 Birch's Creek EWMP is shown in Table 19.

Table 19: Required long-term condition monitoring for the Birch's Creek.

Objective	Method	When
Increase abundance and diversity of opportunistic native fish such as River Blackfish, Mountain Galaxias, Flatheaded Gudgeon and Australian Smelt.	Targeted fish surveys using electrofishing, small mesh gauge fyke nets and unbaited traps. Replicate sampling efforts and distribution of sites previously surveyed. For short lived fish species, repeat survey should be completed with the objective of assessing changes in the proportion of sampling sites in each reach where they are caught. For long lived species, such as River Blackfish repeat survey should assess the number of sites where they are caught, their size class, distribution and relative abundance. Repeat assessment of size distribution will assist in determining if there are recruitment cohorts.	Every 2-3 years preferred, maximum 5 years, in November
Provide conditions that consistently support widespread successful breeding by Platypus to increase population resilience to future drought and floods and to provide surplus juveniles that can disperse to Creswick Creek and Tullaroop Creek.	Incidental Platypus captures as bycatch in fish surveys should be recorded (including the sex of captured animals). Conducting an annual survey to record where local landholders have seen Platypus in the previous 12 months would provide a very cost-effective method to help track population recovery.	Every 2-3 years preferred, maximum 5 years, in November.
Maintain frogs as a component of the system and accept that numbers will fluctuate between drought and non-drought conditions	Frog surveys to inform the contemporary composition and abundance of the frog fauna. Undertaken at the same time with fish surveys.	Every 2-3 years preferred, maximum 5 years, in November.
Maintain water quality that is able to support aquatic biota and ecological processes. Specifically: • limit nutrient concentrations to prevent excessive algal growth and blooms. • Maintain dissolved oxygen levels above 2 mg/L in dry periods. • Prevent water temperature declining below 16^0C during late Spring/Early Summer	Regular monitoring of dissolved oxygen and temperature using temporary loggers at FLOWS assessment sites.	Continuous
	Measurements in Newlyn Reservoir to determine if water is mixed or seasonal stratification occurs	Continuous
	Continuous physiochemical monitoring in Reach 3, close to FLOWS Assessment Site	Continuous
	Monitoring of boreholes in Reach 1 and 2 to assess if groundwater levels close to creek are changing in response to groundwater pumping and implications for groundwater surface water connectivity	Continuous

9.2. 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. platypus).

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.

Table 20: Required intervention monitoring for the implementation of the Birch's Creek EWMP.

Objective	Monitoring question	When	Event	Method
Maintain and improve diversity and abundance of instream aquatics such as Triglochin, Myriophyllum and Potamogeton.	Is instream vegetation responding to flows?	Year 1 and 2[3]	Summer/Autumn fresh	Vegetation surveys
Maintain and improve abundance and diversity of emergent fringing vegetation such as Bulboschoenus spp., Phragmites on benches and edges of channel, but limit their encroachment into the middle of the channel.	Is emergent vegetation responding to flows?	Year 1 and 2[4]	Summer/Autumn fresh	Vegetation surveys
Reduce dominance of exotic instream aquatics such as Elodea (especially in Reaches 1 and 2)	Are exotic instream aquatics removed by Winter/Spring High Flows and Bankfull Flows	Year 3 and 4	Winter/Spring High Flows Bankfull Flows	Photopoints
Maintain adult riparian woody vegetation (e.g. Manna Gum, River Red Gum) and facilitate recruitment	Are River Red Gum trees recruiting after a bankfull flow event	Year 3 and 4[5]	Bankfull Flows	Photopoints
Risk				
Drowning Platypus burrows during Winter/spring high flows and freshes	Is the August winter fresh encouraging Platypus to place their breeding burrows higher in the bank?	Whenever winter/spring high flow/fresh is intended	After Winter Fresh in August	Survey height of burrow entrances relative to mAHD
Blackwater risk of managed summer events?	Are dissolved oxygen levels maintained at acceptable concentrations during Summer/Autumn fresh?	Each year	Summer/Autumn Fresh	Continuous dissolved oxygen monitoring

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

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

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

10.Knowledge Gaps and Recommendations

Birch's Creek 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 21.

Table 21: Knowledge gaps and recommendations

Knowledge Gap	Objective/ Risk	Recommendation	Who	Priority
Objectives				
Groundwater – surface water interactions		Investigate the extent of the contribution from groundwater to surface water flows	NCCMA/GMW	1
Fish passage	P1, S1	Investigate the feasibility of removing Lawrence Weir and the illegal river croissing at Tourello Estate in the context of fish passage	GMW/Consultant	2
Frogs		Determine frog populations in Birch's Creek, in particular populations of Growling Grass Frog	Consultant	2
Risks				
Cold water pollution	S3	Determine if Birch's Creek is impacted by cold water releases from Newlyn	NCCMA/GMW	2

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Appendix 1: Birch's Creek EWMP Consultation

Table A1: Agency staff consulted during EWMP development

Name	Organisation	Expertise/Role
Agency Staff		
Andrea Keleher	Department of Environment Land, Water and Planning	Program Manager - Healthy Landscapes Environment and Natural Resources
Peter Watson	Goulburn Murray Water	Customer Service Officer, Diversions West
Andrew Shields	Goulburn Murray Water	Manager River Operations
Louissa Rogers	North Central CMA	Project Manager
John Frdelja	Central Highlands Water	Acting Manager, Water Resources
Mark Toomey	Victorioan Environmental Water Holder	Environmental Water Coordinator

Table A2: FLOWS review workshop (10 February 2015)

Name	Organisation	Expertise/Role
Dr Andrew Sharpe	Jacobs SKM	Aquatic Ecologist
Dr Simon Treadwell	Jacobs SKM	Aquatic Ecologist
Dr Peter Sandercock	Jacobs SKM	Geomorphologist
Dr Damian Cook	Rakali Ecological Consultants	Vegetation
Dr Melody Serena	Australian Platypus Conservancy	Platypus

Table A3: Birch's Creek EWAG membership

Name	Organisation
Community	
Norm Suckling	Landholder/irrigator
Ron Cosgrave	Landholder/ NRMC Portfolio group
Robert Wilson	Landholder
Richard Carter	Landholder/ NRMC Portfolio group
Stakeholders	
Kerry Webber	CEWH
Caitlin Davis	VEWH
Andrea Keleher	DELWP
Andrew Shields	GMW
Ed Thomas	GMW
Peter Watson	GMW
Peter Sandercock	SKM – Technical expertise

Appendix 2: Watering History

		Season								
		2005-06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013-14
Reach 1										
Summer - Autumn	Low Flow	No data available								
	Freshes									
Winter - Spring	Low Flow									
	Fresh									
	High Flow									
Reach 2										
Summer - Autumn	Low Flow									
	Freshes									
Winter - Spring	Low Flow									
	Fresh									
	High Flow									

Figure A1: Historic attainment of recommended environmental flows

Appendix 3: Species Lists

Table A4: Faunal species recorded at Birch's Creek

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Anas castanea	Chestnut Teal					15/07/2006
Anas gracilis	Grey Teal					15/07/2006
Anas rhynchotis	Australasian Shoveler		vu			15/07/2006
Anas spp.	Unidentified Ducks					18/10/1988
Anas superciliosa	Pacific Black Duck					15/07/2006
Anguilla australis	Short-finned Eel					26/05/1905
Anhinga novaehollandiae	Darter					28/02/1995
Anser anser	Domestic Goose					15/07/2006
Aythya australis	Hardhead		vu			15/07/2006
Biziura lobata	Musk Duck		vu			15/07/2006
Chenonetta jubata	Australian Wood Duck					15/07/2006
*Cherax destructor destructor**	Common Yabby					5/06/2002
Chroicocephalus novaehollandiae	Silver Gull					28/02/1995
Cygnus atratus	Black Swan					15/07/2006
Egretta novaehollandiae	White-faced Heron					15/07/2006
Fulica atra	Eurasian Coot					15/07/2006
*Gadopsis marmoratus**	River Blackfish					5/06/2002
Galaxias olidus#	Mountain Galaxias					5/06/2002
Gallinula tenebrosa	Dusky Moorhen					15/07/2006
Litoria raniformis	Growling Grass Frog	L	en	VU		22/11/2000
Macquaria ambigua	Golden Perch	X	nt			1/03/1995
Malacorhynchus membranaceus	Pink-eared Duck					15/07/2006

Microcarbo melanoleucos	Little Pied Cormorant					15/07/2006
ord. Anseriformes fam. Anatidae	Ducks, Geese, Swans					21/02/1991
ord. Phalacrocoraciformes fam. Phalacrocoracidae	Cormorant's					22/02/1992
ord. Podicipediformes fam. Podicipedidae	Grebes					14/02/1992
*Ornithorhynchus anatinus**	Platypus					2/09/1995
Oxyura australis	Blue-billed Duck	L	en			15/07/2006
Paratya australiensis	Freshwater Shrimp					5/06/2002
Pelecanus conspicillatus	Australian Pelican					15/07/2006
Perca fluviatilis	Redfin				Introduced	24/05/1988
Phalacrocorax carbo	Great Cormorant					13/12/1997
Phalacrocorax sulcirostris	Little Black Cormorant					15/07/2006
Phalacrocorax varius	Pied Cormorant		nt			24/02/1990
*Philypnodon grandiceps**	Flat-headed Gudgeon					3/06/2002
Platalea flavipes	Yellow-billed Spoonbill					24/02/1990
Platalea regia	Royal Spoonbill		nt			17/03/1989
Platelea sp.	Unidentified Spoonbill					5/02/1989
Podiceps cristatus	Great Crested Grebe					15/07/2006
Poliocephalus poliocephalus	Hoary-headed Grebe					15/07/2006
*Retropinna semoni**	Australian Smelt					3/06/2002
Rutilus rutilus	Roach				Introduced	3/06/2002
Salmo trutta	Brown Trout				Introduced	3/06/2002
Stictonetta naevosa	Freckled Duck	L	en			15/07/2006
subf. Galaxiinae gen. Galaxias	Galaxias					2/09/1977
Tachybaptus novaehollandiae	Australasian Grebe					15/07/2006
Tadorna tadornoides	Australian Shelduck					15/07/2006
Threskiornis molucca	Australian White Ibis					22/02/1992

Threskiornis spinicollis	Straw-necked Ibis					14/02/1992
Tiliqua scincoides	Common Blue-tongued Lizard					21/10/1991
Trichosurus vulpecula	Common Brushtail Possum					9/03/1987
Vanellus miles	Masked Lapwing					15/07/2006

*Species caught during 2014 Fish Survey (McGuckin 2015) (Table A6)

#Galaxias species have been re-classified. *Galaxias oliros* (Obscure Galaxias) is identified as the species present in Birch's Creek (also detected in 2014)

Table A5: Floral species recorded at Birch's Creek

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Acacia dealbata	Silver Wattle					1/01/1993
Acacia implexa	Lightwood					17/10/2001
Acacia melanoxylon	Blackwood					17/10/2001
Acaena echinata	Sheep's Burr					17/10/2001
Acaena novae-zelandiae	Bidgee-widgee					23/02/2000
Acetosella vulgaris	Sheep Sorrel				Introduced	17/10/2001
Achillea millefolium	Milfoil				Introduced	1/01/1993
Agrostis stolonifera	Creeping Bent				Introduced	1/02/2012
Alternanthera denticulata s.l.	Lesser Joyweed					23/02/2000
Amaranthus retroflexus	Red-root Amaranth				Introduced	1/01/1993
Amelichloa caudata	Espartillo				Introduced	1/02/2012
Anthoxanthum odoratum	Sweet Vernal-grass				Introduced	1/01/1993
Aphanes arvensis	Parsley Piert				Introduced	1/01/1993
Arctotheca calendula	Cape weed				Introduced	17/10/2001

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Asplenium flabellifolium	Necklace Fern					27/08/2000
Aster subulatus	Aster-weed				Introduced	1/02/2012
Austrostipa bigeniculata	Kneed Spear-grass					1/02/2012
Austrostipa stuposa	Quizzical Spear-grass					1/02/2012
Avena barbata	Bearded Oat				Introduced	1/02/2012
Avena fatua	Wild Oat				Introduced	17/10/2001
Avena sativa	Oat				Introduced	1/01/1993
Bolboschoenus caldwellii	Salt Club-sedge					1/02/2012
Bolboschoenus medianus	Marsh Club-sedge					23/02/2000
Borago officinalis	Borage				Introduced	1/01/1993
Briza minor	Lesser Quaking-grass				Introduced	1/01/1993
Bromus diandrus	Great Brome				Introduced	1/02/2012
Bromus hordeaceus subsp. hordeaceus	Soft Brome				Introduced	20/11/1997
Bromus madritensis	Madrid Brome				Introduced	1/01/1993
Bromus sterilis	Sterile Brome				Introduced	17/10/2001
Bursaria spinosa subsp. spinosa	Sweet Bursaria					17/10/2001
Callistemon sieberi	River Bottlebrush					27/08/2000
Carex appressa	Tall Sedge					27/08/2000
Carex divisa	Divided Sedge				Introduced	1/02/2012
Carex gaudichaudiana	Fen Sedge					23/02/2000
Carex inversa	Knob Sedge					23/02/2000
Cassinia aculeata	Common Cassinia					23/02/2000
Centaurea calcitrapa	Star Thistle				Introduced	22/10/1982
Cerastium glomeratum s.l.	Common Mouse-ear Chickweed				Introduced	1/01/1993

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Chamaecytisus palmensis	Tree Lucerne				Introduced	1/01/1993
Characeae spp.	Stonewort					20/11/1997
Chloris truncata	Windmill Grass					1/01/1993
Cicendia quadrangularis	Square Cicendia				Introduced	1/01/1993
Cirsium vulgare	Spear Thistle				Introduced	1/02/2012
Conium maculatum	Hemlock				Introduced	23/02/2000
Crassula closiana	Stalked Crassula					1/01/1993
Crassula helmsii	Swamp Crassula					23/02/2000
Crataegus monogyna	Hawthorn				Introduced	23/02/2000
Crepis setosa	Bristly Hawksbeard				Introduced	1/01/1993
Cycnogeton procerum (narrow floating leaf variant)	Common Water-ribbons					1/02/2012
Cycnogeton spp.	Water Ribbons					23/02/2000
Cynodon dactylon	Couch					1/02/2012
Cynoglossum suaveolens	Sweet Hound's-tongue					1/01/1993
Cyperus eragrostis	Drain Flat-sedge				Introduced	1/02/2012
Dactylis glomerata	Cocksfoot				Introduced	1/02/2012
Dianella revoluta s.l.	Black-anther Flax-lily					27/08/2000
Discaria pubescens	Australian Anchor Plant	L				17/10/2001
Dysphania pumilio	Clammy Goosefoot				Native but some stands may be alien	1/01/1993
Echium plantagineum	Paterson's Curse				Introduced	1/02/2012
Eleocharis acuta	Common Spike-sedge					1/02/2012
Elodea canadensis	Canadian Pondweed				Introduced	23/02/2000

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Elytrigia repens	English Couch				Introduced	1/02/2012
Epilobium billardierianum	Variable Willow-herb					23/02/2000
Epilobium billardierianum subsp. billardierianum	Smooth Willow-herb					23/02/2000
Epilobium billardierianum subsp. cinereum	Grey Willow-herb					1/01/1993
Epilobium hirtigerum	Hairy Willow-herb					1/02/2012
Epilobium pallidiflorum	Showy Willow-herb					1/01/1993
Epilobium spp.	Willow Herb					17/10/2001
Erodium botrys	Big Heron's-bill				Introduced	1/01/1993
Erodium cicutarium	Common Heron's-bill				Introduced	17/10/2001
Eucalyptus camaldulensis	River Red-gum	X				1/02/2012
Euchiton involucratus s.s.	Star Cudweed					20/11/1997
Festuca arundinacea	Tall Fescue				Introduced	1/01/1993
Fumaria spp.	Fumitory				Introduced	1/01/1993
Galium aparine	Cleavers				Introduced	1/01/1993
Genista monspessulana	Montpellier Broom				Introduced	1/01/1993
Geranium dissectum	Cut-leaf Crane's-bill				Introduced	17/10/2001
Geranium molle	Dove's Foot				Introduced	23/02/2000
Geranium retrorsum s.l.	Grassland Crane's-bill					1/01/1993
Geranium solanderi s.l.	Austral Crane's-bill					17/10/2001
Glyceria australis	Australian Sweet-grass					20/11/1997
Grevillea spp.	Grevillea					17/10/2001
Hedera helix	English Ivy				Introduced	1/01/1993
Hemarthria uncinata var. uncinata	Mat Grass					1/02/2012
Holcus lanatus	Yorkshire Fog				Introduced	1/02/2012

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Hordeum leporinum	Barley-grass				Introduced	17/10/2001
Hydrocotyle sibthorpioides	Shining Pennywort					20/11/1997
Hypochaeris radicata	Flatweed				Introduced	1/01/1993
Ilex aquifolium	English Holly				Introduced	1/01/1993
Isolepis cernua	Nodding Club-sedge					1/02/2012
Isolepis cernua var. cernua	Nodding Club-sedge					20/11/1997
Isolepis inundata	Swamp Club-sedge					20/11/1997
Juncus amabilis	Hollow Rush					23/02/2000
Juncus articulatus subsp. articulatus	Jointed Rush				Introduced	1/02/2012
Juncus bufonius	Toad Rush					1/01/1993
Juncus flavidus	Gold Rush					20/11/1997
Juncus microcephalus	Tiny-headed Rush				Introduced	23/02/2000
Juncus pallidus	Pale Rush					23/02/2000
Juncus pauciflorus	Loose-flower Rush					27/08/2000
Juncus subsecundus	Finger Rush					1/01/1993
Lachnagrostis filiformis s.l.	Common Blown-grass					20/11/1997
Lactuca serriola	Prickly Lettuce				Introduced	1/02/2012
Leontodon taraxacoides subsp. taraxacoides	Hairy Hawkbit				Introduced	1/02/2012
Leptospermum lanigerum	Woolly Tea-tree					27/08/2000
Lotus corniculatus	Bird's-foot Trefoil				Introduced	1/02/2012
Lycium ferocissimum	African Box-thorn				Introduced	17/10/2001
Lythrum salicaria	Purple Loosestrife					23/02/2000
Malva parviflora	Small-flower Mallow				Introduced	1/01/1993
Marrubium vulgare	Horehound				Introduced	1/01/1993
Medicago intertexta	Calvary Medic				Introduced	1/01/1993

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Medicago polymorpha	Burr Medic				Introduced	1/02/2012
Medicago truncatula	Barrel Medic				Introduced	1/01/1993
Melicytus dentatus s.l.	Tree Violet					17/10/2001
Mimulus moschatus	Musk Monkey-flower				Introduced	23/02/2000
Moenchia erecta	Erect Chickweed				Introduced	1/01/1993
Myosotis sylvatica	Wood Forget-me-not				Introduced	1/01/1993
Myriophyllum verrucosum	Red Water-milfoil					1/02/2012
Nassella neesiana	Chilean Needle-grass				Introduced	21/02/2002
Oxalis perennans	Grassland Wood-sorrel					1/01/1993
Oxalis pes-caprae	Soursob				Introduced	1/01/1993
Parentucellia latifolia	Red Bartsia				Introduced	1/01/1993
Paspalum dilatatum	Paspalum				Introduced	1/02/2012
Paspalum distichum	Water Couch				Introduced	1/02/2012
Pelargonium australe	Austral Stork's-bill					27/08/2000
Pelargonium rodneyanum	Magenta Stork's-bill					17/10/2001
Persicaria decipiens	Slender Knotweed					23/02/2000
Persicaria prostrata	Creeping Knotweed					1/01/1993
Phalaris aquatica	Toowoomba Canary-grass				Introduced	1/02/2012
Phalaris minor	Lesser Canary-grass				Introduced	1/01/1993
Phragmites australis	Common Reed					1/02/2012
Plantago coronopus	Buck's-horn Plantain				Introduced	1/01/1993
Plantago lanceolata	Ribwort				Introduced	17/10/2001
Plantago varia	Variable Plantain					1/01/1993
Pleurosorus rutifolius s.l.	Blanket Fern					1/01/1993
Poa annua	Annual Meadow-grass				Introduced	1/01/1993

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Poa bulbosa	Bulbous Meadow-grass				Introduced	1/01/1993
Poa labillardierei	Common Tussock-grass					17/10/2001
Polygonum plebeium	Small Knotweed					1/01/1993
Polypogon monspeliensis	Annual Beard-grass				Introduced	1/02/2012
Populus alba	White Poplar				Introduced	23/02/2000
Potamogeton crispus	Curly Pondweed					1/02/2012
Potamogeton ochreatus	Blunt Pondweed					20/11/1997
Potamogeton tricarinatus s.l.	Floating Pondweed					23/02/2000
Prunella vulgaris	Self-heal				Introduced	23/02/2000
Quercus robur	English Oak				Introduced	23/02/2000
Ranunculus muricatus	Sharp Buttercup				Introduced	1/01/1993
Raphanus raphanistrum	Wild Radish				Introduced	1/01/1993
Romulea rosea	Onion Grass				Introduced	1/01/1993
Rorippa laciniata	Jagged Bitter-cress					1/01/1993
Rosa rubiginosa	Sweet Briar				Introduced	17/10/2001
Rubus anglocandicans	Common Blackberry				Introduced	20/11/1997
Rubus fruticosus spp. agg.	Blackberry				Introduced	23/02/2000
Rumex bidens	Mud Dock					20/11/1997
Rumex crispus	Curled Dock				Introduced	1/02/2012
Rumex spp.	Dock					17/10/2001
Rytidosperma setaceum	Bristly Wallaby-grass					1/02/2012
Salix alba	White Willow				Introduced	17/10/2001
Salix cinerea	Grey Sallow				Introduced	1/02/2012
Salix X rubens	Basket Willow				Introduced	1/01/1993
Salvia verbenaca	Wild Sage				Introduced	1/02/2012

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Salvia verbenaca var. verbenaca	Wild Sage				Introduced	17/10/2001
Schoenoplectus pungens	Sharp Club-sedge					1/02/2012
Schoenoplectus tabernaemontani	River Club-sedge					20/11/1997
Schoenus apogon	Common Bog-sedge					1/02/2012
Scolymus hispanicus	Golden Thistle				Introduced	25/03/1997
Sedum caespitosum	Tiny Stonecrop				Introduced	1/01/1993
Silybum marianum	Variegated Thistle				Introduced	1/02/2012
Solanum nigrum s.l.	Black Nightshade				Introduced	1/02/2012
Sonchus oleraceus	Common Sow-thistle				Introduced	1/02/2012
Stachys arvensis	Stagger Weed				Introduced	1/01/1993
Stellaria media	Chickweed				Introduced	1/01/1993
Taraxacum Sect. Hamata	Garden Dandelion				Introduced	1/01/1993
Themeda triandra	Kangaroo Grass					1/01/1993
Tragopogon porrifolius subsp. porrifolius	Salsify				Introduced	17/10/2001
Trifolium campestre var. campestre	Hop Clover				Introduced	17/10/2001
Trifolium dubium	Suckling Clover				Introduced	17/10/2001
Trifolium repens var. repens	White Clover				Introduced	23/02/2000
Trifolium subterraneum	Subterranean Clover				Introduced	17/10/2001
Triglochin striata	Streaked Arrowgrass					1/02/2012
Typha domingensis	Narrow-leaf Cumbungi					20/11/1997
Ulex europaeus	Gorse				Introduced	1/02/2012
Vallisneria australis	Eel Grass					20/11/1997
Veronica persica	Persian Speedwell				Introduced	1/01/1993
Vicia hirsuta	Tiny Vetch				Introduced	1/01/1993
Vicia sativa	Common Vetch				Introduced	17/10/2001

Scientific Name	Common Name	FFG	VICADV	EPBC	Origin	Last record
Vicia sativa subsp. nigra	Narrow-leaf Vetch				Introduced	1/01/1993
Vinca major	Blue Periwinkle				Introduced	1/01/1993
Vulpia bromoides	Squirrel-tail Fescue				Introduced	1/02/2012

Table A6: Fish species recorded at Birch's Creek by McGuckin (2015)

Common Name	Scientific name	Total count
Native		
River blackfish	*Gadopsis marmoratus*	42
Obscure galaxias	*Galaxias oliros*	567
Flat headed gudgeon	*Philypnodon grandiceps*	44
Australian smelt	*Retropinna semoni*	135
Exotic		
Eastern gambusia	*Gambusia holbrooki*	134
Rainbow trout	*Oncorhynchus mykiss*	9
Tench	*Tinca tinca*	32