# Boundary Creek aquatic ecology investigation

Barwon Water

FINAL

17 March 2017

# Boundary Creek aquatic ecology investigation

| | |
|---|---|
| Project No: | IS017900.2 |
| Document Title: | Boundary Creek aquatic ecology investigation |
| Revision: | FINAL |
| Date: | 17 March 2017 |
| Client Name: | Barwon Water |
| Client No: | 000695 |
| Project Manager: | Louise Lennon |
| Author: | Joshua Hale |

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com

## Contents

# An important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to identify the aquatic values of the Boundary Creek and to determine the flow requirements of these values, in accordance with the scope of services set out in the contract between Jacobs and Barwon Water. That scope of services, as described in this report, was developed with Barwon Water.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by Barwon Water and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Barwon Water, members of the public and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Barwon Water, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Barwon Water. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

# Executive Summary

Barwon Water uses the Barwon Downs Borefield to augment Geelong's potable supplies during dry times. The groundwater extraction licence for Barwon Downs is due for renewal in 2019 and to help prepare for this, Jacobs has undertaken a range studies under the Technical Works Monitoring Program. This study represents, to our knowledge, the first detailed, integrated assessment of the aquatic values of Boundary Creek.

**Objectives and approach**

The objective of this study is to estimate the aquatic flora and fauna species and communities currently supported by Boundary Creek and at a broad scale (i.e. qualitatively), discuss the elements of the creek's flow regime that these values require.

To do this, a combination of direct survey and indirect assessment techniques were used. Macroinvertebrates were surveyed directly while the vegetation, fish, frogs and Platypus species and communities currently supported by Boundary Creek were estimated by considering historic records, other literature and the habitat present at the creek.

**Limitations of the study**

This study is preliminary in nature and the aim is to understand at a high level the ecological condition of Boundary Creek and the ecological values the creeks currently supports. Consequently this study has several limitations. For example, this study has focused on surface water hydrology in Boundary Creek and not explored in detail the groundwater-surface water interactions. A comprehensive understanding of the complex interactions between surface and groundwater in the catchment is critical to understanding the creek more broadly, however, it is not necessary for this study, the focus of which is an identification of the aquatic ecosystems supported by the creek. A detailed discussion of the groundwater-surface water interactions in the catchment is provided in the Barwon Downs Integration Report (Jacobs 2016).

The study has also not considered in detail the condition or ecological values supported by Big Swamp (a large peat swamp located near the middle of the catchment). The groundwater-surface water interactions, soil composition and chemistry and management history of Big Swamp is extremely complex but is critical to understanding the ecology of the lower sections of Boundary Creek. The purpose of this study is to assess the aquatic ecosystems of Boundary Creek and therefore it is beyond the scope to complete a comprehensive investigation of Big Swamp. Big Swamp will be the focus of a future, stand-alone study.

This study did also not involve direct survey for fish, frogs, Platypus and vegetation. This is because as the creek is relatively small, it is likely to support only low numbers of aquatic animals and therefore field surveys may not record many of the expected taxa. As the failure to record a certain species during a field survey does not mean we can confidently infer that it is not present, even intensive field surveys may yield uncertain results. The presence of the ecological values in Boundary Creek has therefore been inferred using the indirect techniques described above (i.e. historic records, other literature and assessments of the habitat present at the creek).

**Description of the catchment and important changes since European settlement**

Broadly speaking, the Boundary Creek catchment can be broken up into three reaches. The upper most reach (Reach 1) retains much of its natural form and the creek flows through an area of intact remnant riparian vegetation with a mixture of broad channel covered in grasses and reeds and sections of more defined channel with fringing and aquatic vegetation and some woody snags. Large parts of the middle of the catchment (Reach 2) have been cleared of native vegetation to support agriculture. Reach 2 is also the location of McDonalds Dam, a large on stream storage. Downstream of McDonalds Dam the creek flows through a broad marshy area, with the waterlogged soils (or 'dampland') supporting a floristically complex community and Big Swamp, a large peat swamp. Downstream of Big Swamp (Reach 3), the creek has been heavily modified to support agricultural activity.

A range of impacts have occurred in the Boundary Creek catchment that may have altered the hydrology. These include:

- Channelisation of the creek (especially in the lower reaches).
- The construction and operation of McDonalds Dam.
- Diverters (including private diverters and farm dams).
- Groundwater extraction from the Barwon Downs borefield.
- The Millennium Drought.
- The drying and acidification of Big Swamp.
- A supplementary flow released by Barwon Water which was designed to compensate for any potential impacts of groundwater extraction.

**Hydrology of Boundary Creek**

The surface water hydrology of Boundary Creek was also reviewed to support the estimate of current ecological values. The following features of the hydrology of Boundary Creek were identified as important for estimating the important ecological values of the creek;

- The supplementary flow makes up a significant portion of the flow in the summer months upstream of Big Swamp (Reaches 1 and 2).
- The flow data available for Boundary Creek (measured at Yeodene from 1986 to 2015) indicates that the creek in this area rarely stopped flowing at any time of year prior to 1999, but since then, flow has stopped in Reach 3 (downstream of Big Swamp) for long periods in summer and autumn in most years.
- The water in Reach 3 of Boundary Creek is highly acidic.

**Ecological values currently supported by Boundary Creek**

The study estimated the range of aquatic values currently supported by Boundary Creek. The species and communities with either a 'High' or 'Medium' probability of being supported by the creek are summarised below.

In Reach 1, the majority of the riparian zone is made up of an overstorey of *Eucalyptus* and *Acacia* is supported, with a ground layer of weeds and occasional sedges and herbs. The channel supports Water Ribbons. Some fish are likely to be present including Short-finned Eels, Flathead Gudgeon and Mountain Galaxias. The macroinvertebrate communities are in excellent condition (AUSRIVAS Band A) and a range of common and widespread frog species is likely to be supported.

Reach 2 contains a 'dampland' with a dense canopy of *Melaleuca squarrosa* and *Leptospermum lanigerum* and a wetland ground-layer of diverse sedges, rushes and reeds that are likely reliant on permanently waterlogged soils. The riparian vegetation upstream of the 'dampland' has been largely cleared for agriculture. Big Swamp (which is outside the scope of this study) is located downstream. The water in the channel in Reach 3 is usually shallow and is therefore unlikely to be suitable for fish, although Flathead Gudgeon may be present. The macroinvertebrate communities are significantly impaired (AUSRIVAS Band B). The reach likely supports the Otway Bush Yabby and the assemblage of common frogs.

Reach 3 dries in most summers, has highly acidic water when it is flowing and has limited aquatic habitat. It is unlikely to support many resident aquatic species (although some frogs may use some habitat in the reach). The macroinvertebrate community is in poor condition (AUSRIVAS Band C).

**Recommendations for additional studies and next steps**

In order to more fully understand (and possibly quantify) the impact of disturbances in the catchment, such as drought and groundwater extraction, on the aquatic ecosystems of Boundary Creek, we need to quantify both

the flow requirements of the ecological values supported by the creek and the catchment disturbances. This study, which identifies the aquatic communities and species supported by Boundary Creek and provides a high level assessment of their flow needs, is therefore the first stage of a multi-staged project.

To quantify the flow requirements of the aquatic values of the creek and the catchment disturbances additional studies and investigations are required, including:

1. Using the current hydrogeological understanding of the catchment to produce a detailed conceptualisation of the surface water-groundwater interactions that operate at Boundary Creek and incorporating the results of the numerical groundwater model to help quantify baseflow contributions to Boundary Creek.

2. Developing hydraulic models at representative sites in the creek to the link depth of water in the channel with flow volume.

3. Determining the quantitative flow needs of the identified aquatic values in Boundary Creek.

4. Undertaking a stand-alone assessment of the soil chemistry and groundwater-surface water interactions of Big Swamp and the impact of Big Swamp on the hydrology of Reach 3.

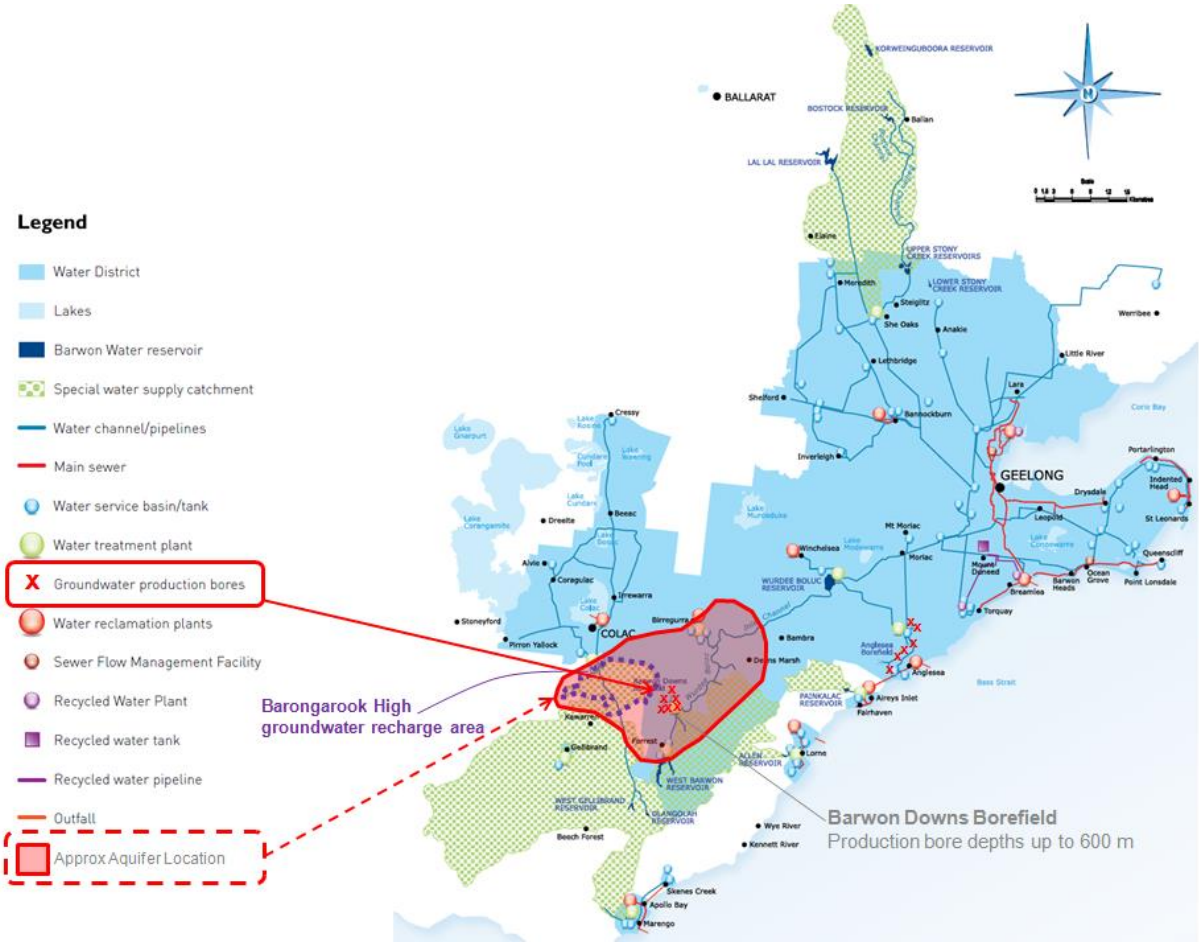
These additional studies, informed by this study, will be the primary tools used to understand potential impacts from the Barwon Downs borefield and to assess what impact the 2ML/day supplementary flow is having on the ecological values of Boundary Creek. These studies will also help to direct intervention efforts in the creek.

# 1. Introduction

## 1.1 Barwon Downs region

The Barwon Downs bore field is located approximately 70 km south west of Geelong and 30 km south east of Colac (refer to Figure 1-1). The surrounding land is a mixture of agriculture and state forest. A substantial proportion of the study area has been farmed for over a century which has resulted in some parts of the landscape being highly modified compared to the surrounding natural environment.

**Figure 1-1 Map of the Barwon Downs region including the aquifer extent and the primary groundwater recharge area**




The regional groundwater system extends beneath two surface water catchments, the Barwon River catchment and the Otways Coast catchment.

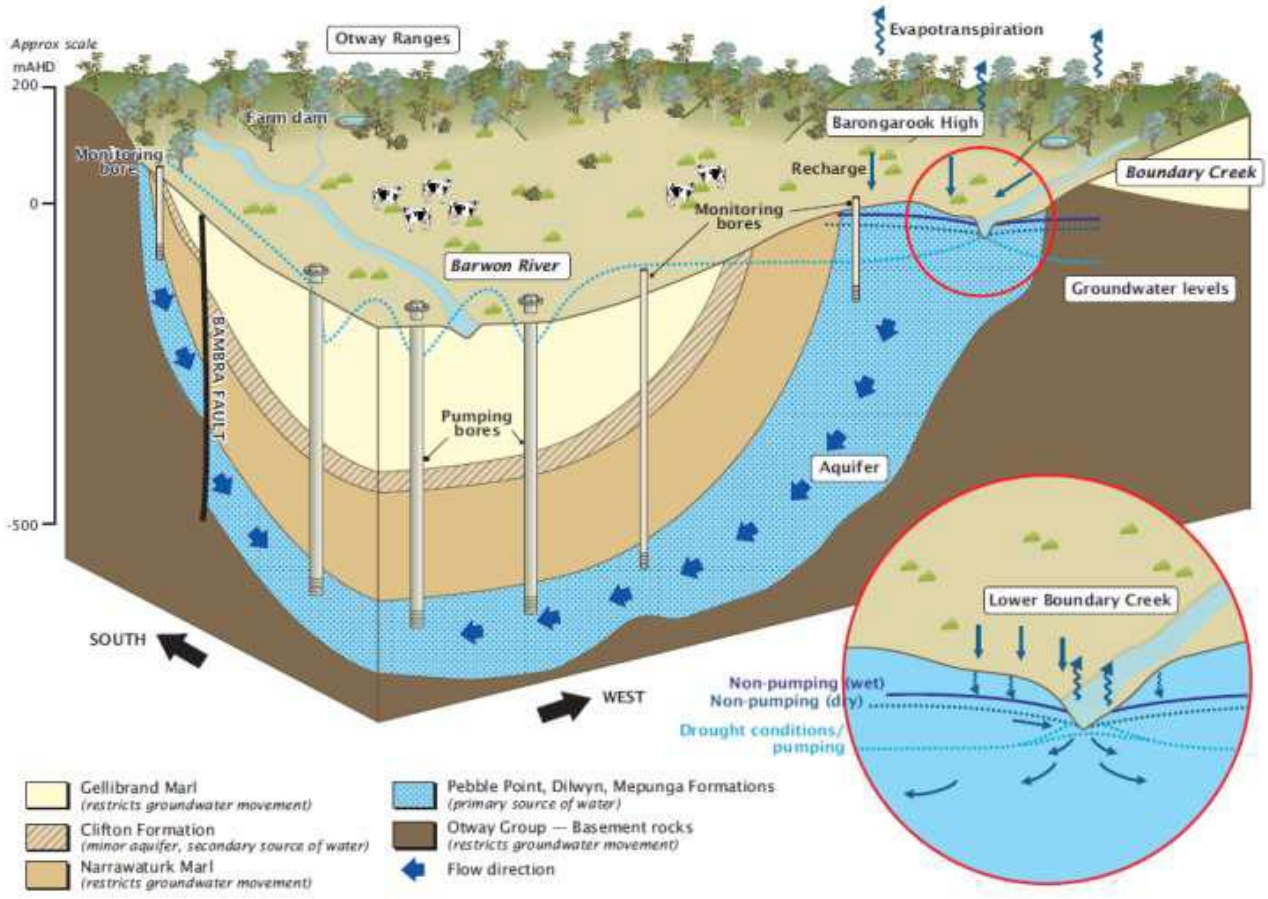
The Barwon River and its tributaries rise in the Otway Ranges and flow north through Forrest and Birregurra. The Barwon River West Branch and East Branch drain the southern half of the catchment and come together just upstream of the confluence with Boundary Creek. Boundary Creek flows east across the Barongarook High and joins the Barwon River around Yeodene.

The Otways Coast catchment is a large catchment with many rivers that flow towards the coast. The Gellibrand River is in the Otways Coast catchment and rises near Upper Gellibrand and flows in a westerly direction towards Gellibrand. The Gellibrand River discharges to the ocean at Princetown.

The borefield taps into an underground source of water, known as the Lower Tertiary Aquifer, with depths of up to 600 metres at the borefield. The aquifer covers an area of approximately 500 km$^2$ below the surface and is

connected to the surface in both the Barwon River catchment (Barongarook High) and the Otways Coast catchment near Gellibrand. Barongarook High is the main recharge area of the aquifer because of its unconfined nature.

**Figure 1-2 Schematic of the Lower Tertiary Aquifer and where it outcrops at the surface**




## 1.2 History of the Barwon Downs borefield

### 1.2.1 Borefield history

In response to the 1967-68 drought, when water supplies reached critical levels, the Geelong Waterworks and Sewerage Trust (now Barwon Water) began investigating groundwater resources as a means of supplementing surface water supplies used for the Geelong region. Investigations conducted in the Barwon Downs region revealed a significant groundwater resource with potential to meet this need.

In 1969 a trial production bore was built and tested close to the Wurdee Boluc inlet channel at Barwon Downs. With knowledge gained from these results another bore was built at nearby Gerangamete in 1977. A long term pump testing programme from 1987-1990 confirmed that the borefield should be centred on Gerangamete.

There are now six production bores in the borefield each between 500 and 600 metres deep. Pumps in each bore are capable of providing daily flows of up to 12 megalitres (ML) per day per bore. The pumped water is treated by an iron removal plant prior to transfer to Wurdee Buloc Reservoir. Total borefield production capacity is 55 ML per day.

### 1.2.2 Groundwater extraction

Barwon Water operates the borefield in times of extended dry periods. This has occurred only five times in the last 30 years. The borefield is a critical back up source for Barwon Water because it is buffered from climate variability due to the depth and large storage capacity of the aquifer, whereas surface water catchments are susceptible to seasonal fill patterns mostly driven by rainfall.

Although extraction occurs infrequently, large amounts of groundwater are drawn when needed to supplement surface water storages during drought. This is completed in compliance with the groundwater licence (refer to Section 1.3). This operational philosophy of intermittent pumping has been an effective way to provide customers with security of supply, especially in times of prolonged dry conditions.

To date, Barwon Water has extracted the following volumes from the aquifer:

- 3,652 ML from February to April in 1983 due to drought,
- 19,074 ML during a long term pump test in the late 1980s,
- 36,817 ML during the 1997 - 2001 drought,
- 52,684 ML during the 2006 – 2010 millennium drought, and
- 2,383 ML in 2016 to boost storages after a very dry summer.

Groundwater extraction has supplemented surface water supply by a total of 114,610 ML, equating to approximately 10 per cent of total water consumed over a 30 year period.

### 1.2.3 Licence history

The first licence was issued in 1975 but did not come into effect until 1982, as the bores were not brought into operation until the 1982-83 drought. This was the first time the borefield was used to supply water to Geelong. The licence issued by the State Rivers and Water Supply Commission (now Southern Rural Water) was to allow Barwon Water to operate four production bores based on the following conditions:

- Extraction for the purpose of urban water supply;
- Maximum daily extraction rate of 42.5 ML;
- Maximum annual extraction rate of 12,600 ML;
- Maximum ten-year extraction rate of 80,000 ML; and
- Periods of licence renewal of 15 years (1975 – 1990).

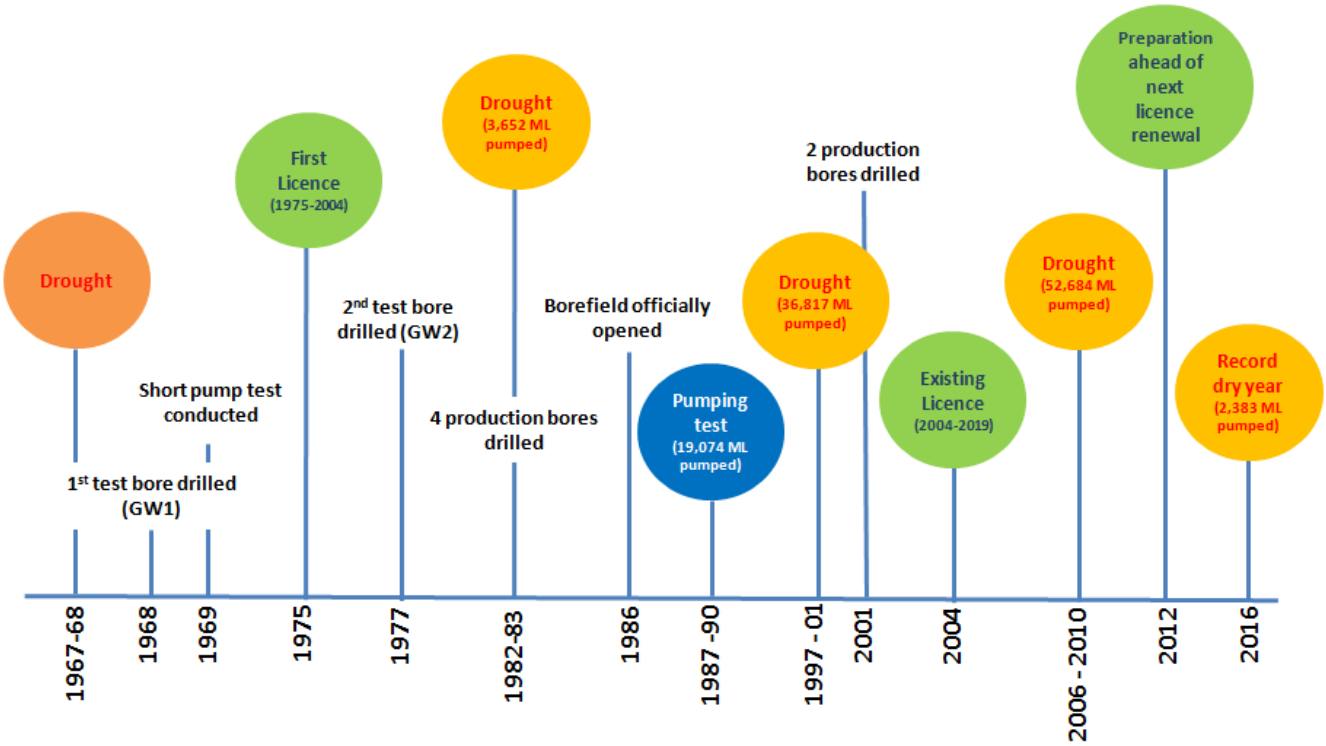
The licence was subsequently renewed for two periods of five years up to 2000. From 2000, the licence was temporarily extended three times for a total of four years to allow the licence renewal to take place through to 31 August 2004.

In 2002[1], Barwon Region Water Authority (now Barwon Water) applied to renew the Barwon Downs borefield licence for extraction of groundwater to meet urban water supply needs. The application proposed the following:

- Maximum daily extraction rate of 55 ML;
- Maximum annual extraction rate of 20,000 ML;
- Maximum ten-year extraction rate of 80,000 ML;
- Long term (100 year period) average extraction rate of 4,000 ML/year; and
- Licence renewal period of 15 years.

From 2004 to 2006, the licence was temporarily extended to allow for the licence renewal to take place. Licence conditions were drafted by the panel taking into consideration the findings of the technical groups and the submissions received. This licence is valid to 30 June 2019.

**Figure 1-3 Timeline of events that surround the development and use of the Borefield**




[1] *Note: Bulk Entitlement was considered in 2002 so that the Upper Barwon System could be managed conjunctively. This was put aside as the view at the time was that the rights to groundwater should continue to be contained in a licence and subject to regular review.*

## 1.3 Current groundwater licence

The Barwon Downs borefield is operated under licence from Southern Rural Water. This licence was granted in 2004 and is due for renewal by June, 2019.

This licence makes provision for extraction limits on a volumetric basis over a range of time scales. As part of the licence conditions, Barwon Water monitor groundwater levels and quality, subsidence, flow in Boundary Creek and Barwon River, as well as the protection of riparian vegetation, protection of stock and domestic use and the protection of flows in the Barwon River tributaries.

Reporting against these licence conditions is provided in an annual report to Southern Rural Water who administers and regulates groundwater licences on behalf of the Water Minister..

## 1.4 Strategic drivers for the Barwon Downs technical works monitoring program

Ahead of the upcoming 2019 licence renewal process, Barwon Water instigated a technical works monitoring program to improve the comprehensiveness of the current monitoring program to ensure the submission of a technically sound licence application.

Driving the need for this monitoring program is the reliance on the borefield to provide water security for Barwon Water customers, to address outstanding community issues particularly where the relationship between cause and effect is not yet fully understood, and to close out any known technical knowledge gaps.

### 1.4.1 Water security

The Barwon Downs borefield provides water for the regional communities of Geelong, the Surf Coast, the Bellarine Peninsula and part of the Golden Plains Shire.

A prolonged period of unprecedented drought (known as the Millennium drought) saw a sustained dry climate average from 1997 to 2011. In 1997, many of the region's water storages were close to capacity, however by January 1998, after high consumption and low catchment inflows, water restrictions were necessary to balance supply and demand in the Geelong area. This clearly highlighted that even by having large storages the region was susceptible to rapid changes.

In 2001, strong catchment inflows from healthy rainfall refilled storages, ending water restrictions in Geelong. Five years later, after a very dry year, strict water restrictions were again required with climate extremes exceeding the historical record. At the height of the Millennium drought, Geelong's water storages dropped to 14 per cent when catchment inflows were severely reduced. To meet demand during this time 52,684 ML was extracted from the borefield providing up to 70 per cent of Geelong's drinking water.

In 2010, improved rainfall restored storages and restrictions were again slowly lifted in the Geelong area. This allowed the Barwon Downs borefield to be switched off and to begin recharging. Without the use of the borefield during this time, residents and industry in Geelong, Bellarine Peninsula, Surf Coast and southern parts of the Golden Plains Shire would have run out of water.

The township of Colac will soon be connected to the Geelong system through construction of a pipeline between Colac and Geelong. This interconnection will also allow the borefield to supply Colac residents and will provide additional water security for the water supply system which is currently susceptible to seasonal fill patterns.

### 1.4.2 Community issues

Although Barwon Water is compliant with the monitoring program associated with the 2004 licence, it is accepted that this program is not comprehensive enough to address community interest about specific issues centered on potential environmental impacts in the local catchment.

Areas of community interest recently have included the:

- extent of stream flow reduction and any ecological impacts at various points along Boundary Creek,
- potential to increase existing acid sulphate soil risks in the Yeodene peat swamp,
- potential to increase the existing fire risk at the Yeodene peat swamp, and
- extraction limits and the current operational regime of the borefield, and whether they are sustainable under climate change projections.

A Community Reference Group was established in 2013 to provide community feedback and input into the technical works monitoring program.

### 1.4.3 Informing the licence renewal

To address community interest adequately and inform the licence renewal in 2019, Barwon Water commissioned a review of the existing monitoring program associated with the 2004 licence. This technical review recommended that a revised technical works monitoring program be developed with the following objectives:

- Better understand the environmental impacts of groundwater extraction;
- Estimate, and quantify where possible, the causes and relative contributions of groundwater variability (for example, groundwater extraction and drought) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

## 1.5 Overview of the technical works monitoring program

### 1.5.1 Monitoring program development

The development of the technical works monitoring program is shown in Figure 1-4 and can be broken down into the following stages.

Stage 1: Review of the existing monitoring program

In 2012, Barwon Water initiated a review of the Barwon Downs monitoring program. The technical works monitoring program was developed in response to the:

- desire to address key community issues (see section 1.4.2), and
- 2008-09 flora study which recommended a long term vegetation and hydrogeological monitoring program be designed and implemented to better understand a range of factors such as groundwater extraction, drought and land use changes that were contributing to the drying of the catchment.

This review took into account both the social and technical issues that needed to be addressed to inform the licence renewal process in 2019 and was initiated early to allow sufficient time to establish a comprehensive monitoring program. A risk based approach was used to rank these issues, and control measures were developed to downgrade the residual risk ranking, which included activities such as additional monitoring and technical studies.

Stage 2: Technical works monitoring program scope refinement

In 2013, the scope of the technical works monitoring program was developed based on the recommendations of Stage 1. The Technical Works Monitoring Program was designed to improve the capacity to differentiate between groundwater extraction and climate effects on the groundwater system, predict water table and stream flow changes, and increase understanding of potential ecological impacts. Key improvement areas include:

- differentiating between groundwater extraction and climate effects on the regional groundwater system,
- understanding the potential risks of acid sulphate soils and whether that could change future extraction practices,
- assessing whether vegetation in areas dependent on groundwater will be at risk from water table decline, which could change future extraction practices,
- assessing flow requirements in Boundary Creek to determine if the current compensatory flow is effective,
- characterising groundwater dynamics in the aquitard to improve hydrogeological understanding of groundwater flow and quantity, and
- better understanding of groundwater and surface water interaction, particularly along Boundary Creek where groundwater contributes to base flow.

In the same year, the Barwon Downs Groundwater Community Reference Group was also formed by Barwon Water to ensure where possible, the monitoring program was adjusted and the scope refined, to take into consideration community issues and views. This was a critical contribution towards the broader licence renewal strategy as it raised confidence that the right monitoring data would be captured to specifically target key areas of community concern.

Stage 3: Construction of additional monitoring assets

During 2014-15, the following construction works were completed:

- 33 new groundwater monitoring bores drilled, including the replacement of one existing bore,
- 3 existing bores refurbished,
- 4 new potential acid sulphate soils monitoring bores were installed,
- 32 data loggers and two barometric loggers installed in new and existing bores,
- 1 new stream flow gauges installed, and
- 2 existing stream flow gauges replaced refurbished and reinstated.

Stage 4: Ongoing monitoring

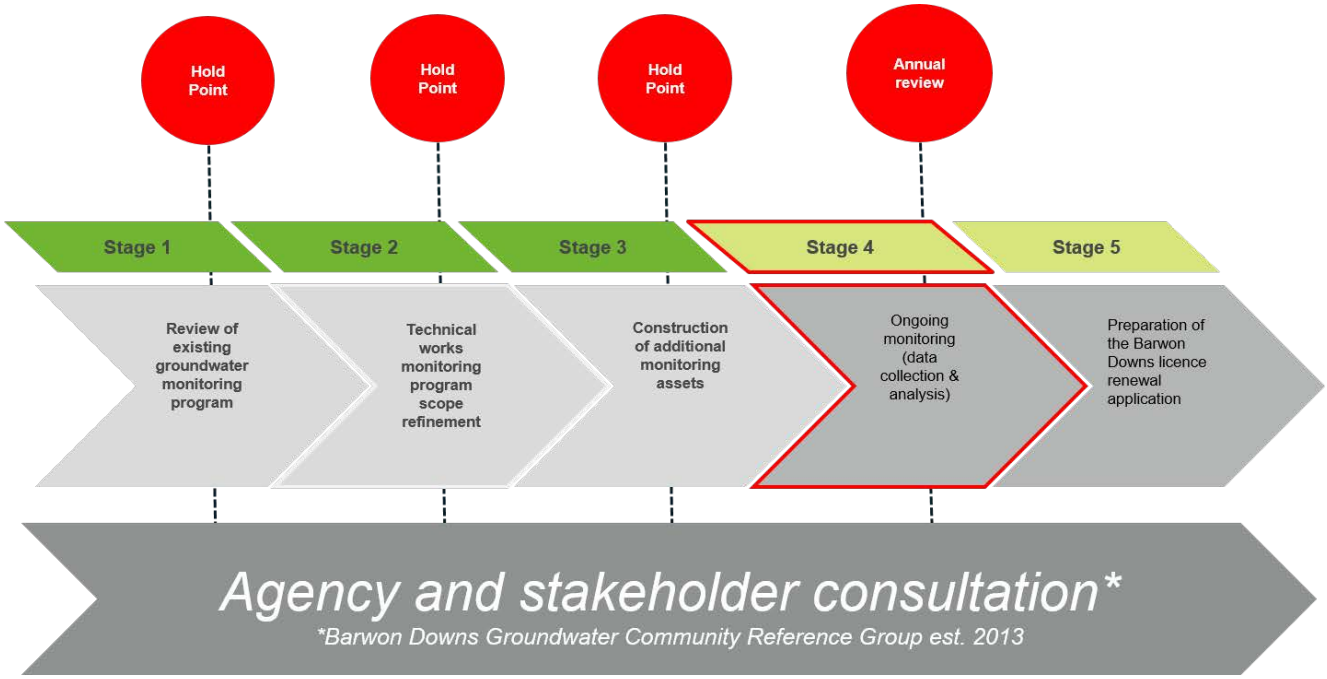
The technical works monitoring program is now in a phase of data collection and preliminary analysis. The intention of this stage is to update the conceptual understanding of the hydrogeology in the Barwon Downs region. This will be based on data collected from additional and existing monitoring assets and the outcomes of a range of investigative technical studies, all of which will be used to update and calibrate the groundwater model.

Preparation will also begin at this stage to form a comprehensive licence application.

Stage 5: Preparation for licence renewal submission

Prior to 2019, Barwon Water will need to formally submit a licence renewal application to Southern Rural Water. This will initiate a groundwater resource assessment process as set out under the Water Act.

**Figure 1-4 Development of the technical works monitoring program**




### 1.5.2 The inter-relationships of the technical works monitoring program

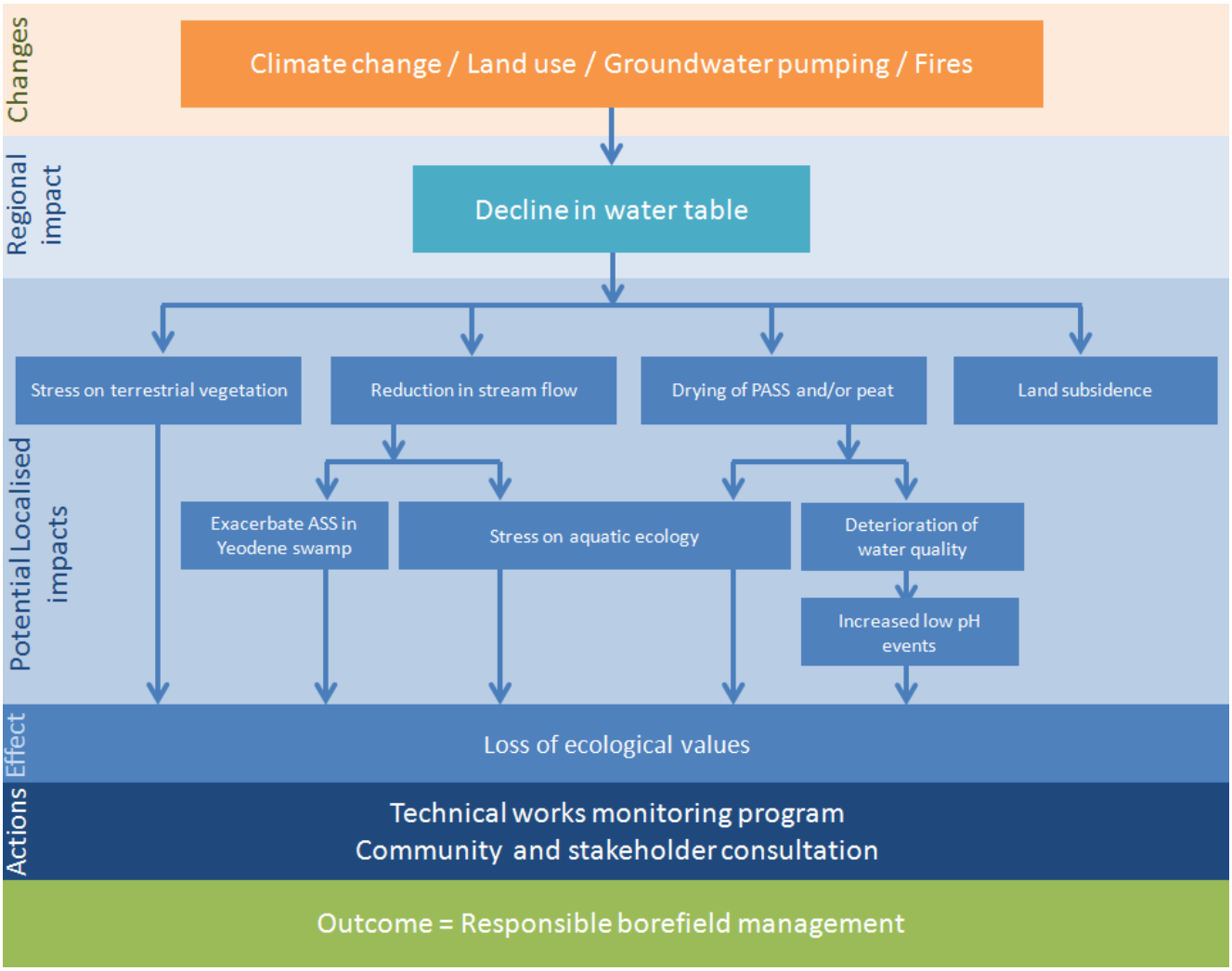
The technical works monitoring program is a complex, multi-disciplinary project due to the overlapping nature of the various components of the program as shown in Figure 1-5.

Changes in climate, land use practices and groundwater pumping will alter water availability throughout the catchment, including stream flow and groundwater levels. Many receptors are sensitive to changes in groundwater levels and stream flows, particularly those that are dependent on groundwater. Ultimately this can lead to the loss of ecological values (refer to Figure 1-5).

For example, a decline in groundwater level beneath a stream can cause a reduction in stream flow, which in turn can impact the habitat of aquatic ecology in the stream. Declining groundwater levels or reduced stream flow also has the potential to impact riparian vegetation and potential groundwater dependent activities.

The technical works monitoring program is designed to address knowledge gaps to better understand potential impacts from the borefield. The program is underpinned by scientific rigor using multiple lines of evidence-based techniques to establish the relationship between cause and effect for potential impacts caused by groundwater extraction.

**Figure 1-5 Potential impacts in the catchment from changes in the catchment**




## 1.6 This report

### 1.6.1 Background to this project

The Boundary Creek catchment has been highly modified over the last century. The changes to the catchment, some of which are permanent and irreversible, have significantly altered the natural hydrological flow regime of Boundary Creek. These changes include a range of natural and human factors:

- Much of the lower part of the catchment has been cleared to support agriculture, likely changing runoff patterns and therefore streamflow.
- An on-stream water storage (McDonalds Dam) was constructed in approximately 1979 about halfway down the catchment. All the flow in the creek is captured by this dam and downstream flow in the creek requires the passing of flow through the dam.
- The catchment has a number of private diverters and farm dams which collect rainfall before it reaches the creek.

- Groundwater has been extracted from the Barwon Downs bore field to augment potable supply during low rainfall conditions.

- Like the rest of south-eastern Australia, the Boundary Creek catchment was impacted significantly by the Millennium Drought. Less rainfall and runoff caused declining stream flows and groundwater levels throughout the state.

- Big Swamp is a peat swamp located in the middle of the catchment (downstream of McDonalds Dam). A fire was reported in the swamp on October 10 1997 (Colac Otway Fire Management Plan 2015), which suggests that it dried at some stage prior to this time. Trenches up to 3 m deep were dug in 2006 by the Country Fire Authority (CFA) at the margins of the swamp in an attempt to control the spread of the fire (Himmelreich 2010). The drying, fire and trenching have had considerable impacts on both the quantity and quality of water flowing out of the swamp.

- Under the conditions of the current groundwater extraction licence, Barwon Water are required to provide supplementary flow (currently 2 ML/day) to Boundary Creek to mitigate potential impacts on stock and domestic users from extraction from the Barwon Downs bore field.

By altering the natural hydrology of the creek, the changes outlined above are likely to have had an impact on the ecological values supported in the catchment. As the operators of the Barwon Downs bore field Barwon Water is interested in understanding the nature of the potential impact of groundwater extraction from the bore field on the ecology of Boundary Creek.

To this end, Jacobs is completing a separate study to update and recalibrate a numerical groundwater model, which is scheduled to be completed in late 2016. The groundwater numerical model is being updated to support the renewal of the Barwon Down licence in 2019. The licence renewal process will involve an assessment of potential impacts under past and proposed operating regimes. The numerical model, together with a hydraulic model, will be used to estimate the impact of extraction on flow in Boundary Creek and to assess the ecological benefits or risks of the 2 ML/day supplementary flow.

In order to understand potential impacts of groundwater extraction on the hydrology and ecology of the creek, an understanding of the aquatic ecological values (species and communities) that the creek currently support is needed. Barwon Water has therefore engaged Jacobs to undertake a background study on the aquatic ecology of Boundary Creek (this report).

### 1.6.2 Objectives of this study

The objective of this study is to estimate the aquatic flora and fauna species and communities (the 'ecological values') currently supported by Boundary Creek.

This study also aims to determine, at a broad scale (i.e. qualitatively), the elements of the creek's flow regime that these values require. In other words, what are the current flow components of Boundary Creek that allow the predicted species and communities to be present? An understanding of the broad flow needs of these values will allow us in the future to use the results of the groundwater model (currently being completed) to investigate potential impacts from groundwater extraction on the aquatic values of Boundary Creek.

### 1.6.3 Our approach to estimate the ecological values supported by Boundary Creek

There have been few studies that have directly assessed the ecological values of Boundary Creek and none have been undertaken recently (i.e. within the past 10 years). Although fauna surveys are easy to undertake and are reliable for some taxa (e.g. macroinvertebrates), direct surveys can have problems in a system like Boundary Creek for taxa such as fish, frogs and Platypus. This is because as the creek is relatively small, it is likely to support only low numbers of aquatic animals and therefore field surveys may not record many of the expected taxa. As the failure to record a certain species during a field survey does not mean we can confidently infer that it is not present, even intensive field surveys may yield uncertain results.

Given these limitations, it was decided to use a combination of techniques to estimate the ecological values currently supported by Boundary Creek. Direct surveys were undertaken for **macroinvertebrates** because relatively short field programs can provide a representative sample of the taxa that are supported by the creek. Furthermore, rapid macroinvertebrate surveys can also be used as an indicator of stream health.

For the other aquatic values (**vegetation, fish, frogs** and **Platypus**) we assembled a panel of specialist ecologists to conduct a systematic background review and habitat assessment on which to base a robust and defensible estimate of the ecological values currently supported by the creek. The specialist panel consisted of:

- **Vegetation:** Professor Paul Boon (Dodo Environmental)
- **Macroinvertebrates, fish:** Dr Andrew Sharpe
- **Frogs, Platypus:** Dr Josh Hale

A range of sources were consulted for the background reviews including past surveys, anecdotal reports from local residents and predicted species distributions. Following the background review, we undertook rapid field inspections to assess the available aquatic habitat at a number of sites in the creek. The field inspections allowed the specialist ecologists to 'ground-truth' the information gathered as part of the background review and to determine if suitable habitat is present in the creek to support the species and communities predicted to occur.

An understanding of the hydrology of Boundary Creek is critical to estimating the ecological values supported and therefore an assessment of the surface water hydrology of the creek was also undertaken. The assessment was completed by:

- **Surface water (hydrology):** Amanda Woodman

### 1.6.4 Limitations, assumptions and uncertainty

This study is preliminary in nature and the aim is to understand at a high level the ecological condition of Boundary Creek and the ecological values the creeks currently supports. Therefore, there are number of limitations and assumptions that should be recognised.

- The objective of this study is not to determine the precise cause of any hydrological changes in Boundary Creek or to determine the relative impacts of the changes that occurred in the catchment.
- It is not the objective of this study to assess the impact of the Barwon Downs bore field on ecological values in the Boundary Creek. The impact of the bore field on the hydrology of the creek will be assessed following the update and re-calibration of the numerical groundwater model, due to be completed in late 2016.
- This study has focused on surface water hydrology in Boundary Creek and not explored in detail the groundwater-surface water interactions of the catchment. A comprehensive understanding of the complex interactions between surface and groundwater in the catchment is critical to understanding the creek more broadly, however, it is not necessary for this study. The focus of this study is an identification of the aquatic ecosystems supported by the creek. A detailed discussion of the groundwater-surface water interactions in the catchment is provided in the Barwon Downs Integration Report (Jacobs 2016).
- The study has not considered in detail the condition or ecological values supported by Big Swamp (a large peat swamp located near the middle of the catchment). The groundwater-surface water interactions, soil composition and chemistry and management history of Big Swamp is extremely complex but is critical to understanding the ecology of the lower sections of Boundary Creek. The purpose of this study is to assess the aquatic ecosystems and therefore it is beyond the scope to

complete a comprehensive investigation of Big Swamp. Big Swamp will be the focus of a future, stand-alone study.

- This study did not involve direct survey for fish, frogs, Platypus and vegetation. The approach adopted for this study (as described in Section 1.6.3) is based on an assessment of a number of indirect factors and specialist opinion and is therefore subjective. However, given the likely issues with direct surveys in systems such as Boundary Creek, we believe this method is the most suitable approach. To remove the subjectivity as far as possible, we have endeavoured to make clear the assumptions underpinning each estimate. We have also used a rating classification (high, medium, low) to rate the assessment of probability that the creek could support each ecological value (see Section 4).

- Boundary Creek is now heavily gauged, however, historically, that was not the case and there is limited hydrological data for the creek. This study uses all the available gauged data in the catchment but the assessment is limited by the length of record (see Section 3.1).

### 1.6.5 Report structure

The report has been divided into five sections.

- Section 2 describes the Boundary Creek catchment, including the key changes in the catchment and the locations of the features important to determining the hydrological regime of the creek (e.g. McDonalds Dam, Big Swamp).

- Section 3 describes our current understanding of the hydrology of Boundary Creek. Where records allow, this has been compared to historic data. A detailed investigation of the causes of any changes in the hydrology of the creek is outside the scope of the current study.

- Section 4 presents our estimate of the current ecological values supported by Boundary Creek using the approach outlined in Section 1.6.3

- Section 5 summarises the report and outlines the further work that will be required.

# 2. Description of the Boundary Creek catchment

This section describes the Boundary Creek catchment and identifies the reaches and sites assessed for the current study. Also described are the major changes that have occurred in Boundary Creek since European settlement.

Boundary Creek rises south of Colac, near Barongarook West, and flows in an easterly direction for approximately 18 km, before joining the Barwon River east of Yeodene.

In the upper reach, near Barongarook, Boundary Creek flows through a mixture of broad channel covered in grasses and reeds and sections of more defined channel with fringing and aquatic vegetation and some woody snags. In the area near Langdons Road, the creek flows through native forest. The channel in this area has generally retained its natural form and there are diverse instream habitats including small pools with undercut banks and submerged wood, shallow runs and riffles with regular branch piles and leaf packs.

Large parts of the middle of the catchment have been cleared of vegetation to support agriculture. McDonalds Dam, a large, on-stream storage, is located in this area. Boundary Creek downstream of McDonalds Dam flows through areas of largely unmodified native vegetation and into Big Swamp, a large, peat swamp.

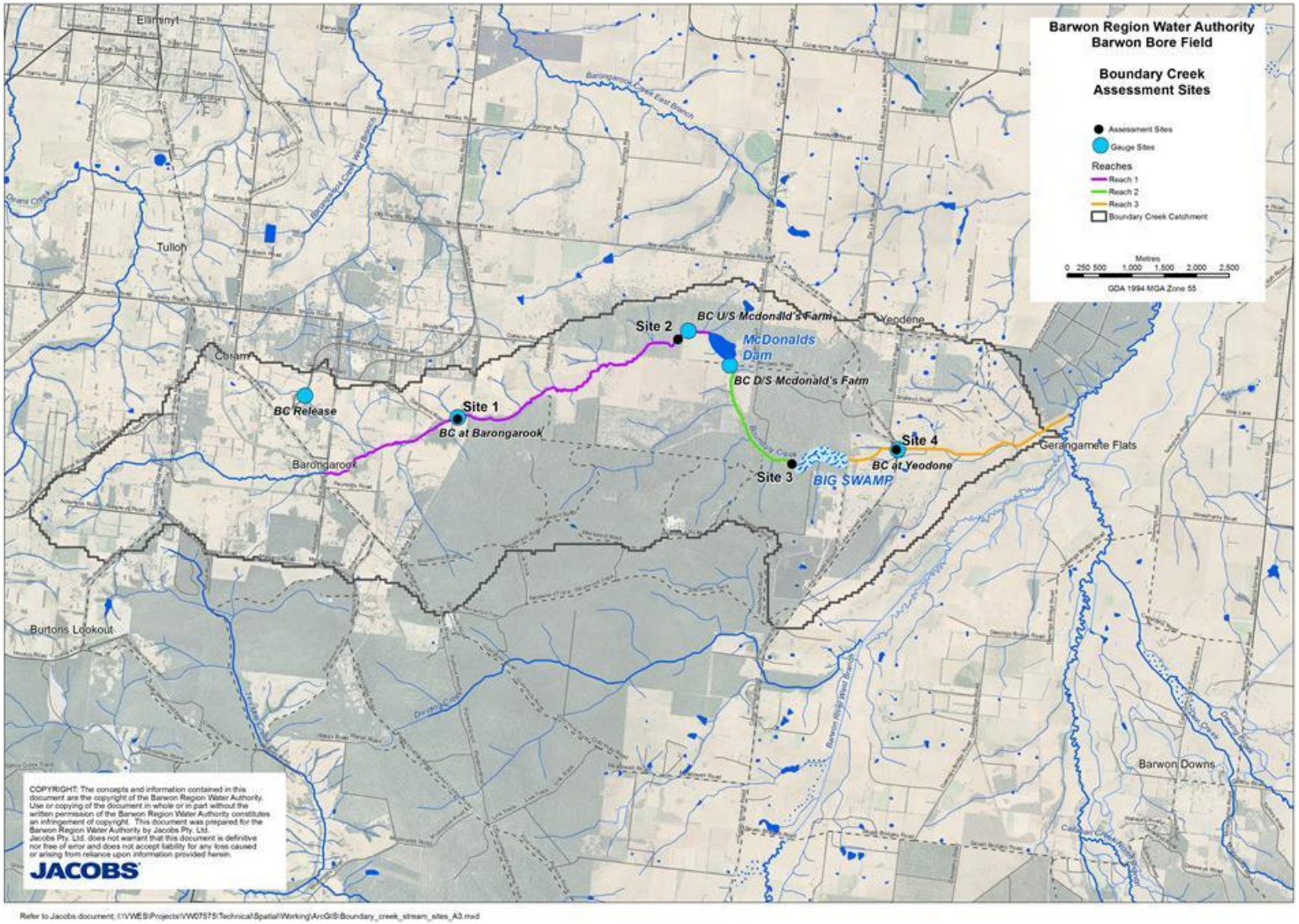
Most of the creek downstream of Big Swamp to the confluence with the upper Barwon, has been heavily modified to support agricultural activity. The channel has been straightened and excavated and the majority of the pre-European large riparian vegetation has been cleared

## 2.1 Boundary Creek reaches

For the purposes of this study, Boundary Creek has been divided into three reaches which exhibit broadly uniform geomorphology, hydrology, hydrogeology and system operation. The three reaches are:

1. Upstream of McDonalds Dam
2. McDonalds Dam outlet to the downstream end of Big Swamp
3. Downstream of Big Swamp to confluence with Barwon River.

These reaches are shown in Figure 2-1.




Refer to Jacobs document: I:\VWES\Projects\VW07575\Technical\Spatial\Working\ArcGIS\Boundary_creek_stream_sites_A3.mxd

**Figure 2-1 Boundary Creek catchment showing the reaches and assessment sites for the current study.**

## 2.2 Habitat assessment sites

One site was selected per reach at which to undertake a detailed habitat assessment and to 'ground-truth' the information collected during the background review (completed in December 2014). The sites were selected during a whole of catchment inspection in April 2013 and were chosen to capture the diversity of habitat available at the reach. The representativeness of this site in the context of the broader catchment is described below.

For Reach 1, the habitat assessment site is downstream of Langdons Road, just upstream of McDonalds Dam. The channel in this area is deeply incised in parts and the wetted width was about 1 m at the time of the assessment in December 2014 (Figure 2-2). The creek in this section flows over a number of shallow rocky riffles, approximately 10 cm deep. Some pool/run sections in this area were up to about 50 cm deep during the assessment and there was some overhanging vegetation and undercut banks. A conceptual model of Boundary Creek at the habitat assessment site in Reach 1 is provided in Figure 2-3.

The rapid catchment wide inspection and an examination of aerial imagery suggests that the habitat assessment site is broadly representative of the habitat found in Reach 1. There are some sections of the creek that have been cleared for agriculture, but most of the reach looks to have a continuous and vegetated riparian zone.

**Figure 2-2 Boundary Creek upstream of McDonalds Dam, the habitat assessment site in Reach 1.**

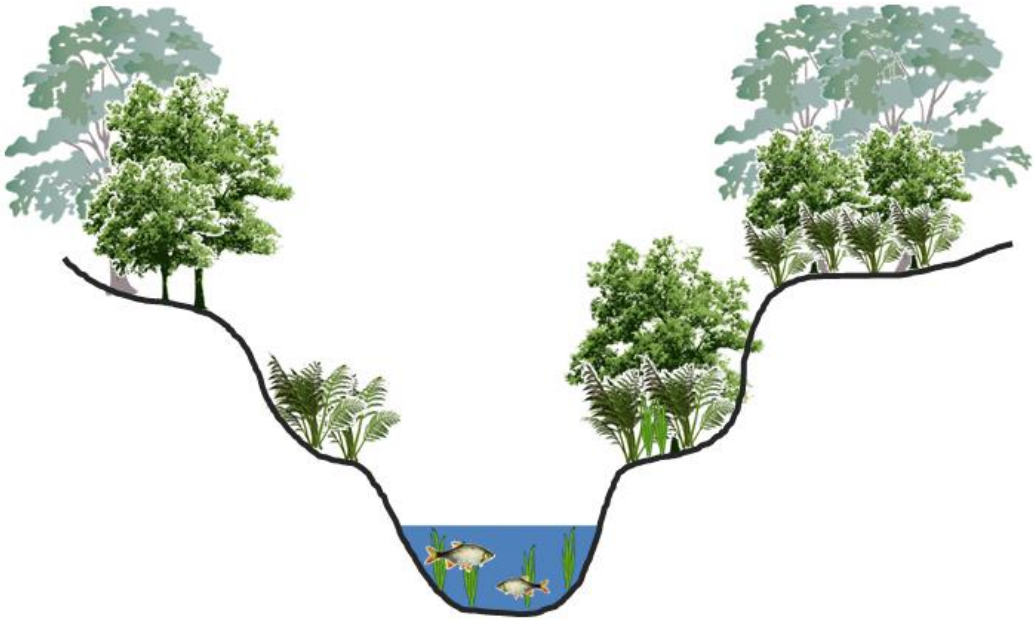


**Figure 2-3 Conceptual model of Boundary Creek at the habitat assessment site in Reach 1. Note that the communities and species depicted are for illustrative purposes and are not intended to represent the actual species present at Boundary Creek.**

The habitat assessment site selected in Reach 2 is upstream of the Big Swamp and is representative of the broad, dispersed, marshy nature of Boundary Creek in this area. The stream channel and riparian zone are in excellent condition and are free of weeds. The flow is dispersed through a number of channels with a broad damp marshy character and waterlogged ground. There is a moderate load of large wood (i.e. fallen trees) and leaf litter in the channel, and overhanging and submerged vegetation. Downstream of the site are some deeper pools that would provide excellent habitat for native fish, macroinvertebrates and frogs. The area was dotted with burrows, likely of the Otway Bush Yabby. The ecological values in this area likely rely on the waterlogged soils, prompting the coining of the term ‘damplands’ for this area.

Photos of the habitat assessment site in Reach 2 are shown in Figure 2-4. A conceptual model illustrating the aquatic habitats at this site is presented in Figure 2-5.

Reach 2, between McDonalds Dam and the ‘damplands’, has been heavily modified and cleared for agriculture. Just downstream of the ‘damplands’ is Big Swamp. The ecology of the lower part of Boundary Creek is influenced significantly by Big Swamp, however, the groundwater-surface water interactions, soil composition and chemistry and management history of Big Swamp is extremely complex. The purpose of this study is to assess the aquatic ecosystems of Boundary Creek and therefore it is beyond the scope to complete a comprehensive investigation of Big Swamp. Big Swamp will be the focus of a future, stand-alone study.

**Figure 2-4 Boundary Creek, just upstream of Big Swamp at the location of the habitat assessment site in Reach 2.**

**Figure 2-5 Conceptual model of Boundary Creek at the habitat assessment site in Reach 2. Note that the communities and species depicted are for illustrative purposes and are not intended to represent the actual species present at Boundary Creek.**

The site of the Yeodene flow gauge on the Colac-Forrest Road was the selected habitat assessment site in Reach 3. The river at this site has been channelised and largely cleared of native vegetation, although the riparian zone upstream of the road crossing was re-vegetated 10-15 years ago. It has a mature eucalypt overstorey and a dense mid storey layer. Some sections of the channel downstream of the Colac-Forrest Road have been fenced and re-vegetated.

The channel in this section was dry during the April 2013 site inspection and there was no obvious flow on the day of the habitat assessment in December 2014 (Figure 2-6). This was despite the supplementary flow being provided to the creek and there being obvious flow upstream of Big Swamp.

**Figure 2-6 Boundary Creek at the Yeodene flow gauge near the Colac-Forrest Road. Left: Photo taken in April 2013 when the channel was dry. Right: Photo taken in December 2014, no flow was apparent at the time of the assessment.**

An additional site, about halfway between the gauge and the upper Barwon River was assessed as part of a previous study completed on the broader Barwon River catchment by Lloyd *et al (*2005). This part of the channel was also characterised by a largely cleared riparian zone with much of the aquatic habitat provided by fringing and submerged vegetation (Figure 2-7).

Little has changed in the available habitat or character of this reach since the 2005 study, and therefore, in consultation with Barwon Water, it was decided to include this site in the project, but not to visit this site as part of the habitat assessment.

**Figure 2-7 Boundary Creek at the location of the previous assessment, about halfway between the Yeodene gauge and the upper Barwon River (photo taken from Lloyd *et al.* 2005).**

Conceptual models showing the available aquatic habitats at the sites in Reach 3 are presented in Figure 2-8.

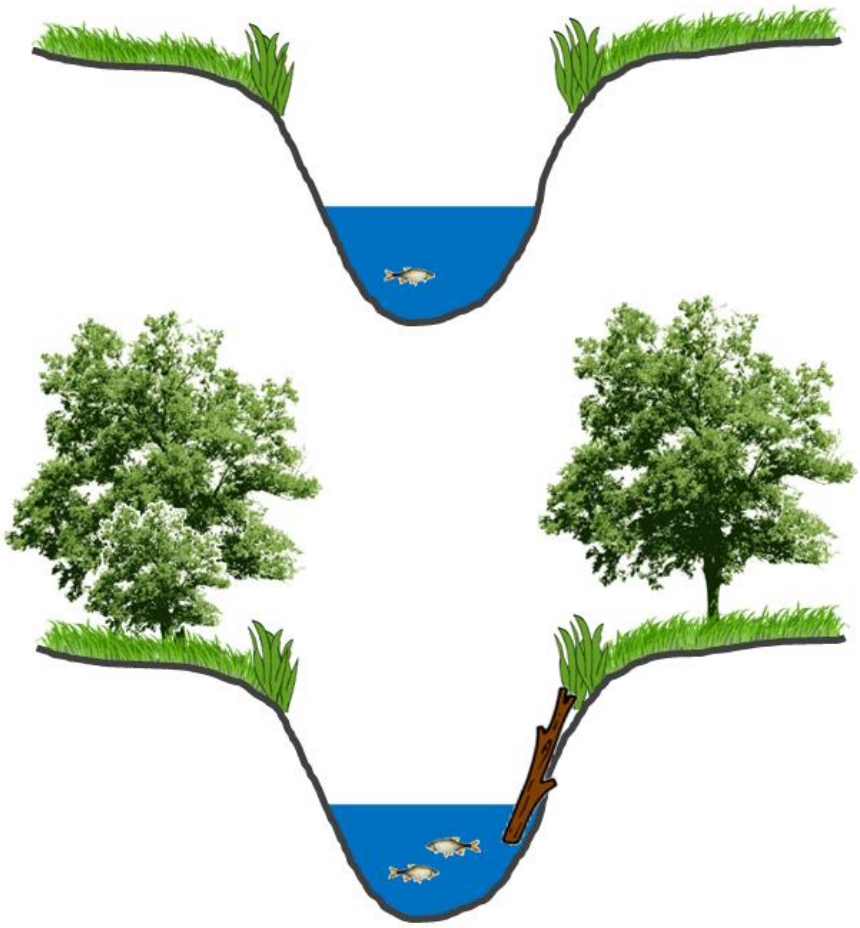


**Figure 2-8 Conceptual model of Boundary Creek at the assessment sites in Reach 3. The top image shows the creek in areas that have been cleared of riparian vegetation. The bottom image shows the habitats that would likely be provided in areas of the creek that have replanted riparian vegetation. Note that the communities and species depicted are for illustrative purposes and are not intended to represent the actual species present at Boundary Creek.**

## 2.3 Macroinvertebrate monitoring sites

Macroinvertebrate monitoring was conducted at each of the habitat assessment sites in Reaches 1, 2 and 3 (described above) and at one additional site near Langdons Road, Barongarook, in Reach 1. Boundary Creek at the location of the additional macroinvertebrate monitoring site flows through native riparian forest and has generally retained its natural channel form. There are diverse instream habitats including small pools with undercut banks and submerged wood, shallow runs and riffles with regular branch piles and leaf packs (Figure 2-9). Some sections of the stream also support stands of native submerged and emergent macrophyte species such as *Triglochin*. Much of the bank has been infested with Blackberry, which has increased significantly since April 2013 when this site was briefly inspected.

At the time of the habitat assessment in December 2014, water depth through much of the channel at this site was between 10 and 30 cm, with some pool/run sections up to 50 cm deep. This site is located downstream of the inflow of the supplementary flow release at Bushby Road.

**Figure 2-9 Boundary Creek at Langdons Road, site of the macroinvertebrate sampling.**

## 2.4 Summary of assessment sites

Table 2-1 presents a summary of the assessment sites. Site 1, the most upstream site (at Barongarook)

**Table 2-1 Habitat assessment and macroinvertebrate sampling sites.**

| Site # | Site | Location | Habitat assessment | Macroinvertebrate monitoring |
|---|---|---|---|---|
| 1 | Reach 1: Boundary Creek at Langdons Road, Barongarook | 206056 / 5742782 | | ✓ |
| 2 | Reach 1: Boundary Creek upstream of McDonalds Dam | 209460 / 5744009 | ✓ | ✓ |
| 3 | Reach 2: Boundary Creek upstream of swamp | 211223 / 5742089 | ✓ | ✓ |
| 4 | Reach 2: Boundary Creek at Colac-Forrest Rd | 212837 / 5742306 | ✓ | ✓ |

## 2.5 Changes in the Boundary Creek catchment since European settlement

Although relatively small, the Boundary Creek catchment has undergone a range of changes since European settlement, some of which have permanently altered the flow regime of the creek. The major changes are outlined briefly below.

### 2.5.1 Channelisation

The upper part of the catchment retains extensive areas of remnant native vegetation and a largely unmodified channel structure (Figure 2-10). However, the lower part of the catchment, near the confluence with the upper Barwon River, has been cleared of native vegetation and the creek has been channelised (Figure 2-10). Pre-European settlement, it is likely that the lower part of the creek would have been a broad, undefined marsh, with the channel dug in the early years of settlement to improve drainage to the Barwon River and to open up the area for agricultural development. Channelisation changed the hydrology of the lower part of Boundary Creek by conveying flows efficiently to the Barwon River and drying the marshland which is likely to have been present.

**Figure 2-10 Left: Boundary Creek in the upper reaches, at Barongarook. Right: Boundary Creek immediately upstream of the confluence with the Barwon River (photo April 2013).**

### 2.5.2 McDonalds Dam

McDonalds Dam is an on-stream water storage located in the middle of the catchment and was constructed in approximately 1979 (Figure 2-11). All the flow in the creek is captured by this dam and when it is not full and overtopping, downstream flow in the creek requires the active passing of flow. The dam may provide refuge habitat for a range of aquatic species in dry conditions, however the dam wall is likely to be a movement barrier for most fish species.

**Figure 2-11 McDonalds Dam and Boundary Creek immediately downstream.**

### 2.5.3 Private diversions

Boundary Creek has a number of private diverters. In total, diversion licences of up to 91 ML a year are in place for the creek, of which 86 ML are winterfill and 5 ML are stock and domestic (SKM 2006). This means that farmers extract flow from the creek during winter months when the flows are reasonably high.

Farm dams have also been constructed in the catchment, with a combined volume of 532 ML (SKM 2005). In some instances these farm dams intercept water before it enters the creek or are filled by pumping from the creek. Interception of runoff from farm dams has the potential to reduce streamflow throughout the catchment all year round.

### 2.5.4 Groundwater extraction

Groundwater has also been extracted from Barwon Downs to augment Geelong's water supply during drought. The Barwon Downs bore field has been used to augment Geelong's water supply over three time periods: 1987 to 1990; 1997 to 2001 and 2006 to 2010. The most recent pumping activity commenced in April 2016. Small scale pumping has also taken place outside these periods.

The bore field extracts from the Lower Tertiary Aquifer which is very deep at the borefield (600 m), but the aquifer rises to the surface in the Boundary Creek catchment. Groundwater levels decline in response to groundwater extraction. Many rivers and vegetation rely on shallow groundwater levels as a water source so declining groundwater levels has the potential to impact these receptors by lowering the regional water table.

### 2.5.5 Supplementary flow

Barwon Water releases a supplementary flow of 2 ML/day into Boundary Creek to compensate stock and domestic users who may have been impacted by groundwater extraction from the Barwon Downs bore field. This flow was not intended to support the ecological values of Boundary Creek. The supplementary flow is released except when the groundwater level in bore Yeo 40 recovers above a level of 158.5 m AHD following the cessation of pumping or at any time between 1 June and 30 November that the natural flow at Yeodene exceeds 1 ML/day (Southern Rural Water 2006). The supplementary flow has been provided since at least 2003 (Barwon Water 2004) and is delivered to a tributary of Boundary Creek near Bushby Road (Figure 2-12). The tributary joins Boundary Creek approximately 1 km downstream of Barongarook Road.

**Figure 2-12 Tributary of Boundary Creek at Bushby Road, showing the 2 ML/day release.**

### 2.5.6 Millennium drought

Like the rest of south-eastern Australia, the Boundary Creek catchment was likely impacted significantly by the Millennium Drought. Less rainfall and runoff caused a decline in streamflow and groundwater levels throughout Victoria. Assessing the relative impact of the climate (compared to other disturbances), on the hydrology of Boundary Creek will be informed by the numerical groundwater model and will be included in subsequent stages of this project (see Section 5.2).

### 2.5.7 Big Swamp

Big Swamp is a peat swamp located near the middle of the catchment downstream of McDonalds Dam (Figure 2-13). A fire was reported in the swamp on October 10 1997 (Colac Otway Fire Management Plan 2015), which suggests that it dried at some stage prior to this time. Subsequent fires presented at the surface at various times between 1997 and 2010, with the peat swamp burning underground throughout that period (Colac Otway Fire Management Plan 2015). Trenches up to 3 m deep were dug by the Country Fire Authority (CFA) at the margins of the swamp in an attempt to control the spread of the fire (Himmelreich 2010). The drying, fire and trenching have had considerable impacts on both the quantity and quality of water flowing out of the swamp.

There is no obvious main flow path of the creek through the swamp area, which would likely have been historically. If surface water is evident at all in the swamp, it is likely to be dispersed through a number of small, braided channels.

The current study has not considered in detail the condition or ecological values supported by Big Swamp. The groundwater-surface water interactions, soil composition and chemistry and management history of Big Swamp

is extremely complex but is critical to understanding the ecology of the lower sections of Boundary Creek. The purpose of this study is to assess the aquatic ecosystems and therefore it is beyond the scope to complete a comprehensive investigation of Big Swamp. Big Swamp will be the focus of a future, stand-alone study.

**Figure 2-13 Big Swamp.**

# 3. Hydrology of Boundary Creek

This section describes the surface water hydrological processes that influence the Boundary Creek catchment. The hydrology of the creek has been assessed to assist in the determination of the ecological values currently supported by the creek.

It should be noted that this study does not consider the hydrogeological processes underlying the surface water hydrology of Boundary Creek. An understanding of the groundwater-surface water interactions occurring in Boundary Creek catchment will be complete using the calibrated numerical model which is due to be completed in 2017.

In this section the flow data available in Boundary Creek has been reviewed to investigate the hydrology of the creek. The hydrological components that are important for helping us estimate the ecological values supported by Boundary Creek are then identified.

## 3.1 Flow gauges in Boundary Creek

There are five active stream flow gauges in the Boundary Creek catchment between Barongarook and Yeodone (Table 3-1). Three of these gauges have been recently installed or reinstated: Barongarook, upstream of McDonalds Dam and downstream of McDonalds Dam.

The only active long-term gauge is the one at Yeodene, in the lower part of the catchment. An overview of the monitoring record for each gauge is presented in Table 3-1. The locations of the gauges are shown in Figure 2-1.

**Table 3-1 Available gauge data for Boundary Creek**

| Gauge Number | Gauge Name | Period of record | Periods of missing data | Confidence in accuracy of data |
|---|---|---|---|---|
| bw763 | Release | At least 2002 – current | | High |
| 233273 | Barongarook | July 2014 – current | No periods of missing data. Level only, no stream flow data | Low (prior to Aug 2016)<br>Moderate (after Aug 2016) |
| 233231 | Upstream McDonalds Dam | Dec 1989 – Feb 1994<br>Mar 2015 – current | Feb 1994-June 2014. Data for 2014 may be unreliable due to a leak under the gauge control structure. | High |
| 233230 | McDonalds Dam **INACTIVE** | Dec 1989 – Feb 1994 | No periods of missing data. Level only, no stream flow data | High |
| 233229 | Downstream McDonald Dam | Dec 1989 – Feb 1994<br>Mar 2015 – current | None | High |
| 233228 | Yeodene | Mar 1985 – current | Minimal | High |

## 3.2 Reach 1

It is difficult to determine the natural flow regime in Reach 1 of Boundary Creek due to the influence of the supplementary flow. The 2 ML/day supplementary flow has been released into Boundary Creek since at least 2003 (Barwon Water 2004). To investigate the contribution of this flow on the hydrology of the upper part of Boundary Creek, we looked at the flow record from the release site (bw763) and at Barongarook (233273). The flow measured at these gauges is plotted in Figure 3-1.

It should be noted that the Barongarook gauge was unreliable until August 2016 as grass has grown around the gauge, which has caused inflated flow readings. This is most obvious between October 2015 and August 2016

and this period of the flow record should be ignored. Maintenance was undertaken on the gauge to remove the grass (pers. comm. Kate Maddy, Barwon Water, April 2016).

As shown in Figure 3-1 the 2 ML/day release contributes significantly to the baseflow in Reach 1 during the summer months. This is most clearly seen in April 2015, when the release was turned off for maintenance of the gauge upstream of McDonalds Dam. Boundary Creek at Barongarook during this period appeared to have also ceased to flow.

The evidence from these gauge sites suggests that the supplementary flow makes up a reasonably large proportion of the baseflow in Boundary Creek in the summer months.

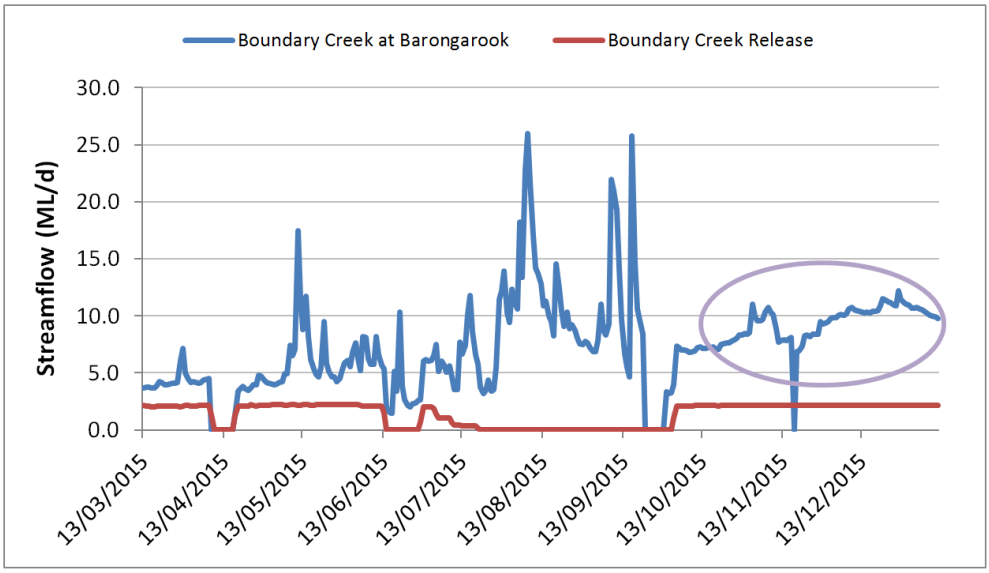



**Figure 3-1 Streamflow at the Barongarook gauge compared to the Release site (Reach 1). Purple circle indicates the period of the flow record that is likely to be unreliable.**

## 3.3 Reach 2

The major feature impacting flow in Reach 2 of Boundary Creek is McDonalds Dam. There are no historical flow records from before McDonalds Dam was constructed in approximately 1979. There are two gauges that have been installed recently, however, one located upstream and one located downstream of the dam. The flow recorded since March 2015 is shown in Figure 3-2.

The supplementary flow to Boundary Creek is released upstream of the dam and the operator is required to pass the 2 ML/day supplementary flow. During the winter months, presumably when the dam is full, the flow records at the gauges are almost identical. However during the summer months, there is some variability in the flow. At some points the inflow is less than the apparent outflow but at other times more water is being released than is entering the dam.

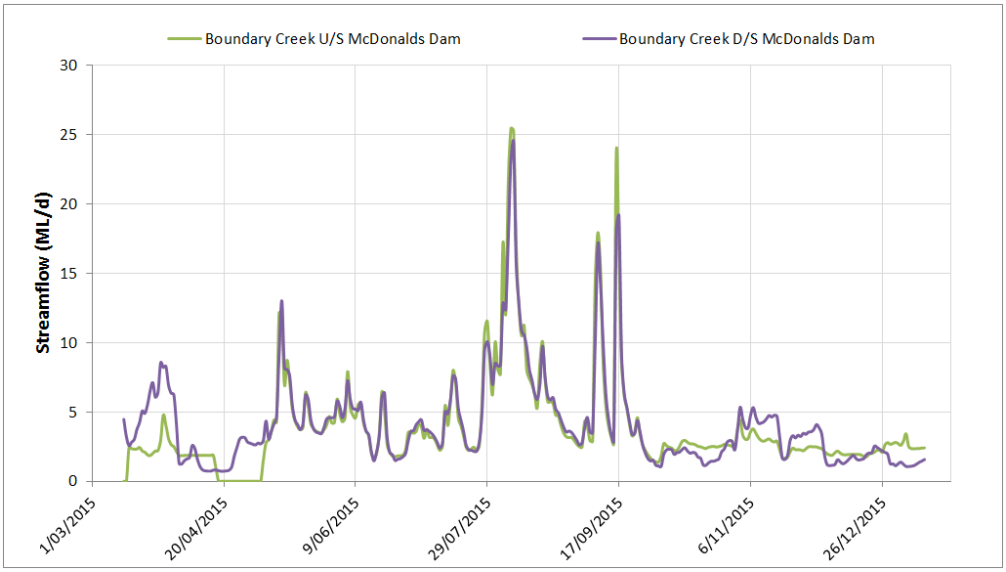



**Figure 3-2 Stream flow record from gauges in Reach 2.**

## 3.4 Reach 3

Boundary Creek stream flow is gauged upstream and downstream of Big Swamp at the gauge downstream of McDonalds Dam and at Yeodene. The flow record indicates that in the summer months Boundary Creek is flowing upstream of Big Swamp but not downstream (Figure 3-3). Flow magnitude is reduced downstream of the swamp in winter but to a minor extent. This is only a very short period of record, however, it shows that the supplementary flow is making it downstream of McDonalds Dam, but rarely downstream of Big Swamp in the summer months.

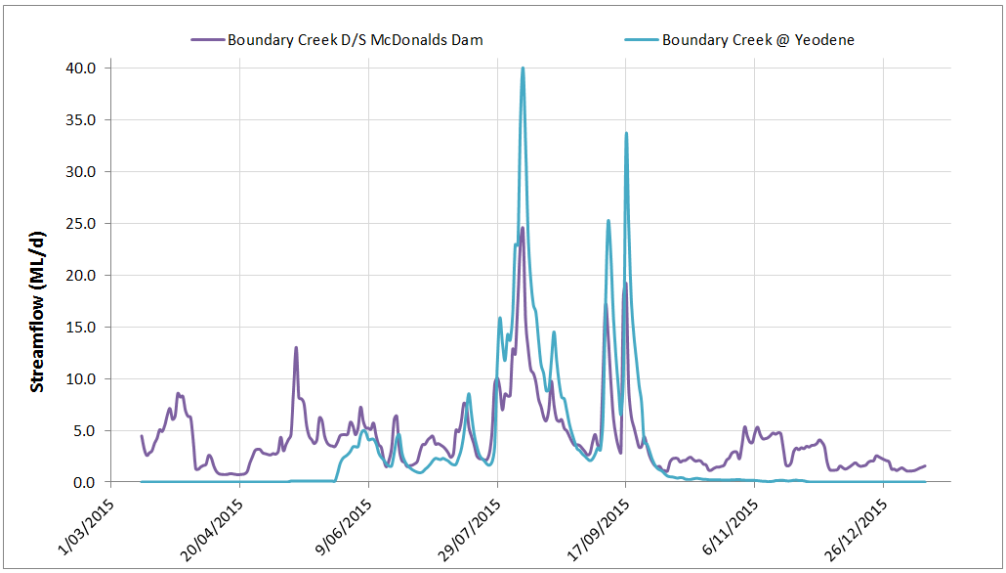



**Figure 3-3 Stream flow record from gauges upstream and downstream of McDonalds Dam.**

The flow record from the Yeodene gauge is the most complete in the catchment, having recorded flow continuously from 1985 to present (Figure 3-4). The flow data show a noticeable step change in the flow record in the late 1990s with a decrease in the magnitude of high flows and more periods of low flow.

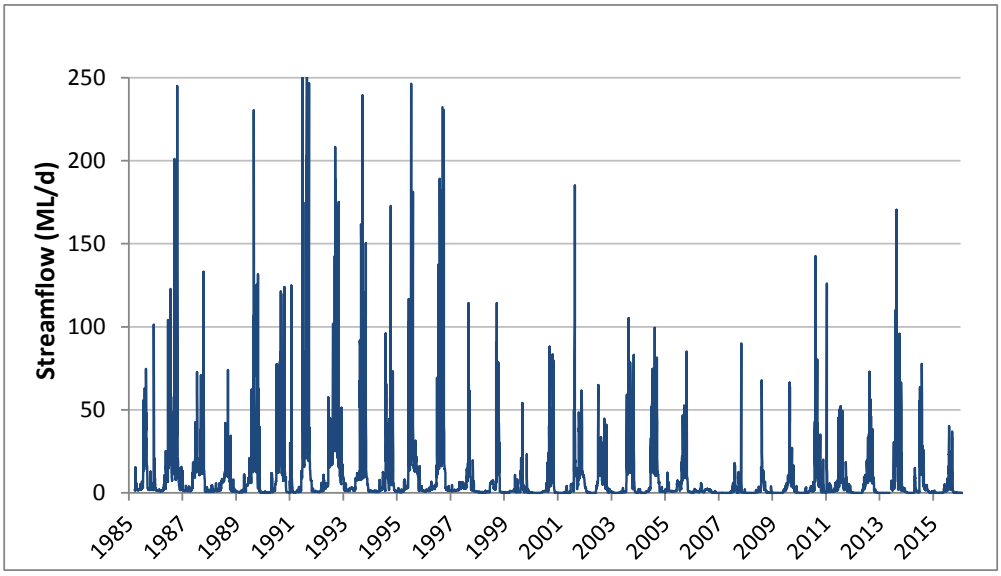



**Figure 3-4 Stream flow record in Boundary Creek at Yeodene (233228A) in Reach 3.**

This trend is clearer in Figure 3-5 which displays the amount of time that flow in Boundary Creek falls below 0.1 ML/day (effectively, ceasing to flow). These data show that surface water flow has ceased for long periods nearly every summer and autumn since 1999, however, before that time (1985-1998), Boundary Creek rarely stopped flowing (the only time being in autumn 1990).

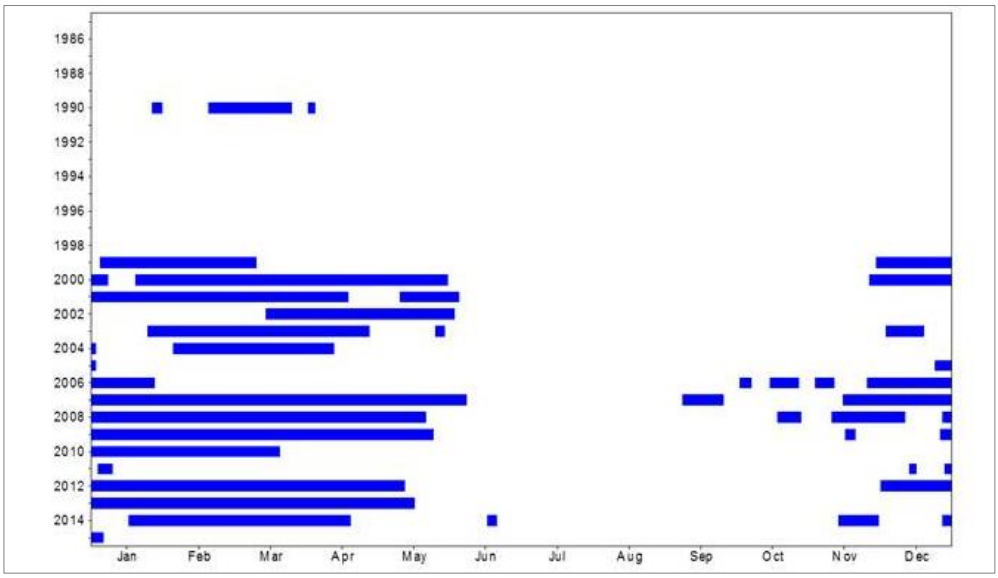



**Figure 3-5 Spells plot showing flows less than 0.1 ML/day at Yeodene (233228A)**

There is an obvious difference between the frequency of cease-to-flow events pre and post 1999, as demonstrated in the flow duration curve of summer and autumn months (Figure 3-6). Between 1986 and 1998 flow at the Yeodene gauge stopped approximately 2% of the time during summer and autumn months. After 1999 Boundary Creek at Yeodene stopped flowing approximately 58 % of the time during summer months. Occasional cease-to-flow events have been recorded at Yeodene in winter and spring since 1999 (Figure 3-7). The cause of this is not currently well understood.

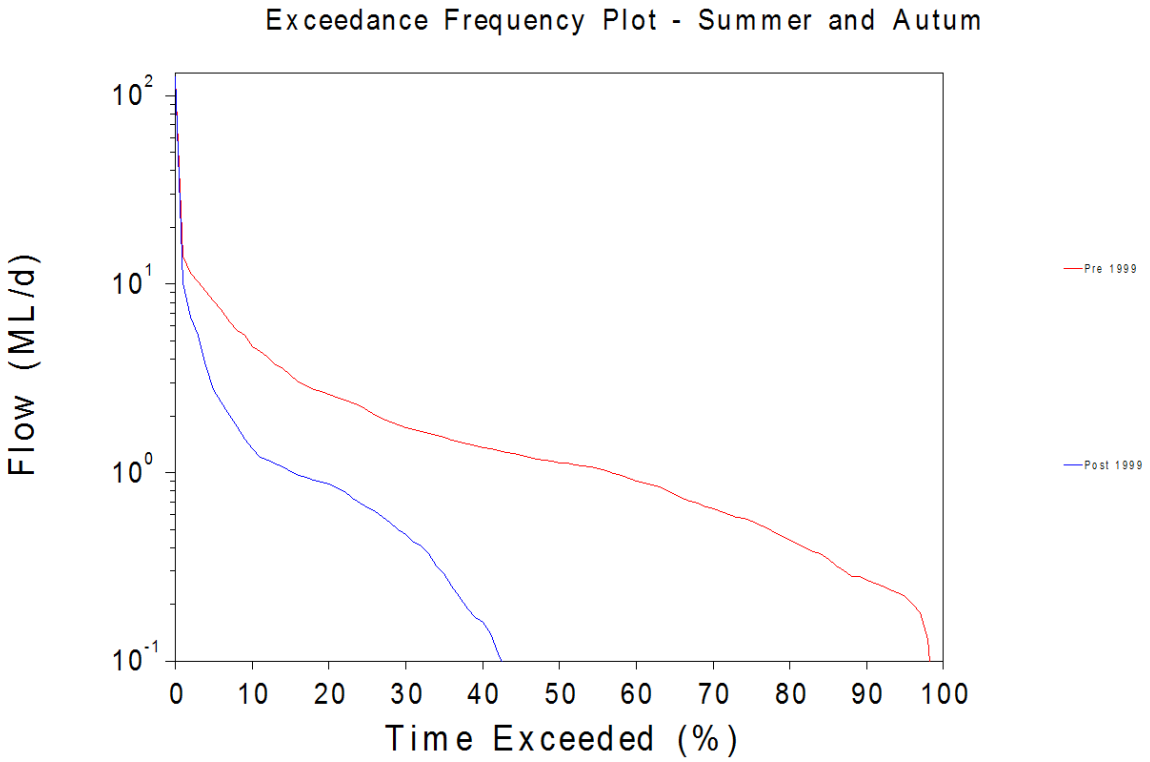



**Figure 3-6 Flow duration curve for summer and autumn months at Yeodene gauge (233288) pre (red) and post (blue) 1999.**

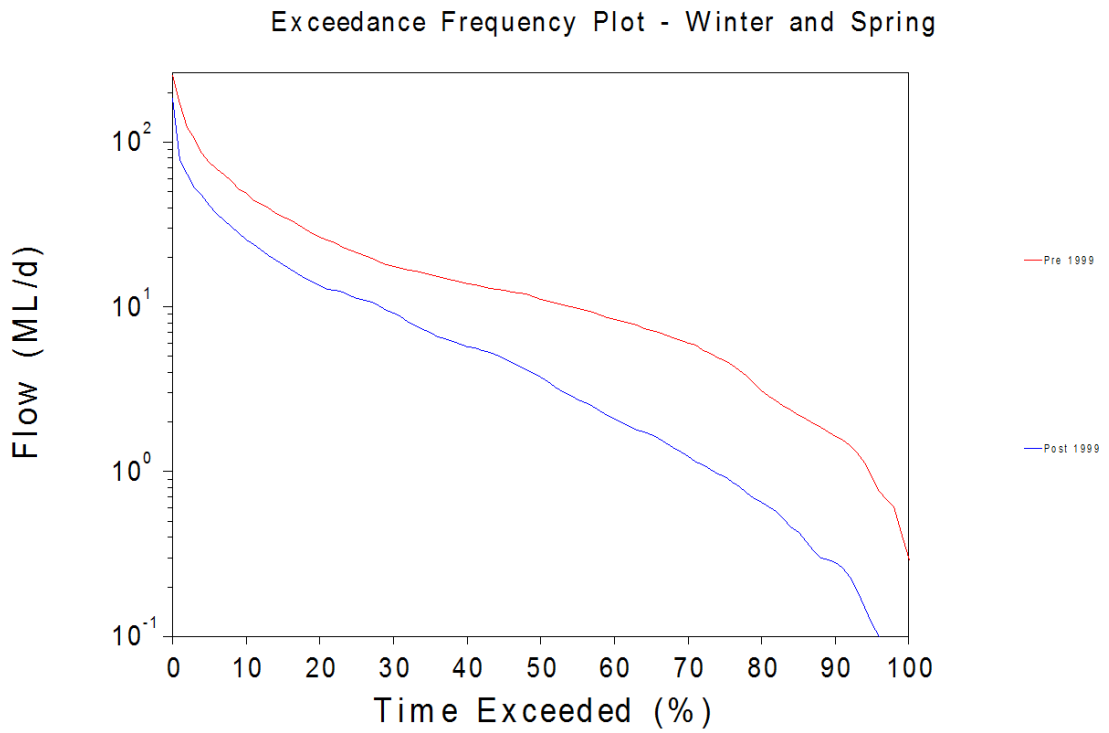



**Figure 3-7 Flow duration curve for winter and spring months at Yeodene gauge (233288) pre (red) and post (blue) 1999.**

## 3.5 Water quality in Boundary Creek

Water quality was measured in Boundary Creek during the macroinvertebrate monitoring in spring and autumn in 2014/2015. The water quality results for the sites in Reaches 1 and 2 (Barongarook, and upstream and downstream of McDonalds Dam) are fairly similar to each other and consistent over time (Table 3-2).

The site in Reach 3, Boundary Creek at Colac-Forrest Road, however, has significantly lower pH levels and dissolved oxygen than the upstream sites. The electrical conductivity at this site in spring was also very high compared to upstream and the alkalinity was low. While all other sites had flowing water during each sampling event, the site in Reach 3 was stagnant at the times of sampling.

The water quality in Reach 3 has been influenced by the acidification of soils in Big Swamp. It is beyond the scope of this study to investigate the causes and details of this acidification, but the consequence (i.e. the highly acidic water in Reach 3) is critical to the assessment of values.

**Table 3-2 Water quality recorded in Boundary Creek in spring 2014 and autumn 2015.**

| | Season | pH | Temp (°C) | Turbidity (NTU) | Salinity (EC) (µS/cm) | DO (mg/L) | DO (%) | Alkalinity (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Reach 1: Boundary Creek at Langdons Road, Barongarook | Spring | 6.55 | 12.8 | 9.02 | 183.3 | 10.45 | 100.8 | 10 |
| | Autumn | 6.61 | 12.2 | 9.45 | 172.1 | 7.3 | 70.6 | 10 |
| Reach 1 - Boundary Creek u/s McDonalds Dam | Spring | 6.51 | 13.4 | 11.8 | 280.20 | 9.92 | 94.0 | 15 |
| | Autumn | 7.07 | 12.5 | 23.9 | 216.2 | 7.93 | 77.0 | 15 |
| Reach 2 - Boundary Creek d/s McDonalds Dam | Spring | 6.58 | 17.7 | 8.37 | 387.4 | 6.40 | 68.1 | 15 |
| | Autumn | 6.90 | 14.3 | 8.22 | 261.9 | 8.18 | 82.7 | 15 |
| Reach 3 - Boundary Creek at Colac-Forrest Rd | Spring | 3.54 | 12.5 | 4.62 | 716 | 1.37 | 13.3 | 0 |
| | Autumn | 5.55 | 12.1 | 32.7 | 138.8 | 3.67 | 35.5 | 10 |

## 3.6 Comparisons with nearby gauged catchments

As part of this assessment, we investigated whether there were suitable nearby catchments that had been gauged which could be used provide more context to the flow observed in Boundary Creek over the recent past. We could not find catchments that shared similar characteristics in terms of area, landuse and grade that were also gauged. This comparison is therefore not possible with the data currently available.

## 3.7 Summary of the components of the hydrology of Boundary Creek important to estimating the ecological values currently supported by the creek

The following components of the surface water hydrology of Boundary Creek are important to consider when estimating the ecological values supported by each reach.

- The supplementary flow makes up a significant portion of the flow in Reach 1 (and possibly Reach 2) in the summer months.
- The flow in Boundary Creek is passed through McDonalds Dam reliably in the winter months, but there is variability in the inflow and outflow in the summer months.
- Flow is recorded throughout the summer upstream of Big Swamp, but rarely downstream of the swamp (at Yeodene).
- Boundary Creek rarely stopped flowing at any time of year prior to 1999, but since then has stopped flowing for long periods each summer.
- The water in Reach 3 of Boundary Creek (measured at the Yeodene gauge on the Colac-Forrest Road) is highly acidic.

# 4. Ecological values currently supported by Boundary Creek

The ecological values in the Boundary Creek catchment have not been described in detail previously. In this section, we estimate the species and communities that are likely to be supported by the creek by considering the limited records that exist from the catchment and nearby areas, the aquatic habitat in the creek and the current hydrology of the creek.

The ecological values in each reach are described in the following sections organised by group; vegetation, fish, macroinvertebrates, Platypus and frogs. For the groups we have not directly assessed (i.e. groups other than vegetation and macroinvertebrates), we have also assigned a rating (high, medium, low) reflecting our assessment of the probability that a particular species or community is supported by each reach. We also describe the qualitative flow needs of the values likely to be supported.

## 4.1 Vegetation

### 4.1.1 Current Ecological Vegetation Classes (EVC)

The Department of Environment, Land, Water and Planning (DELWP) maintain an online biodiversity register which shows the modelled pre-European (~1750) and current-day (2005) distribution of various vegetation groups, as well as their regional biodiversity conservation significance. The current day Ecological Vegetation Classes (EVC) in Boundary Creek catchment is quite different to prior to European settlement.

For example, the downstream parts of Boundary Creek no longer support any remnant native vegetation. The middle section has a narrow band of Swampy Riparian Woodland (EVC 83), but the vegetation is now discontinuous and isolated. Swampy Riparian Woodland is described as a woodland type associated with very low-gradient streams, typically as a linear wetland along the river (DEPI 2012). Swampy Riparian Woodland in the Boundary Creek catchment is described as 'endangered', which is the highest biodiversity conservation significance listing. Riparian Scrub/Swamp Woodland Complex (EVC 17), which previously lined the smaller tributaries, is largely intact.

The vegetation of Boundary Creek was assessed as part of the habitat assessments conducted in December 2014. The habitat assessment sites in each of the reaches (Table 2-1) were assessed during the field examination.

### 4.1.2 Vegetation supported in Reach 1

The habitat assessment site in Reach 1 (upstream of McDonalds Dam – Site 2) is situated in open forest. The narrow stream supports frequent beds of Water Ribbons (*Triglochin procerum*). Coloured water, likely a result of dissolved tannins probably derived from the surrounding vegetation was also observed during the site assessment. The overstorey vegetation was largely intact, and consisted of adult *Eucalyptus* and *Acacia* spp. The ground-layer was weedy and dominated by Blackberries (*Rubus* spp.) and pasture grasses that had presumably escaped from adjacent agricultural land. Occasional sedges and ferns (tree ferns and smaller fish-bone ferns, *Blechnum* spp.) were observed along the edges of the creek, but mainly on the northern bank. Our observations suggest that this riparian vegetation is likely reliant on groundwater soaks on the northern bank of the creek rather than surface flow.

The habitat assessment site in Reach 1 is likely to be representative of the vegetation in the sections that still retain an intact riparian zone. Examination of aerial imagery suggests that the sections that have been cleared for agriculture do not support any riparian vegetation.

### 4.1.3 Vegetation supported in Reach 2

The habitat assessment site in Reach 2 (upstream of Big Swamp – Site 3) is a large ‘dampland’ with a dense canopy of *Melaleuca squarrosa* and *Leptospermum lanigerum* and a wetland ground-layer of diverse sedges, rushes and reeds. The presence, among other species, of the following taxa of vascular plants was noted: *Eucalyptus ovata* and *Acacia melanoxylon* as canopy species, *Melaleuca squarrosa*, *Leptospermum lanigerum*,

*Bursaria spinosa* (Sweet Bursaria) and *Kunzea* spp. forming the shrub layer (and in the absence of taller trees, the canopy layer as well), and a diverse suite of wetland/dampland emergent species including *Gahnia sieberiana* (Red-fruit Saw-sedge), *Carex appressa* (Tall Sedge), and *Lepidosperma elatius* (Tall Saw-sedge).

Much of the riparian vegetation upstream of the 'damplands' has been cleared to support agriculture. Downstream of the 'damplands' is Big Swamp, which has a different vegetation community to the 'damplands'. While Big Swamp does support ecological values that need to be considered as part of an integrated understanding of Boundary Creek, the complexity of the groundwater-surface water interactions and soil chemistry means that it is beyond the scope of this study to consider them here.

### 4.1.4 Vegetation supported in Reach 3

There is a distinct change in the vegetation downstream of the Colac-Forrest Road (the habitat assessment site in Reach 3) compared to upstream. Downstream of the Colac-Forrest Road the vegetation has been heavily modified to allow intensive agriculture, although some riparian fencing and re-vegetation has been undertaken in this area. The river at the habitat assessment site has been channelised and largely cleared of native vegetation, although the riparian zone upstream of the road crossing was re-vegetated 10-15 years ago. It has a mature eucalypt overstorey and a dense mid storey layer. Some sections of the creek downstream of the Colac-Forrest Road have also been fenced and re-vegetated.

### 4.1.5 Qualitative flow needs of the vegetation in Boundary Creek

The field guide to Victorian wetland EVCs (DEPI 2012, page 128) notes that EVC 937 Swampy Woodland is a '… poorly understood vegetation type'. Nevertheless, it is known that EVC 937 occurs on poorly drained but seasonally waterlogged heavy soils that are watered by seepage and/or local runoff rather than direct flooding from the stream. If this is the case for the other EVCs present along the creek in Reach 1 (which is a reasonable assumption), it is likely that prolonged periods of low flow in the creek maintain moist conditions in the soils fringing the stream, and higher flows (e.g. freshes) of variable frequency episodically wet more elevated parts of the bank and riparian zone. The higher flows, which would occur following rain events, would also support water-dependent vegetation such as ferns. The low flows in the creek facilitate the growing of the Water Ribbons observed in Reach 1.

The flow needs of the 'dampland' vegetation in Reach 2 are poorly understood. The best source of information on the water needed to maintain the floristically complex ground and shrub layers in the 'dampland' (e.g. Red-fruit Saw-sedge, Tall Sedge, and Tall Saw-sedge etc) come from studies of broadly similar systems in Western Australia (e.g. Froend *et al.* 1993, Chambers *et al.* 1995, Water and Rivers Commission 2001). These Western Australian and other relevant reports (e.g. more locally, from Florabank) indicate that the ground and shrub layer taxa observed in Reach 2 are drought-sensitive and many require almost permanent waterlogging to survive and to reproduce. The canopy-forming species (e.g. *Eucalyptus ovata* and *Acacia melanoxylon*; *Melaleuca squarrosa*, *Leptospermum lanigerum*, *Bursaria spinosa* and *Kunzea* spp.), are likely to be more tolerant of periodic drying, and thus only require seasonal inundation. Small variations in topography within the site creates a spatial and temporal mosaic of subtly different wetting and drying regimes that are likely to be critical for maintaining a structurally and floristically diverse understorey, and healthy tea-tree and paperbark adults (Raulings *et al*. 2010, Boon 2011).

The 'dampland' in this reach probably forms because of the almost permanently waterlogged soils in the area. It is not currently known how important surface water is to maintaining the waterlogged soils in this area. The surface water-groundwater interactions are likely to be important to the functioning of Boundary Creek and further work is recommended to investigate this.

If flow was provided to Reach 3, that was of suitable quality (i.e. not acidic) then some aquatic plants may be supported. The influence of Big Swamp on the ecology of Reach 3 will be considered as part of future studies.

## 4.2 Fish

The information presented in this section is based on a review of records in the Victorian Biodiversity Atlas (DELWP 2015), archival material provided by Southern Rural Water and data reports produced from other targeted fish surveys in the region (e.g. Turnbridge 1988, Zampatti and Grgat 2000, Zampatti and Koster 2002).

### 4.2.1 Victorian Biodiversity Atlas records

The Victorian Biodiversity Atlas (VBA) records from Boundary Creek include four native species:

- Mountain Galaxias (*Galaxias olidus*)
- Southern Pygmy Perch (*Nannoperca australis*)
- Short-finned Eel (*Anguilla australis*)
- River Blackfish (*Gadposis marmoratus*)

Two introduced species have also been recorded:

- Brown Trout (*Salmon trutto*)
- Redfin Perch (*Perca fluviatilis*).

The vast majority of records are from the early 1990s or before.

### 4.2.2 Records from Turnbridge (1988)

Only one fish survey has been conducted specifically in Boundary Creek and this was undertaken by Turnbridge in 1988. Turnbridge (1988) surveyed the fish community of Boundary Creek at about the location of the Colac-Forrest Road (Reach 3) and found four native species:

- Southern Pygmy Perch (*Nannoperca australis*)
- Short-finned Eel (*Anguilla australis*)
- River Blackfish (*Gadposis marmoratus*)
- Dwarf Galaxias (*Galaxiella pusilla*) - listed as vulnerable under commonwealth legislation (Environment Protection and Biodiversity Conservation (EPBC) Act 1999, and listed under the Victorian Flora and Fauna Guarantee (FFG) Act 1988)

Turnbridge also recorded the introduced Brown Trout (*Salmon trutto*).

### 4.2.3 Anecdotal records

In 1990 the Rural Water Commission surveyed landowners and local community members in the Boundary Creek catchment to document any changes in streamflow or biological condition they had observed since the Barwon Downs Scheme was commissioned (Peter 1990). That report includes two specific references to fish. J. W. McCready, who held a property just downstream of Big Swamp, indicated that Boundary Creek supported a breeding population of River Blackfish. In addition, small fish were visible near the confluence with the Barwon River, although the species were not identified.

### 4.2.4 Records from nearby systems

Zampatti and Grgat (2000) and Zampatti and Koster (2002) conducted a series of fish surveys in the Barwon River between 1998 and 2000. Boundary Creek was not surveyed directly. Eight native species were recorded

from the three survey sites closest to Boundary Creek. In addition to the native species recorded on the VBA and by Turnbridge (1988), the Yarra Pygmy Perch (*Nannoperca obscura*), Flat-headed Gudgeon (*Philypnodon grandiceps*), Australian Smelt (*Retropinna semoni*) and Common Galaxias (*Galaxias maculatus*) were also found. The Yarra Pygmy Perch is classified as vulnerable under the commonwealth's Environment Protection and Biodiversity Conservation (EPBC) Act 1999 and is listed under the state of Victoria's Flora and Fauna Guarantee (FFG) Act 1988.

### 4.2.5 Changes in the catchment since 1988

Since 1988 (when Turnbridge's study was completed), there have been significant changes in the catchment that have been discussed previously and have altered the habitat for fish populations in all three reaches. The impacts that these changes have had on fish habitat are outlined below:

- Reach 1 may have experienced cease to flow events prior to the 2 ML/day supplementary flow release which commenced in the early 2000s. Currently the reach has good in stream habitat for fish with permanent pools, although McDonalds Dam prevents movement of most fish species.
- Reach 2 contains the 'dampland' and Big Swamp which provide poor in-stream habitats.
- The hydrology of Reach 3 has changed significantly since the late 1990s and the reach is now dry for long periods and has highly acidic water entering from Big Swamp.

These changes have been considered in the assessment of the fish species likely to be supported by each reach.

### 4.2.6 Fish species likely supported in Reach 1

There are small riffles in Reach 1 and longer pool/run sections up to 50 cm deep. There is also a high amount of fringing and aquatic vegetation that would provide good quality habitat for a range of fish species. As the catchment is small and water depth would probably not have been high in this area naturally, historically it is likely that predominantly small bodied fish would have been supported. This would include all of the species that we know have previously been supported by Boundary Creek or nearby catchments (River Blackfish, Dwarf Galaxias, Southern Pygmy Perch, Yarra Pygmy Perch, Flathead Gudgeon, Mountain Galaxias Common Galaxias, Australian Smelt and Short-finned Eel). However, the changes in the catchment over the past 25 years mean that the number of species likely to be supported currently is much lower.

The habitat in Reach 1 is suitable to potentially support Common Galaxias and Australian Smelt. However, both of these species are diadromous, meaning they need to migrate to the ocean or to lakes to complete their life cycles (McDowall 1996; Lintermans 2007). Neither of these species are able to overcome large fish barriers and therefore McDonalds Dam would prevent these species from colonising Reach 1 following spawning. Short-finned Eels are also diadromous, but can overcome fish barriers.

The pools in Reach 1 would provide refuges for fish during low flow periods, but would probably become unsuitable during extreme low flows. If during the Millennium Drought the creek dried completely or ceased to flow for long periods (i.e. months), fish would have had to find refuge habitat in McDonalds Dam. If McDonalds Dam also dried, or didn't provide suitable refuge habitat, then fish species would have been lost from Reach 1. The only species that would have been able to recolonise once flows returned would be species that can overcome fish barriers, which in Boundary Creek is only likely to be the Short-finned Eel.

In summary, we have a high level of confidence that Reach 1 would support Short-finned Eels. The hardy, small-bodied species, the Flathead Gudgeon and Mountain Galaxias could probably have found refuge habitat in dry times and do not need to migrate and therefore it is a moderate probability that these species could be supported by Reach 1. River Blackfish, Southern Pygmy Perch, Yarra Pygmy Perch and Dwarf Galaxias could theoretically be supported by Reach 1, however, it is unlikely (and therefore are assigned a low probability).

### 4.2.7 Fish species likely supported in Reach 2

For most of Reach 2 Boundary Creek flows through the 'dampland' and Big Swamp, although some areas of defined channel are present just downstream of the dam and deeper pools are found intermittently upstream of the Big Swamp. Through the 'damplands' and the Big Swamp, the flow path is dispersed through a number of smaller channels, with water depth (at the time of the assessment in December 2014) being about 10 cm in the dispersed flow paths. The water was flowing at the time of the assessment, likely due to the 2 ML/day release at Busby Road being passed downstream of McDonalds Dam. It is unclear what the water level would be without this flow, however, it is likely that the surface water depth in the 'dampland' and swamp areas would not be more than 10-15 cm in the channel (although it would be deeper in the intermittent pools in this area).

Due to the shallow depth of the channel in this area, the 'dampland' and Big Swamp are unlikely to represent high quality habitat for fish. If any fish do use this area, they are likely to be small bodied species that are tolerant of a range of habitat types, such as the Flathead Gudgeon. Southern Pygmy Perch and Dwarf Galaxias may use the few deep pools in the area (such as those downstream of the detailed assessment site). Fish would probably be able to pass through this habitat during higher flows but most species would then be stopped moving further upstream by McDonalds Dam.

Reach 2 provides only limited habitat to support resident fish populations. Flathead Gudgeon have a moderate probability of being present. Southern Pygmy Perch and Dwarf Galaxias may find some suitable habitat in this reach, however, this is only a low probability.

### 4.2.8 Fish species likely supported in Reach 3

Pre-European settlement, Reach 3 would have likely been a marshy area. It was channelised probably shortly following settlement of the area to convey flows efficiently to the Barwon River and to open up the area for agriculture. When it was a marsh it was unlikely to have supported many fish species, however, they would have been able to pass through under high flows.

The creek in Reach 3 is primarily now a trapezoidal channel, however, as identified by Turnbridge (1988) and Lloyd et al. (2005), this reach has some diverse aquatic habitat. Turnbridge (1988) noted that habitat where he completed his survey consisted of a pool (40 cm in depth) and a riffle flowing over a mud substrate (flowing at 35 cm/sec). Lloyd et al. (2005b) also commented that the aquatic habitat was surprisingly good, particularly in areas where the riparian zone had been re-vegetated. Pools of 40 cm depth with aquatic and fringing vegetation and woody debris would have been suitable to support all of the species that have been recorded as occurring in Boundary Creek by Turnbridge 1988.

The water quality in Reach 3 is now highly acidic and Reach 3 is now dry for significant periods in most summers. Therefore, it is very unlikely the Reach 3 supports any resident populations of fish.

### 4.2.9 Qualitative flow needs of the fish in Boundary Creek

There are small riffles in Reach 1 and longer pool/run sections up to 50 cm deep. There is also a high amount of fringing and aquatic vegetation that would provide good quality habitat for a range of fish species. Flow that maintains the water level in pools would allow the predicted small bodied native fish species to be present in this reach. Most fish species could probably survive periods of up to a month or maybe more of being restricted to isolated pools if flows fall and the riffles become too shallow to cross, provided that water quality remains suitable in the pools.

Most of Reach 2 is unlikely to represent good habitat for many fish species, with most species likely to be able to move through this reach during higher flow periods, but unlikely to be resident during low flow. The small bodied species that could use this reach more than just temporarily would probably be supported by the deeper pools downstream of the habitat assessment site. If surface water flow is playing a part in maintaining the pools in Reaches 2 then it is likely to be important for supporting any of the fish that are present.

Reach 3 is not currently suitable to support fish. It is possible that at times of the year that the flow could be sufficient and the water quality suitable to support occasional use by fish from the upper Barwon River, but Reach 3 is unlikely to support resident fish populations.

## 4.3 Macroinvertebrates and crustaceans

Macroinvertebrates are an important part of aquatic ecosystems. They constitute a major source of food for other macroinvertebrates, fish, Platypus, frogs and waterbirds and complete a number of important ecosystem processes such as nutrient cycling and decomposition (Wallace and Webster 1996). The composition and condition of the macroinvertebrate community in a given stream or at a particular site is often used as an indicator of the stream's health.

### 4.3.1 Previous studies

Macroinvertebrates have not been surveyed in Boundary Creek before this study. Canale *et al.* (2001) assessed condition at three sites in the upper Barwon River and five sites in the Barwon River near Winchelsea and compared the composition of macroinvertebrate communities against objectives set out in the State Environmental Protection Policy (SEPP). The SEPP provides objectives for biological measures in each of the bioregions throughout Victoria. All of the surveyed sites failed to meet SEPP guidelines, and therefore they concluded that the sites were degraded and subject to mild pollution. Canale *et al.* (2001) did not directly investigate the macroinvertebrate communities at Boundary Creek.

The only other large scale macroinvertebrate sampling conducted in the catchment was as part of the statewide *Index of Stream Condition* (ISC) Assessment. The condition of the macroinvertebrate communities was directly assessed in the upper Barwon River, but did not include Boundary Creek. Like the results reported by Canale *et al.* (2001) the ISC assessment found that communities in both reaches of the upper Barwon River were moderately degraded compared to the reference state.

The VBA has records of three crustacean species from Boundary Creek (DELWP 2015);

- Otway Bush Yabby (*Geocharax gracilis*)
- Southern Victorian Spiny Crayfish (*Euastacus yarraensis*)
- Freshwater Shrimp (*Paratya australiensis*)

The Otway Bush Yabby is listed as endangered on the *Advisory List of Threatened Invertebrate Fauna in Victoria* (DSE 2009), the main threats to its persistence coming from habitat loss, particularly agricultural development and pollution (Johnston and Schultz 2010). March and Robson (2006) found that areas of stream with intact natural riparian vegetation cover overhanging the stream, low soil compaction and good water quality had a higher density of burrows than streams with thin vegetation and stock access. Otway Yabbies build burrows that are connected to the groundwater (i.e. their burrows are in, or connect with, waterlogged soils) and therefore changes to groundwater levels also may threaten the local persistence of this species (Johnston and Schultz 2010).

### 4.3.2 Macroinvertebrate survey in Boundary Creek (current assessment)

A macroinvertebrates survey of Boundary Creek was completed as part of the current study. The full report is presented in Appendix A and the results are summarised below.

The results of sampling undertaken at the four sites throughout the catchment (Table 2-1) indicate that the macroinvertebrate community of Boundary Creek degrades from the headwaters (Reach 1) to the confluence with the Barwon River.

Our assessment used the AUSRIVAS method, one of the outputs being a categorisation of the observed compared to the expected number of taxa at a site, which gives an indication of how similar the site is to a reference, or unimpacted site. The AUSRIVAS Reporting Bands are presented in Table 4-1.

Overall, it was assessed that Site 1 (the most upstream sampling location near Langford Road) was **Band A**, similar to reference condition. Site 2 and Site 3, upstream and downstream of McDonalds Dam respectively were assessed to be **Band B**, indicating a significantly impaired community compared to reference. The most downstream site, at Colac-Forrest Road (Site 4) was assessed to be **Band C**, indicating a severely impaired macroinvertebrate community.

The lack of flow and poor water quality was highlighted as an obvious impact on the lower part of the creek which may explain the poor condition of the community in Reach 3.

**Table 4-1 AUSRIVAS Reporting Bands**

| Band Label | Band Name | Band Description |
|---|---|---|
| Band X | More biologically diverse than reference sites. | More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment |
| Band A | Reference condition. | Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity. |
| Band B | Significantly impaired. | Fewer families than expected. Potential impact either on water quality or habitat quality or both resulting in loss of taxa. |
| Band C | Severely impaired. | Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality. |
| Band D | Extremely impaired. | Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded. |

### 4.3.3 Qualitative flow needs of the macroinvertebrates and crustaceans in Boundary Creek

In Reach 1, the excellent macroinvertebrate community probably indicates that the flow in this reach is engaging the emergent and aquatic vegetation and providing flow over riffles for the majority of the time.

At Reach 2, the major flow need would be for the Otway Bush Yabby. As outlined, this species build burrows that are connected to the groundwater and so their likely presence in Reach 2 suggests that the yabbies are able to access groundwater in this area. There is a diversity of physical habitat (vegetation, woody substrate) in this reach and the surface water that does flow likely supports the diverse array of macroinvertebrates.

The community of Reach 3 is significantly impaired, a consequence of the intermittent flow regime and poor water quality in this reach.

## 4.4 Platypus

It is not known whether Platypus (*Ornithorhynchus anatinus*) currently use habitat in Boundary Creek, however, their habitat preferences suggest that at least parts of Boundary Creek would be suitable. Platypus normally build their burrows on steep or undercut banks that are at least 1 m high and which have dense vegetation or tree root cover. This vegetation cover allows animals to move safely from the burrow to the water without being detected by predators (e.g. foxes) and also protects the burrow from erosion (Serena *et al.* 1998). To safeguard the burrow from flooding, the opening is normally at least 0.5 m above the normal water level (Serena *et al.* 1998).

Platypus have not been recorded in Boundary Creek, although anecdotal records suggest that they may have been present historically. There is an established population in the west Barwon River, with McKinnon and Milner (2009) recording 15 individuals in 24 net-nights of fyke-netting effort in February 2009. The Australian Platypus Conservancy (APC) also confirmed the presence of Platypus in the Barwon River near Birregurra (APC 2002). Occasional sightings have also been made in Pennyroyal Creek, which joins the Barwon River downstream of Birregurra and Callahan Creek which is small tributary in the upper reaches of the West Branch of the Barwon River, up until about the mid-1990s (Melody Serena, APC, pers. comm.)

Ideal foraging habitats for Platypus are pools that are at least 0.5 m deep, which provides cover, but are not so deep that individuals use significant energy accessing the river bed (Serena *et al.* 2001, Bethge *et al.* 2003). Platypus most often use slow flowing environments and stick to submerged backwater habitats during high flow events (Gust and Handasyde 1995). Platypus can have large home ranges and can forage an area up to approximately 7 km in length. Continuous sections of aquatic habitat are therefore preferred as they are vulnerable to predation if they need to move overland to access foraging habitat (Serena *et al.* 1998).

### 4.4.1 Probability that Platypus could be supported by Reach 1

While the habitat in Reach 1 may be suitable to support Platypus (e.g. near Langdons Road and upstream and within McDonalds Dam), it is only a low probability that they are present. Platypus are unlikely to be found in Reaches 2 and 3 of Boundary Creek (see below) which means that if they are present at all in Reach 1, they would be disconnected from other populations in the upper Barwon and therefore are unlikely to be found in significant numbers. Platypus are therefore rated as having a low probability of occurring in Reach 1.

### 4.4.2 Probability that Platypus could be supported by Reach 2

It is highly unlikely that Reach 2 would provide suitable habitat for Platypus. The dispersed flow path through the 'damplands' probably does not provide sufficient depth of water to allow Platypus to swim or forage successfully without the significant risk of predation. The cleared, agricultural channel upstream of the 'damplands' would not be suitable to support Platypus.

### 4.4.3 Probability that Platypus could be supported by Reach 3

The channelisation and lack of native vegetation in the lower section of Boundary Creek (Reach 3) means that the creek in this area does not provide suitable habitat for Platypus. The highly acidic water and lack of flow in summer also makes Reach 3 unsuitable.

### 4.4.4 Qualitative flow needs of Platypus in Boundary Creek

There is only a low probability that Reach 1 supports Platypus. However, the inundated pools with connecting flow most of the time that provide sufficient food resources could, theoretically, support Platypus in this reach.

It is unlikely that Reaches 2 or 3 would support resident populations of Platypus.

## 4.5 Frogs

The VBA has records of two frog species in the Boundary Creek area: the Common Froglet (*Crinia signifera*) and the Victorian Smooth Froglet (*Geocrinia victoriana*). The Common Froglet records are all from 1990 and come from the Six Mile Dam, which is at the very top of the catchment, near the Colac-Lavers Hill Road. Four Victorian Smooth Froglet records are present from the Boundary Creek area, three from Barongarook in 1972, 1979 and 1987 and one from the Colac-Forrest Road in 1979.

Pobblebonks (*Limnodynastes dumerilii*) were also heard during the site assessment for this project in December 2014 in the vicinity of the Big Swamp.

Although, they haven't been formally recorded, based on their distribution and habitat preferences (as per Cogger 2000), the Southern Brown Tree Frog (*Litoria ewingii)*, Striped Marsh Frog (*Limnodynastes peronii*) and the Spotted Marsh Frog (*Limnodynastes tasmaniensis*) are also likely to occur in or near the Boundary Creek area.

Each of the species recorded, or predicted to occur, in Boundary Creek are common and abundant. Each is also able to use a wide range of habitats.

### 4.5.1 Habitat requirements of potentially supported frog species

Most Victorian frog species require surface water for foraging and breeding at some stage during their life cycle. Different frog species can breed in a variety of water bodies ranging from rain-fed ponds and small depressions to rivers and river-flow controlled wetlands. However, generally speaking all breeding water bodies must satisfy three broad requirements:

1) Surface water must be available at the right time of year (i.e. during the breeding season, which for most species is winter/spring). This is because the majority of Victorian frog species amplex (mate) in water and lay their eggs near, or attached to, fringing vegetation.
2) The water body (pool, pond, wetland) needs to hold water long enough to allow tadpoles to develop into adult frogs (metamorphose). The required hydroperiod varies for different species, but also depends on water temperature, food availability and predation pressure (Anstis, 2007). The hydroperiod can be as short as 6 weeks for small, fast developing species, and up to 12 months for larger species (Wassens 2011).
3) Still or very slow flowing conditions are maintained for as long as tadpoles are present in the waterbody because tadpoles are not strong swimmers and can easily be washed out of suitable habitats if high flows occur at the wrong time (Wassens 2011).

### 4.5.2 Frog species likely supported in Reach 1

Reach 1 consists of a series of pool and runs with a high amount of emergent and submerged vegetation along the channel. McDonalds Dam is also included in Reach 1. Reach 1 provides a diversity of suitable frog habitat frogs and therefore is likely to support each of the species recorded or predicted to occur in the catchment.

### 4.5.3 Frog species likely supported in Reach 2

Similarly, Reach 2, in particular the ‘damplands’ provides a diversity of suitable habitat for frogs. Each of the species recorded, or predicted to occur, has a high probability of being present in Reach 2.

### 4.5.4 Frog species likely supported in Reach 3

The trapezoidal channel of Reach 3 is not ideal for frogs, however, each of the species recorded in the area are habitat generalists and may be able to use the area. The low pH water and the lack of flow considerably reduces the suitability of this area for frogs. As a consequence, Reach 3 has only a low probability of supporting the frog assemblage of the upper reaches of Boundary Creek.

### 4.5.5 Qualitative flow needs of frogs in Boundary Creek

The frog species likely to occur in Boundary Creek are able to use a wide diversity of habitats. It is likely that those that are present are using a variety of in-channel and associated habitats, the main requirement being that the flow velocity is low and that the inundation period covers the time that tadpoles are developing, which for most species is winter/spring.

## 4.6 Summary of ecological values

Table 4-2 summarises the ecological values estimated to be supported in each of the three reaches in Boundary Creek.

**Table 4-2 Summary of ecological values in the three reaches of Boundary Creek.**

| Ecological value | High probability | Medium probability | Low probability | Extremely low probability | Qualitative flow needs |
|---|---|---|---|---|---|
| **Reach 1** | | | | | |
| **Vegetation** | Overstorey consisting of *Eucalyptus* and *Acacia.* Weedy ground layer with occasional sedges and herbs. Frequent beds of Water Ribbon in the channel. | | | | Prolonged periods of low flow in the creek maintain moist conditions in the soils fringing the stream required for Swampy Woodland. Periodic higher flows (e.g. freshes) of variable frequency episodically wet more elevated parts of the bank and riparian zone and support ferns. The low flows in the creek facilitate the growing of the Water Ribbons. |
| **Fish** | Short-finned Eel | Flathead Gudgeon, Mountain Galaxias | River Blackfish, Southern Pygmy Perch, Yarra Pygmy Perch, Dwarf Galaxias | | Flow that maintains the water level in pools would allow the predicted small bodied native fish species to be present in this reach. Most fish species could probably survive periods of up to a month or maybe more of being restricted to isolated pools if flows fall and the riffles become too shallow to cross, provided that water quality remains suitable in the pools. |
| **Macroinvertebrates and crustaceans** | Macroinvertebrates communities in excellent condition (AURIVAS Band A – Reference condition) | | | | In Reach 1, the excellent macroinvertebrate community probably indicates that the flow in this reach is engaging the emergent and aquatic vegetation and providing flow over riffles for the majority of the time. |
| **Platypus** | | | Platypus | | There is only a low probability that Reach 1 supports Platypus. However, the inundated pools with connecting flow most of the time that provide sufficient food resources could, theoretically, support Platypus in this reach. |
| **Frogs** | Victorian Smooth Froglet, Common Froglet, Pobblebonk, Striped Marsh Frog, Spotted Marsh Frog, Southern Brown Tree Frog | | | | It is likely that the species that are present are using a variety of in-channel and associated habitats, the main requirement being that the flow velocity is low and that the inundation period covers the time that tadpoles are developing, which for most species is winter/spring. |
| **Reach 2** | | | | | |
| **Vegetation** | 'Dampland' with a dense canopy of *Melaleuca squarrosa* and *Leptospermum lanigerum* and a wetland ground-layer of diverse sedges, rushes and reeds. | | | | The 'dampland' in this reach probably forms because of the almost permanently waterlogged soils in the area. It is not currently known how important surface water is to maintaining the waterlogged soils in this area. Cleared riparian zone in other sections of Reach 2. |

| Ecological value | High probability | Medium probability | Low probability | Extremely low probability | Qualitative flow needs |
|---|---|---|---|---|---|
| **Fish** | | Flathead Gudgeon | Southern Pygmy Perch, Dwarf Galaxias | | The small bodied species that could use this reach more than just temporarily would probably be supported by the deeper pools downstream of the habitat assessment site. If surface water flow is playing a part in maintaining the pools in Reaches 2 then it is likely to be important for supporting any of the fish that are present. |
| **Macroinvertebrates and crustaceans** | Macroinvertebrates communities in moderate condition (AURIVAS Band B – Significantly impaired).<br>Otway Busy Yabby | | | | At Reach 2, the major flow need would be for the Otway Bush Yabby. This species build burrows that are connected to the groundwater (i.e. their burrows are in, or connect with, waterlogged soils) and so their likely presence in Reach 2 suggests that the yabbies are able to access near constantly waterlogged soils in this area. |
| **Platypus** | | | | Platypus | It is unlikely that Reach 3 would support resident populations of Platypus. |
| **Frogs** | Victorian Smooth Froglet, Common Froglet, Pobblebonk, Striped Marsh Frog, Spotted Marsh Frog, Southern Brown Tree Frog | | | | It is likely that the species that are present are using a variety of in-channel and associated habitats, the main requirement being that the flow velocity is low and that the inundation period covers the time that tadpoles are developing, which for most species is winter/spring. |
| **Reach 3** | | | | | |
| **Vegetation** | Largely cleared of native vegetation, although the riparian zone upstream of the Colac-Forrest Road crossing was re-vegetated 10-15 years ago. It has a mature eucalypt overstorey and a dense mid storey layer. Some sections of the riparian zone downstream of the road has also been re-vegetated. | | | | If flow was provided to Reach 3, that was of suitable quality (i.e. not acidic) then some aquatic plants may be supported. The influence of Big Swamp on the ecology of Reach 3 will be considered as part of future studies. |
| **Fish** | | | | Fish unlikely to be supported at all by Reach 3. | Reach 3 is not currently suitable to support fish. It is possible that at times of the year that the flow could be sufficient and the water quality suitable to support occasional use by fish from the upper Barwon River, but Reach 3 is unlikely to support resident fish populations. |

| Ecological value | High probability | Medium probability | Low probability | Extremely low probability | Qualitative flow needs |
|---|---|---|---|---|---|
| **Macroinvertebrates and crustaceans** | Macroinvertebrates communities in poor condition (AURIVAS Band C – Severely impaired) | | | | The macroinvertebrate community of Reach 3 is significantly impaired, a consequence of the intermittent flow regime and poor water quality in this reach. |
| **Platypus** | | | | Platypus | It is highly unlikely that Reach 3 would support resident populations of Platypus. |
| **Frogs** | | | Victorian Smooth Froglet, Common Froglet, Pobblebonk, Striped Marsh Frog, Spotted Marsh Frog, Southern Brown Tree Frog | | Provided that water of suitable quality (i.e. not acidic) is available for period during breeding season (for most species is winter/spring), and flow velocity is not too high, frogs could use Reach 3. |

# 5. Conclusions and recommendations

## 5.1 Conclusions

The key conclusions from this study are outlined below.

The **Boundary Creek catchment has experienced significant changes** since European settlement some of which have permanently altered the flow regime of the creek. Changes include channelisation, construction of McDonalds Dam, farm dams, private diverters, groundwater extraction, supplementary flow release, drought and the drying, trenching and acidicification of Big Swamp.

The **hydrology of Boundary Creek** has been significant modified by these changes in the catchment. Key features of the hydrology that have shaped the ecological values of the creek are:

- The supplementary flow makes up a significant portion of the flow in the summer months in Reach 1 and 2.
- The supplementary flow is evident in the streamflow until Big Swamp, but is not apparent downstream under many conditions. Boundary Creek in Reach 3 rarely stopped flowing at any time of year prior to 1999, but since then has stopped flowing for long periods in most summer and autumn months downstream of Big Swamp.
- The water in Reach 3 of Boundary Creek is highly acidic.
- The influence of Big Swamp on the hydrology of Reach 3 of Boundary Creek is likely to be significant, however, the complexity of the groundwater-surface water interactions, soil chemistry and management history means that investigating this influence is beyond the scope of this study. Big Swamp will be the focus of a future, stand-alone study.

The **ecological values** currently supported by Boundary Creek are summarised below:

- In Reach 1, the majority of the riparian zone is made up of an overstorey of *Eucalyptus* and *Acacia* is supported, with a ground layer of weeds and occasional sedges and herbs. The channel supports Water Ribbons. Some fish are likely to be present including Short-finned Eels, Flathead Gudgeon and Mountain Galaxias. The macroinvertebrate communities are in excellent condition (AUSRIVAS Band A) and a range of common and widespread frog species is likely to be supported.
- Reach 2 contains a ‘dampland’ with a dense canopy of *Melaleuca squarrosa* and *Leptospermum lanigerum* and a wetland ground-layer of diverse sedges, rushes and reeds that are likely reliant on permanently waterlogged soils. The riparian vegetation upstream of the ‘dampland’ has been largely cleared for agriculture. Big Swamp (which is outside the scope of this study) is located downstream. The water in the channel in Reach 3 is usually shallow and is therefore unlikely to be suitable for fish, although Flathead Gudgeon may be present. The macroinvertebrate communities are significantly impaired (AUSRIVAS Band B). The reach likely supports the Otway Bush Yabby and the assemblage of common frogs.
- Reach 3 dries frequently in summer, has highly acidic water when it is flowing and has limited aquatic habitat. It is unlikely to support many resident aquatic species (although some frogs may use some habitat in the reach). The macroinvertebrate community is in poor condition (AUSRIVAS Band C).

In general, enough flow to maintain water quality in pools and longitudinal connectivity in Reach 1 and the waterlogged soils in Reach 2 is sufficient to meet the **qualitative flow needs** of the aquatic ecological values currently supported by the creek. The frequent drying of Boundary Creek downstream of Big Swamp and the highly acidic water when it does flow means that Reach 3 is currently unsuitable for most aquatic biota.

Recommendations to improve the understanding of the impacts of the changes in the catchment, the influence they have had on the ecological values and quantify the flow requirements are outlined below.

## 5.2 Recommendations for additional studies and next steps

This study has used the best information available at the time to estimate the current ecological values in Boundary Creek (excluding Big Swamp) and provide a high level qualitative assessment of their flow needs. The next step is to improve the understanding of the current groundwater surface water interactions and the influence of Big Swamp, assess the effectiveness of the current location of the supplementary flow release, (given it does not appear to reach Reach 3) and quantify the flow requirements of the current ecological values.

To quantify the flow requirements of the aquatic values of the creek and improve the understanding of groundwater surface water interactions and the role of the supplementary flow, additional studies and investigations are required, including:

1. Using the current hydrogeological understanding of the catchment to produce a detailed conceptualisation of the surface water-groundwater interactions that operate at Boundary Creek and incorporating the results of the numerical groundwater model to help quantify baseflow contributions to Boundary Creek.

2. Developing hydraulic models at representative sites in the creek to the link depth of water in the channel with flow volume.

3. Determining the quantitative flow needs of the identified aquatic values in Boundary Creek.

4. Undertaking a stand-alone assessment of the soil chemistry and groundwater-surface water interactions of Big Swamp and the impact of Big Swamp on the hydrology of Reach 3.

These additional studies, informed by this study, will be the primary tools used to understand potential impacts from the Barwon Downs borefield and to assess what impact the 2ML/day supplementary flow is having on the ecological values of Boundary Creek. These studies will also help to direct intervention efforts in the creek.

# 6. References

APC (2002) Ecology and conservation of Platypus in the Barwon River Catchment: II. Results of population surveys, Summer 2002. Australian Platypus Conservancy.

Barwon Water (2004) Groundwater Licence No. 893889 Gerangamete Area 2003/2004 Report. Barwon Water.

Bethge, P., Munks, S.O., H. and Nicol, S. (2003) Diving behaviour, dive cycles and aerobic dive limit in the Platypus *Ornithorhynchus anatinus*. Comparative Biochemistry and Physiology, Part A 136, 799-809.

Boon, P.I. (2011) The rehabilitation of coastal wetlands: why small-scale variations in topography are critical to success. Australasian Plant Conservation 20: 9-10.

Canale, G. A., Papas, P. J., Nicol,. D.M., Kefford, B. J., Crowther, D. and McKay, S. (2001) Preliminary Assessment of the Health of the Barwon River Catchment in the Absence of Saline Water Disposal. Draft report by. Freshwater Ecology, Department of Natural Resources and Environment. for the Corangamite Catchment Management Authority.

Carrick, F. N., Grant, T. R., and Temple-Smith, P. D. (2008). Platypus. In 'The Mammals of Australia'. 3rd edn. (Eds S. Van Dyck and R. Strahan.) pp. 32–35. (Reed New Holland: Sydney.)

Chambers, J.M., Fletcher, N.L. and McComb. A.J. (1995) A guide to emergent wetland plants of south-western Australia. Murdoch University, Perth.

Colac Otway Fire Management Plan (2015): Version 11: September 2012-2015, updated to March 2017. Colac Otway Shire Council, CFA, Department of Environment, Land, Water and Planning.

Cogger, H. (2000) Reptiles and amphibians of Australia, Reed New Holland.

DEPI (2012) A field guide to Victorian wetland ecological vegetation classes for the Index of Wetland Condition. Department of Environment and Primary Industries, East Melbourne.

DSE (2009) Advisory list of threatened invertebrate fauna in Victoria – 2009. Department of Sustainability and Environment, East Melbourne, Australia.

Froend, R.H., Farrell, R.C.C., Wilkins, C.F., Wilson, C.C. and McComb, A.J. (1993). Wetlands of the Swan Coastal Plain. Volume 4. The effect of altered water regime son wetland plants. Water Authority of Western Australia, Perth.

Gust, N. and Handasyde, K. (1995) Seasonal-variation in the ranging behaviour of the Platypus (*Ornithorhynchus anatinus*) on the Goulburn River, Victoria. Australian Journal of Zoology, 43, 193-208.

Himmelreich, E. (2010) Peat fire repeats – after 13 years. The Standard, 19 March 2010, http://www.standard.net.au/story/744270/peat-fire-repeats-after-13-years/, accessed 7 November, 2016.

Jacobs (2016) Draft Barwon Downs Integration Report. Unpublished report for Barwon Water.

Johnston, K. and Schultz, M. 2010. *Geocharax gracilis*. The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org. Downloaded 5-2-2015.

Lintermans, M. (2007) Fishes of the Murray-Darling Basin: An introductory guide. Murray Darling Basin Commission, No.10/07.

Lloyd *et al.* (2005) Environmental flow determination for the Barwon River (Site, Issues and Recommendations Papers). Report by Lloyd Environmental, Fluvial Systems and Ecological Associates for the Corangamite Catchment Management Authority.

March, T.S. and Robson, B.J. (2006) Association between burrow densities of two Australian freshwater crayfish (Engaeus sericatus and Geocharax gracilis: Parastacidae) and four riparian land uses. Aquatic conservation: marine and freshwater ecosystems 16: 181-191.

McCabe, D.J. and Gotelli, N.J. (2000) Effects of disturbance frequency, intensity, and area on assemblages of stream macroinvertebrates. Oecologia, 124, 270-279.

McDowall, R. (1996) Freshwater fishes of south-eastern Australia. Reed Books. Chatswood, NSW.

McKinnon, L.J. and G.L. Milner (2009) Empowering industry R and D: trials of gear modification to reduce bycatch in freshwater fyke nets. Report, FRDC project 2008/017.

Peter, S. (1990) Rural Water Commission of Victoria, Memorandum: Boundary Creek Survey, February 1990. Rural Water Commission of Victoria, Ballarat Brach (From the Southern Rural Water Archives).

Raulings, E., Morris, K., Roache, M. and Boon, P.I. (2010) The importance of water regimes operating at small spatial scales for the diversity and structure of wetland vegetation. Freshwater Biology 55: 701-715.

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

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

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

Serena, M., Thomas, J.L., Williams, G.A. and Officer, R.C.E. (1998) Use of stream and river habitats by the Platypus, *Ornithorhynchus anatinus*, in an urban fringe environment. Australian Journal of Zoology, 46, 267-282.

Serena, M., Worley, M., Sinnerton, M. and Williams, G.A. (2001) Effect of food availability and habitat on the distribution of Platypus (*Ornithorhynchus anatinus*) foraging activity. Australian Journal of Zoology, 49, 263-277.

Serena, M. and Williams, G.A. (2008) Distribution and management of Platypus in the Greater Melbourne Region. A report to Melbourne Water by the Australian Platypus Conservancy.

SKM (2005) Environmental Water Requirements of the Barwon System. Preparation of daily streamflow data for the Barwon River. Final 1. July 2005. Sinclair Knight Merz for Corangamite Catchment Management Authority. (SKM Ref: WC03216).

SKM (2006) Central Region Sustainable Water Strategy. Configuration of a basin wide REALM model for the Barwon/ Moorabool Basin. Final 1. 19 July 2006. Sinclair Knight Merz for Department of Sustainability and Environment. (SKM Ref: WC03467).

Southern Rural Water (2006) Barwon Region Water Authority – Groundwater Licence No 893889.

Turnbridge, B. R. (1988) Environmental flows and fish populations of waters in the South-Western Region of Victoria. Arthur Rylah Institute for Environmental Research, Technical Report Series No. 65.

Wallace, J.B. and Webster, J.R. (1996) The role of macroinvertebrates in stream ecosystem function. Annual Review of Entomology, 41: 115-139.

Wassens, S. (2011) Frogs In: Floodplain wetland biota in the Murray-Darling Basin: water and habitat requirements. (ed) Rogers, K. and Ralph, T.J. CSIRO Publishing, Collingwood, Victoria.

Zampatti, B. and Grgat, G. (2000) 1999 Fish survey of the Barwon River. Report for the Lake Colac-Lough Calvert Operational Committee. Arthur Rylah Institute for Environmental Research, Department of Natural Resources and Environment, Victoria, Australia.

Zampatti, B. and Koster, W. (2002) A summary of three years survey data (1998-2000) of fish populations in the Barwon River. Report by the Department of Natural Resources and Environment for the Corangamite Catchment Management Authority.

# Appendix A. Boundary Creek macroinvertebrate monitoring

A study of the macroinvertebrate communities of Boundary Creek was commissioned as part of the current project and was completed by Austral Research and Consulting.

## A.1 Introduction

Macroinvertebrates were sampled at four sites along Boundary Creek, a tributary of the Barwon River, in accordance with the recommended monitoring regime (SKM 2013). Samples were collected over two seasons (spring and autumn) in 2014/2015.

## A.2 Methods

Macroinvertebrates and water samples were collected at each site and photos and site assessment sheets were completed as per Victorian EPA guidelines (EPA Victoria, 2003). Edge and riffle habitats were sampled where present in Spring (18/11/2014) and Autumn (7/04/2015). A 250µm mesh dip net was used to sample the macroinvertebrate habitats. Macroinvertebrates were live picked, preserved in 70% alcohol and identified in the laboratory in accordance with the guidelines; to class for Oligochaeta and Mites, chironomids to sub-family and all other taxa to family except those that are not included in EPA Victoria biotic calculations (EPA Victoria, 2003).

Biotic indices such as AUSRIVAS, SIGNAL, SIGNAL2, EPT (Ephemoptera, Plecoptera, Trichoptera) and taxa richness scores were calculated in accordance with EPA Victoria biological objectives (EPA Victoria, 2004). AUSRIVAS scores and bands are considered to give the most accurate assessment of the health of a site as the program compares the test site to a number of reference sites that have similar physical and chemical characteristics but are relatively free of environmental impacts. The score indicates how many macroinvertebrate families were found compared to those found at reference sites. The Statewide model for edge habitat was used as the variables required to run the region specific model was not available at the time of writing. Explanations of the bands and scores are outlined below (see AUSRIVAS Banding).

SIGNAL and SIGNAL2 are biotic indices based on the tolerance or intolerance of biota (macroinvertebrates) to water pollution. Sites with high scores are likely to have low nutrient, salinity and turbidity levels and high oxygen levels. EPA biological objectives use the SIGNAL score but SIGNAL2 is also calculated as it uses updated, refined scores (Chessman, 2003).

The EPT score indicates the number of families that are sensitive to pollution that are present at the site. A low score usually indicating that there has been some type of disturbance. Together, these scores give a good picture of the health of the waterway at a site and potentially what is causing any disturbance.

Multi dimensional scaling (MDS) plots were also produced to give an indication of how similar the macroinvertebrate community compositions are to each other. Only the edge samples were used for this analysis as only one of the sites has a consistent riffle habitat.

Water quality was measured using a YSI Pro Plus Water Quality Probe. Parameters were measured in-situ and included temperature, dissolved oxygen (mg/L), specific conductivity (µs/cm), pH, turbidity (NTU), temperature (°C) and alkalinity (mg/L).

## A.3 Results

Water quality results for sites 1, 2 and 3 are all fairly similar to each other and consistent over time (Table A-1). Site 4 has different pH levels, electrical conductivity and alkalinity (in spring), and dissolved oxygen to the other sites. While all other sites had flowing water during each sampling event, Site 4 was stagnant and appeared to be fed by runoff from the road and bridge immediately prior to and during the autumn sampling event.

**Table A-1 Water quality results in Spring and Autumn at four sites in Boundary Creek**

| | Season | pH | Temp (°C) | Turbidity (NTU) | EC (µS/cm) | DO mg/L | DO% | Alkalinity (mg/L) |
|---|---|---|---|---|---|---|---|---|
| Site 1- Boundary Ck at Barongarook | Spring | 6.55 | 12.8 | 9.02 | 183.3 | 10.45 | 100.8 | 10 |
| | Autumn | 6.61 | 12.2 | 9.45 | 172.1 | 7.3 | 70.6 | 10 |
| Site 2- Boundary Ck u/s McDonalds Dam | Spring | 6.51 | 13.4 | 11.8 | 280.20 | 9.92 | 94.0 | 15 |
| | Autumn | 7.07 | 12.5 | 23.9 | 216.2 | 7.93 | 77.0 | 15 |
| Site 3- Boundary Ck d/s McDonalds Dam | Spring | 6.58 | 17.7 | 8.37 | 387.4 | 6.40 | 68.1 | 15 |
| | Autumn | 6.90 | 14.3 | 8.22 | 261.9 | 8.18 | 82.7 | 15 |
| Site 4- Boundary Ck at Colac-Forrest Rd | Spring | 3.54 | 12.5 | 4.62 | 716 | 1.37 | 13.3 | 0 |
| | Autumn | 5.55 | 12.1 | 32.7 | 138.8 | 3.67 | 35.5 | 10 |

Combining macroinvertebrate results from both autumn and spring gives the most accurate assessment of a site, therefore the results have been combined for all edge samples (Table A-2). The riffle samples have been combined over season for site 3 and also presented for each season so that the Site 1 riffle Spring sample can be compared to another sample (no Autumn sample for Site 1 due to lack of habitat).

**Table A-2 Biological Indicators for four sites in Boundary Creek, combined over season.**

| | Habitat | Number of families | SIGNAL | SIGNAL2# | EPT | AUSRIVAS O/E | AUSRIVAS Band | Key no. of families |
|---|---|---|---|---|---|---|---|---|
| Site 1 | Edge | 26 | 5.81 | 4.65 | 5 | 0.9 | A | 25** |
| | Riffle | 15* | 6.07* | 5.28* | 7* | | | |
| Site 2 | Edge | 23 | 5.91 | 4.35 | 6 | Outside the experience of the model | | 21** |
| | Riffle | - | - | - | - | | | |
| Site 3 | Edge | 27 | 5.41 | 3.70 | 3 | 0.78 | B | 24 |
| | Riffle | 22 | 5.18 | 3.82 | 2 | | | |
| Site 4 | Edge | 10 | 4.50 | 2.70 | 0 | 0.38 | C | 7** |
| | Riffle | - | - | - | - | | | |

* Only based on one season

** Only based on one season and/or one habitat

# No objectives for SIGNAL2

Shaded cells are those sites and indices that meet Biological Indicators of Environmental Quality (SEPP Wov)(EPA Victoria, 2004) objectives.

Site 1 meets the most biological objectives of the four sites although it doesn't meet all of the objectives. The edge habitat has a similar macroinvertebrate community composition to reference sites (Band A). The riffle habitat was only sampled in one season and so cannot be compared to objectives. Edge samples at Sites 2 and 3 each meet one objective; SIGNAL and number of families respectively. It is unknown why Site 2 is outside the experience of the AUSRIVAS model but the score and banding is likely to be similar to the AUSRIVAS rating at Site 3 which is 'below reference', based on the other indices. Site 4 has the poorest macroinvertebrate assemblage with the lowest biological indices scores, none of the sensitive EPT present and, using AUSRIVAS has many fewer macroinvertebrate families than would be expected.

A plot of SIGNAL2 scores and the number of families at a site (restricted to edge habitats to enable comparisons) shows that Site 4 has much lower values than the other three sites and is most likely impacted by one or more human impacts (Chessman, 2004) (Figure A-1). Whilst Sites 1, 2 and 3 have more macroinvertebrate families present, the SIGNAL2 scores are still low suggesting that there are some human impacts but they are relatively benign (Chessman 2004).

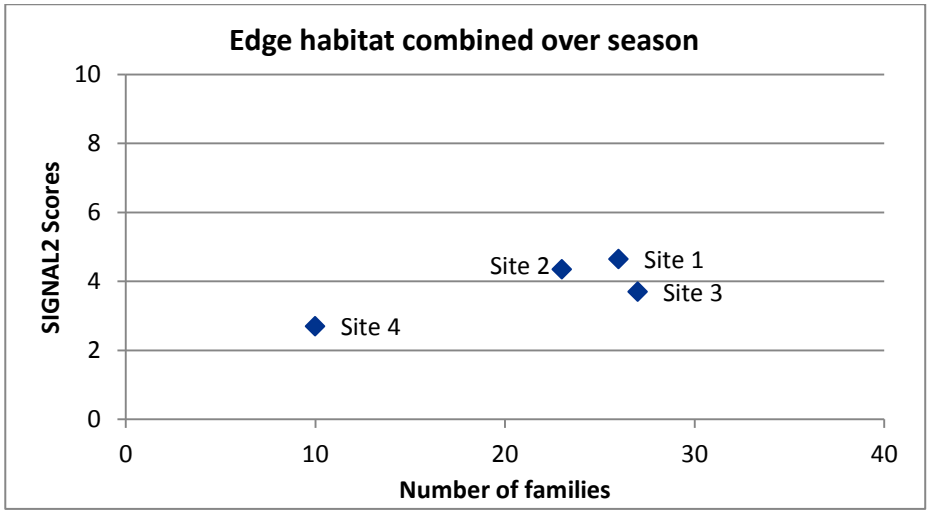



**Figure A-1 Plot of SIGNAL2 and Number of families scores for edge habitats combined over season.**

The MDS (Multidimensional Scaling) plot (Figure A-2) shows how similar, or dissimilar, the macroinvertebrate families at each site are to one another. Those that have 20% of the macroinvertebrate families in common are indicated by a dotted line. Only edge habitats are plotted as a riffle habitat wasn't present at every site.

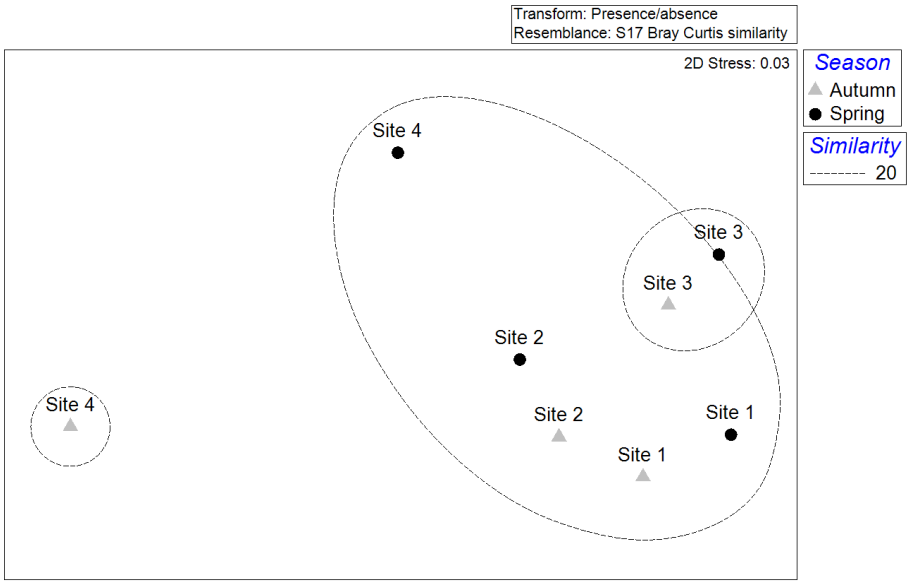



**Figure A-2 MDS plot of families from edge habitat of each site.**

Macroinvertebrate families at Site 4 in autumn are very different to all other sites, almost certainly due to the very low water levels at this site. Site 4 in spring is also dissimilar to the other sites, and Site 3 has similar macroinvertebrate families over season.

## A.4 Discussion

All of the data presented above suggests that Boundary Creek degrades from Site 1 at the headwaters to Site 4 close to the confluence with the Barwon River. There are a number of obvious impacts along the creek such as McDonalds Dam and the peat swamp above Sites 3 and 4 respectively with the lack of flow and poor water quality at Site 4 severely impacting creek health at this site. The recent weed control and riparian re-vegetation works at Sites 2 and 3 should assist in improving creek health at these sites but weed control particularly at Sites 1 and 3 will need to be ongoing.

## A.5 References

Chessman B, (2003) SIGNAL 2 – A Scoring System for Macroinvertebrate('Water Bugs') in Australian Rivers, Monitoring River Heath Initiative Technical Report no 31, Commonwealth of Australia, Canberra.

Environment Protection Authority Victoria (EPA) (2003) Rapid Bioassessment of Victorian Streams. Publication No. 604.1

EPA (2004) Biological Objectives for Rivers and Streams – Ecosystem Protection. Publication No. 793.2

SKM (2013) Barwon Downs Monitoring Program - Stage 1 Field Investigations and Monitoring Program Scope. Report by Sinclair Knight Merz for Barwon Water.

## A.6 Biological Objectives

Region 3 (Forests B)

| Habitat | Number of Families | SIGNAL Index score | EPT Index score | Key Families Combined Habitat Score | AUSRIVAS O/E score | AusRivAS Band |
|---|---|---|---|---|---|---|
| Edge | 24 | 5.8 | 9 | 26 | 0.87-1.13 | A |
| Riffle | 23 | 6.0 | 10 | | 0.87-1.13 | A |

EPA (2004)

## A.7 AUSRIVAS BANDING

Victoria- Combined Season- Edge

| Band | OE 50 score | Description |
|---|---|---|
| X | 1.15+ | More biologically diverse than reference sites |
| A | 0.85-1.14 | Reference condition |
| B | 0.56-0.84 | Significantly impaired |
| C | 0.27-0.55 | Severely impaired |
| D | 0-0.26 | Extremely impaired |

AusRivAS Macroinvertebrate Predictive Modelling Version 3.2.0

## A.8 Macroinvertebrate taxa list

| Spring 2014 | Families | Site 1 | | Site 2 | Site 3 | | Site 4 |
|---|---|---|---|---|---|---|---|
| | | Kick | Sweep | Sweep | Kick | Sweep | Sweep |
| IB019999 | Hydridae | | | | | 3 | |
| IF619999 | Dugesiidae | | | 1 | 4 | | |
| II999999 | Nematoda | | | | 1 | | |
| KG029999 | Hydrobiidae | | | 5 | | | |
| KG079999 | Planorbidae | | | 5 | | | |
| KG089999 | Physidae | | | | 17 | 14 | |
| KP039999 | Sphaeriidae | | | | 9 | 6 | |
| LH019999 | Glossiphoniidae | | | | | 12 | |
| LO999999 | Oligochaeta | 1 | 2 | | 12 | 3 | 1 |
| MM999999 | Mites | 3 | 14 | 6 | 12 | 5 | |
| OP029999 | Ceinidae | | | | 12 | 12 | |
| OP069999 | Paramelitidae | 3 | 1 | | 10 | | |
| OP089999 | Perthiidae | | | 1 | | | |
| OR189999 | Janiridae | | | | | | 5 |
| OV019999 | Parastacidae | | 1 | 1 | 1 | 5 | |
| QC099999 | Dytiscidae | | | 1 | 3 | 2 | 2 |
| QC09999I | Dytiscidae (Larva) | | | 1 | 2 | | 9 |
| QC119999 | Hydrophilidae | | 4 | | 1 | 1 | |
| QC11999I | Hydrophilidae (Larva) | | | | | 1 | |
| QC209999 | Scirtidae sp. | 1 | 2 | | | | 10 |
| QC349999 | Elmidae | 7 | | | 1 | | |
| QC34999I | Elmidae (Larva) | 4 | | | 1 | | |
| QD019999 | Tipulidae | | | | 1 | | |
| QD069999 | Dixidae | | 4 | 17 | | | |
| QD079999 | Culicidae | | | 1 | | | 8 |
| QD099999 | Ceratopogonidae | 2 | 1 | | | | |
| QD109999 | Simuliidae | 23 | 8 | | 26 | 27 | |
| QD249999 | Stratiomyidae | | 1 | | | | |
| QDAE9999 | Tanypodinae | | 3 | 2 | | 12 | 2 |
| QDAF9999 | Orthocladiinae | 4 | 37 | | 7 | 1 | |
| QDAJ9999 | Chironominae | 5 | 60 | 5 | 1 | 13 | 43 |
| QDZZ999I | Diptera (Pupa) | | | | | | 5 |
| QE039999 | Oniscigastridae | | | 2 | | | |
| QE069999 | Leptophlebiidae | 30 | 24 | 61 | | 2 | |
| QH569999 | Veliidae | 2 | 1 | 72 | 1 | 14 | 7 |
| QH659999 | Corixidae | | | 1 | 10 | 20 | 1 |
| QO219999 | Telephlebiidae | 8 | 6 | | | | |
| QO309999 | Hemicorduliidae | | | | 1 | 1 | |
| QO999997 | Zygoptera Unident. | | 2 | | | | |
| QP039999 | Gripopterygidae | 4 | 6 | 8 | | | |
| QT019999 | Hydrobiosidae | 6 | 2 | | 33 | 1 | |
| QT039999 | Hydroptilidae | | 15 | 3 | | | |
| QT249999 | Calamoceratidae | 1 | 1 | | | | |
| QT259999 | Leptoceridae | | 3 | 7 | 1 | 7 | |

| Autumn 2015 | Families | Site 1 | Site 2 | Site 3 | | Site 4 |
|---|---|---|---|---|---|---|
| | | Sweep | Sweep | Kick | Sweep | Sweep |
| IB019999 | Hydridae | | | 2 | 7 | |
| IF619999 | Dugesiidae | | | 4 | 20 | |
| KG029999 | Hydrobiidae | 2 | 9 | | 1 | |
| KG079999 | Planorbidae | 3 | 1 | | | |
| KG089999 | Physidae | | | | 11 | |
| KP039999 | Sphaeriidae | | | 35 | | |
| LH019999 | Glossiphoniidae | | | | 2 | |
| LO999999 | Oligochaeta | | | 7 | 10 | |
| MM999999 | Mites | 22 | 13 | 5 | 2 | |
| OP029999 | Ceinidae | | | | 1 | |
| OP069999 | Paramelitidae | | | | 2 | |
| OT019999 | Atyidae | | | | 1 | |
| QC209999 | Scirtidae sp. | 13 | | | | |
| QC349999 | Elmidae | | 2 | | | |
| QD019999 | Tipulidae | 1 | | | | |
| QD069999 | Dixidae | 16 | 2 | | 2 | |
| QD079999 | Culicidae | | 2 | | | 34 |
| QD07999I | Culicidae (Pupa) | | | | | 10 |
| QD109999 | Simuliidae | 1 | | 23 | 38 | |
| QD899999 | Muscidae | | | | | 1 |
| QDAE9999 | Tanypodinae | 2 | 2 | 1 | 1 | |
| QDAF9999 | Orthocladiinae | 11 | 3 | | 1 | |
| QDAJ9999 | Chironominae | 14 | 1 | 10 | 8 | |
| QE029999 | Baetidae | 5 | | | | |
| QE069999 | Leptophlebiidae | 20 | 48 | | 2 | |
| QH569999 | Veliidae | 1 | 15 | 1 | 5 | 1 |
| QH619999 | Nepidae | | | | 1 | |
| QH659999 | Corixidae | | 1 | | 13 | |
| QH679999 | Notonectidae | | 5 | | | |
| QO029999 | Coenagrionidae | | | | 1 | |
| QO219999 | Telephlebiidae | 4 | 2 | | | |
| QP049999 | Notonemouridae | 1 | 1 | | | |
| QT019999 | Hydrobiosidae | 6 | | | | |
| QT039999 | Hydroptilidae | 37 | 1 | | | |
| QT259999 | Leptoceridae | 60 | 61 | | 11 | |