Icon Water

Murrumbidgee Ecological Monitoring Program
Impact Monitoring - Autumn 2019 and Spring 2019

August 2020

Executive summary

To assess the influence of the construction and operation of the Murrumbidgee to Googong transfer pipeline (M2G) and the Murrumbidgee Pump Station (MPS) on ecological conditions in associated waterways, Icon Water developed a detailed Murrumbidgee Ecological Monitoring Program (MEMP) to establish comprehensive baseline data and to satisfy the EIS and compliance commitments for the projects. Currently, the MEMP is aimed at investigating:

- *Potential impacts of water abstraction from the Murrumbidgee River at Angle Crossing and the Murrumbidgee Pump Station (Components 1 & 3)*
- *Subsequent changes that might occur in Burra Creek (Component 2)*

The aim of the 2019 impact monitoring presented in this report is to provide baseline data prior to changing to operational phase. This data will be used to compare the ecological conditions of control sites to those of the impacted sites over time to determine if there is any major catchment scale changes to the aquatic ecology in either the Murrumbidgee River or Burra Creek during the projects operational phase. Under the current modes of operation, the major conclusions from the monitoring are:

- *A drier climate has resulted in low flows in the Murrumbidgee River and Burra Creek in recent years.*
- *Low flows reduces available habitat in the Murrumbidgee River and Burra Creek. Although there is a loss of riffle habitat in Burra Creek during low flow periods, the general health of the two waterways has not dramatically changed over time.*
- *Both the Murrumbidgee River and Burra Creek have high nutrient loads.*
- *There has been no increase in the occurrence of periphyton in the in the Murrumbidgee River and Burra Creek overtime.*
- *There has been no dramatic changes in riparian or instream vegetation in Burra Creek.*
- *There are several areas prone to bank erosion and slumping in Burra Creek that are likely to be at greater risk during high flows.*
- *The macroinvertebrate communities in the Murrumbidgee River and Burra Creek are generally reflective of mild to moderate pollution impacts and/or significant impairment with water quality and/or habitat potentially impacted resulting in loss of taxa.*
- *Despite the condition of the macroinvertebrate community, the composition still displays a high level of seasonal variation. This suggests that any impairment is not sufficient to mask natural variability.*
- *Fish surveys in the Murrumbidgee River determined there is a relatively diverse community, although this is also composed of several exotic species. However, 2019 results suggest there has been successful breeding events by Murray Cod and evidence of recruitment of juveniles.*
- *There were limited differences between control and impact sites for all aspects of the waterways monitored. Consequently, the MEMP should allow for an assessment of the influence of the operation modes once they are implemented.*
- *The lack of differences between control and impact sites suggests that the construction of infrastructure and current level of operation has not impacted on waterways health and ecological conditions.*

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List of abbreviations

ACT – Australian Capital Territory

ACTEW – ACTEW Corporation Limited

ALS – Australian Laboratory Services

ANZECC –Australian and New Zealand Environment and Conservation Council

APHA – American Public Health Association

APPLE – Angle Crossing Planned Pumped Lubrication Exercise (Icon Water acronym)

ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand

AUSRIVAS – Australian River Assessment System

EC – Electrical Conductivity

ECD – Enlarged Cotter Dam

EIS – Environmental Impact Statement

EPA – Environmental Protection Authority

EPT – Ephemeroptera, Plecoptera and Trichoptera taxa

GL/a – Gigalitres per annum

GPS – Global positioning system

M2G – Murrumbidgee to Googong

MEMP – Murrumbidgee Ecological Monitoring Program

ML/d – Megalitres per day

MPS – Murrumbidgee Pump Station

NATA – National Association of Testing Authorities

NSW – New South Wales

NTU – Nephlelometric Turbidity Units

QA – Quality Assurance

QC – Quality Control

TN – Total Nitrogen

TP – Total Phosphorus

1. Introduction

During the 2000-2010 drought in the Australian Capital Territory (ACT) and surrounding regions of New South Wales (NSW), dam storage volumes in the ACT declined to unprecedented levels. Icon Water (formally ACTEW Corporation), the major water utility in the ACT, developed a water security program that involved building additional and upgrading existing infrastructure to improve the future water supply for residents of Canberra and Queanbeyan. The water security projects include:

- Murrumbidgee to Googong transfer pipeline (M2G): from Angle Crossing just within the ACT's southern border to Burra Creek in the Googong Reservoir catchment, at a nominal 100 ML/d
- Murrumbidgee Pump Station (MPS): adjacent to the existing Cotter Pump station to increase pump capacity from ~50 ML/d to 150 ML/d (nominally 100 ML/d)
- Tantangara Reservoir release: for run of river flow to the M2G abstraction point at Angle Crossing[1]
- Enlarged Cotter Dam (ECD): enlargement to 78 GL just downstream of the existing 4 GL Cotter Dam[1]

The M2G pipeline includes the pump station at Angle Crossing that transfers water from the Murrumbidgee River through a 12 km underground pipeline into Burra Creek. The water is then transported a further 13 km by run-of-river flows into Googong Reservoir. Water abstraction from the Angle Crossing pump station is dictated by the capacity of Googong Reservoir and the availability of water in the Murrumbidgee River. The system is designed to enable pumping of up to 100 ML/d, and construction was completed in August 2012. Abstraction from the Murrumbidgee River and the subsequent discharges to Burra Creek are directed by the Operational Environmental Management Plan (Icon Water, 2017).

The MPS is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the Cotter Pump Station, which can abstract up to 100 ML/d, contributing to the water supply for the ACT. New infrastructure has increased the abstraction amount from the Murrumbidgee River to approximately 150 ML/d via the MPS. The upgraded pump station was commissioned in 2010 and pumping is dependent on demand, licence requirements, and water quality. The upgraded infrastructure also provides a recirculating flow from the Murrumbidgee River to the base of the Enlarged Cotter Dam (ECD), providing environmental flows to the lower Cotter River below the dam and is referred to as the Murrumbidgee to Cotter (M2C) transfer.

There are a number of potential risks to ecological conditions in the Murrumbidgee River and Burra Creek due to operation of the M2G and MPS. In the Murrumbidgee River, risks are generally related to reduced flow due to water abstraction. For example, during periods of low flow, there may be a loss of aquatic habitat and changes to macroinvertebrate communities, excessive periphyton growth in riffle habitats or a shift to late successional communities dominated by filamentous algae, and a deterioration in water quality. In Burra Creek, some beneficial ecological effects may be expected due to increased flow including increased flow permanence and connectivity between pools allowing more frequent fish use, increased macroinvertebrate biodiversity and a reduction in the extent of macrophyte encroachment in the main channel. However, there may also be negative impacts to macroinvertebrate communities, water quality, channel and bank geomorphology, and riparian vegetation.

[1] Note this report does not consider the Tantangara Reservoir release or enlarged Cotter Dam.

To assess the influence of the construction and operation of the M2G and MPS on ecological conditions in associated waterways, Icon Water developed a detailed Murrumbidgee Ecological Monitoring Program (MEMP) to establish comprehensive baseline data and to satisfy the EIS and compliance commitments for the projects. Comparisons of this baseline data to conditions during and following construction, and also during the operation of M2G and MPS, can be used to determine if there is a detectable change in ecological conditions. This report presents the results of monitoring that occurred in autumn and spring 2019 as part of the MEMP.

1.1 Background and adaptive management: changes to the MEMP since 2008

The MEMP has been supported by Icon Water to investigate potential impacts of water abstraction from the Murrumbidgee River and the influence of increased water volumes in Burra Creek on ecological conditions (Figure 1-1). The MEMP was implemented prior to the commencement of the M2G project, allowing Icon Water to collect pre-abstraction baseline data to compare against the post-abstraction data once the M2G project began operation. Seasonal monitoring has occurred in spring and autumn each year between 2008 and 2019.

Over the course of this monitoring program, there have been a number of changes and modifications in line with the adaptive management philosophy of the MEMP. Between spring 2008 and autumn 2013 there were four component areas considered as part of the MEMP:

- Component 1: Angle Crossing (M2G)
- Component 2: Burra Creek (M2G)
- Component 3: Murrumbidgee Pump Station (MPS)
- Component 4: Tantangara to Burrinjuck (Tantangara Transfer)

Following the autumn 2013 monitoring, Icon Water reviewed the MEMP which resulted in the discontinuation of Component 3 (the MPS component) and Component 4 (the Tantangara to Burrinjuck component). The MEMP continued to assess Component 1 and Component 2 from spring 2013 to spring 2014.

The most recent and major change to the MEMP followed a peer review by Jacobs (2014). In this review, Component 3 was recommended to recommence, and three modes of operation were defined for the M2G and MPS to help target the monitoring program. These are defined for the M2G as:

- Standby (maintenance) – Ready to run, all components in place and being operated routinely for maintenance purposes. Peak pump volumes are typically 49 ML/d and transferring approximately 50 ML in total.
- Operating (full pump) – Operating in earnest under normal flow conditions, with continuous transfer of bulk water to Googong Reservoir for a period of greater than 30 consecutive days.
- Operating (drought conditions: full pump, drought flows) – Operating in earnest under drought flow conditions with continuous transfer of bulk water to Googong Reservoir for a period of greater than 30 consecutive days.

For the MPS, the modes of operation are defined as:

- Standby – Abstraction from the Murrumbidgee River is not occurring. Ready to run, all components in place and being operated routinely for maintenance purposes.

- Recirculating Pump Operation – Flow up to 40 ML/d transferred to the base of the Cotter Dam to provide environmental flows to the lower Cotter River. Water to the Cotter River re-enters the Murrumbidgee River just upstream of the MPS.
- Operating (full pump) – Abstraction of up to 150 ML/d of water for raw water supply to Stromlo Water Treatment Plant for greater than 30 consecutive days. While this is the maximum capacity of the MPS, this extraction volume rarely occurs due to water quality in the Murrumbidgee River. Hence, smaller volumes are likely to be taken (e.g. 80 ML/d) and shandied with cleaner Cotter River water from the Bendora Main.

During periods of standby for M2G and MPS, the risks from these projects to the ecological condition of the Murrumbidgee River and Burra Creek is minimal. Alternatively, it is anticipated that any risks to these waterways are most likely to manifest during periods of full operation. With this in mind, the revised MEMP adopted a two-stage approach which incorporates sentinel monitoring during standby operation modes and impact monitoring during the various operation modes. These two types of monitoring are described in sections 1.1.1 and 1.1.2 respectively. The monitoring elements for each component of the revised monitoring program are outlined in Table 1-1.

Table 1-1. General suite of monitoring elements and monitoring scenario to which they will be undertaken

Monitoring element	Provider	Sentinel Monitoring		Impact Monitoring	
		M2G	MPS	M2G	MPS
Online Water Quality	Icon Water	✓	✓	✓	✓
Laboratory Water Quality	GHD	✓	✓	✓	✓
Macroinvertebrates	GHD	✓	✓	✓	✓
Periphyton	GHD	Not required	Not required	✓	✓
Geomorphology	GHD	✓	Not required	✓	Not required
Riparian vegetation	GHD	✓	Not required	✓	Not required
Fish	ACT Government	✓	✓	✓	✓

1.1.1 Sentinel monitoring (M2G & MPS)

The purpose of the sentinel monitoring is to understand if major catchment-scale changes to the aquatic ecology are taking place and to establish background data. Sentinel monitoring occurs during standby periods when the risk to the ecosystem is deemed to be very low. Sentinel monitoring occurs in autumn and spring every three years which begun in autumn 2015. Based on the Jacobs (2014) review, the number of monitoring sites was reduced from six to two for each component resulting in one site upstream and one site downstream of Angle crossing (M2G), the Burra Creek discharge structure (M2G) and the Murrumbidgee Pump Station (MPS). Single macroinvertebrate samples are collected from both edge and riffle habitats when present. Quantitative periphyton monitoring is not required in the sentinel monitoring and qualitative methods, such as photogrammetry and AUSRIVAS habitat assessments, are used to track the conditions of these sites on a broad spatial and temporal scale. Under this scenario testing of hypotheses and targeted monitoring are not required. Sentinel monitoring has been completed in autumn and spring during 2015 and 2018.

1.1.2 Impact monitoring (M2G & MPS)

The trigger for impact monitoring is the decision to operate the M2G or MPS infrastructure. This monitoring scenario requires a before/after and control/impact (BACI) approach, and relies on replicated monitoring protocols. Several univariate indicators of river health and condition will be analysed before and after the operation period at upstream and downstream locations. Qualitative periphyton photogrammetry is assessed during both time periods and compared between locations. The key difference between impact and sentinel monitoring is the number of sites (two upstream and downstream), macroinvertebrate replicates (two riffle samples or edge samples if riffles not present), monitoring events (impact monitoring requires at least one before and one after event) and the level of detail used in the analysis.

Icon Water made the decision to undertake impact monitoring during 2019 due to the planned transition to operation phase during 2020. Based on this, the first round of impact monitoring was conducted in autumn 2019 for the M2G component, and subsequently in spring 2019 for both the M2G and MPS components.

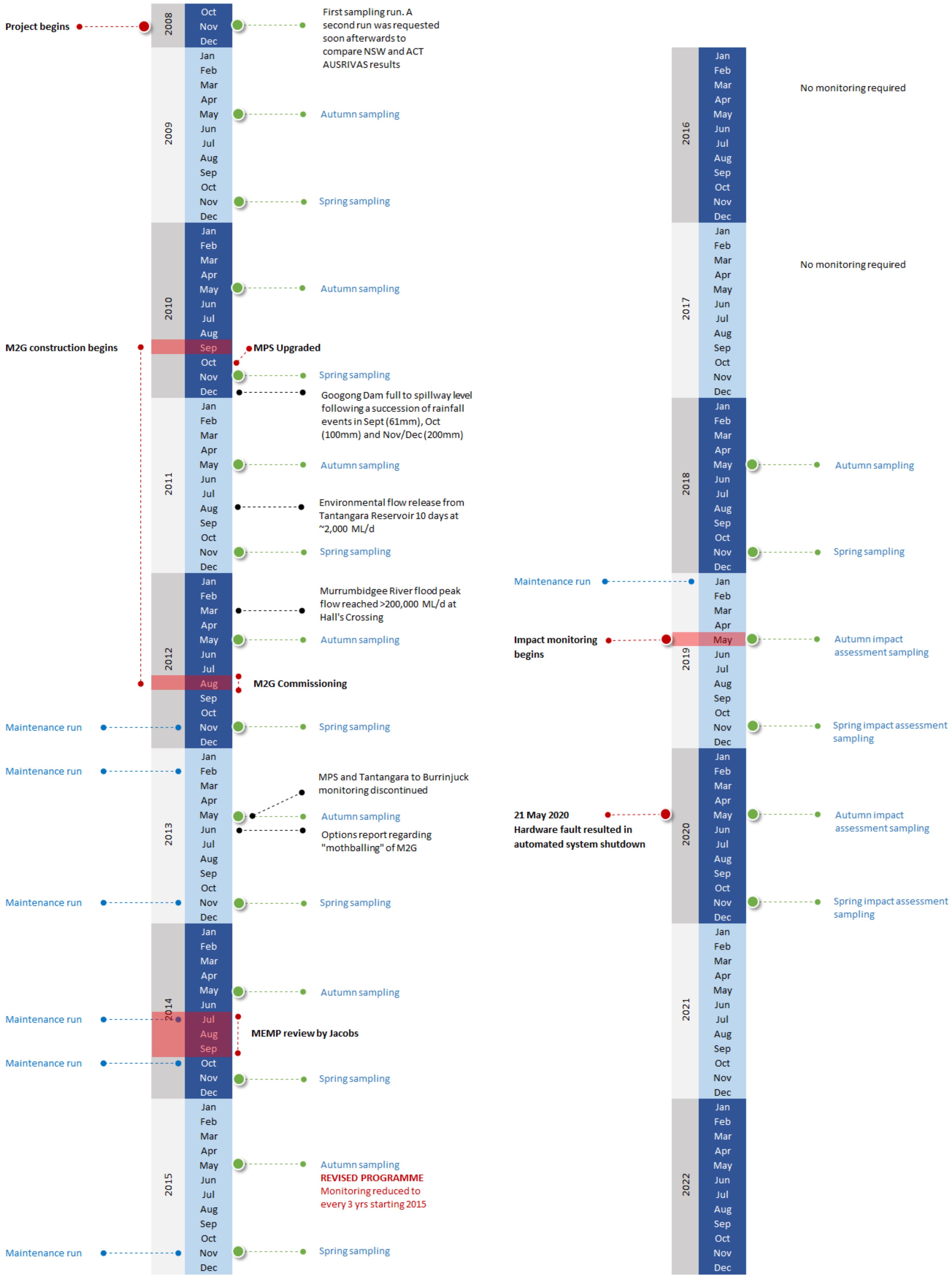

Figure 1-1. Schematic time line of the Murrumbidgee Ecological Monitoring Program

1.1.3 Environmental flow protection rules

Operation of the M2G component are based on environmental flow rules adopted from the framework outlined in the Environmental Flow Guidelines (ACT Government, 2013). The rules are aimed at ensuring that sufficient base flows remain in the Murrumbidgee River to protect ecological values and processes including pool and riffle habitats, fish movement and water quality. Base flow is considered the 80th percentile from November to May and the 90th percentile from June to October. This 80:90 rule has been applied to hydrological modelling of the Murrumbidgee River at Angle Crossing for the M2G environmental operational plan (Icon Water, 2017) and was based on data collected from the Lobb's Hole gauging station (Figure 1-2). As can be seen from Figure 1-2, the lowest flows in the Murrumbidgee River occur in summer and autumn. It is during these low flow months that abstraction from the Murrumbidgee River is likely to have the most significant impact, as the proportion of the abstraction rate to the base flow is the greatest.

Under the current licence agreement (Icon Water's Licence to take water, 2015 under the Water Resources ACT 2007), flows in the Murrumbidgee River at the MPS must be maintained at 20 ML/d during any stage of water restrictions. When these restrictions do not apply, flows must be maintained using the 80:90 rule.

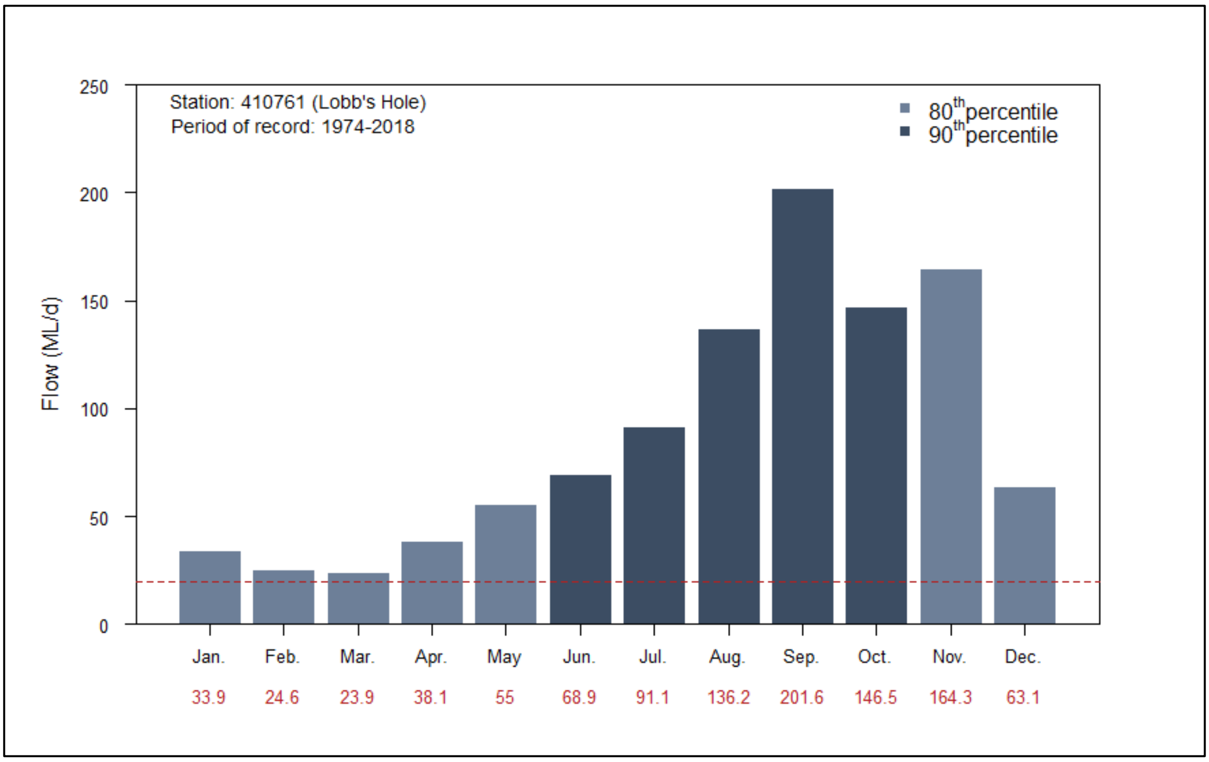

Figure 1-2. Environmental flow values for the operation of the M2G pipeline

Note: Flow data values to 31/05/2018. Monthly values in red are mega litres per day (ML/d) and are based on continuous daily flow data from the Lobb's Hole gauging station (410761) since its commencement of operation in 1974. Dashed line shows 20 ML/d.

1.2 Project objectives

The MEMP was established by Icon Water to evaluate:

- Potential impacts of water abstraction from the Murrumbidgee River at Angle Crossing and the MPS (Components 1 & 3)
- Subsequent changes that might occur in Burra Creek (Component 2).

Since the completion of the M2G infrastructure and the MPS upgrade, both have been used infrequently as Icon Water has opted to use available water from other catchments which offer raw water with lower production costs. Furthermore, the breaking of the drought in 2010 reduced the need to operate M2G or MPS because of improved water storage levels. However, a decision to transition to operation mode has triggered pre-operational impact monitoring in autumn and spring 2019.

The aim of the 2019 impact monitoring presented in this report is to provide baseline data prior to changing to operational phase. This data will be used to compare the ecological conditions of control sites to those of the impacted sites over time to determine if there are any major catchment scale changes to the aquatic ecology in either the Murrumbidgee River or Burra Creek during the projects operational phase. These potential impacts have been assessed by the relevant Government authorities through submission of Environmental Impact Statements (EIS) or similar assessments. One of the components of the EIS is to undertake an ecological monitoring program, on which this program is based.

Ultimately, the MEMP is aimed at addressing a series of hypotheses developed by Jacobs (2014). The MEMP has been designed to enable to information generated to test the hypotheses and whether mitigations rules are effective in protecting river health (Table 1-2).

1.3 Scope of works

The scope of this report is to convey the results from the initial two rounds of impact monitoring in autumn and spring 2019 for Component 1 – Angle Crossing, Component 2 – Burra Creek, and the initial impact round of impact monitoring for Component 3 – MPS in spring 2019.

As outlined in the MEMP proposal to Icon Water (GHD, 2015b), this work includes:

- Macroinvertebrate samples collected from riffle and edge habitats using AUSRIVAS protocols at the relevant sites
- Macroinvertebrate samples counted and identified to the taxonomic level of genus[2]
- Riffle and edge samples assessed through the appropriate AUSRIVAS model
- The use of photogrammetry to monitor periphyton, vegetation and geomorphology at the relevant sites
- *In-situ* water quality measurements
- Water quality grab samples analysed for nutrients in the Australian Laboratory Services (ALS) Canberra NATA accredited laboratory
- A review of fish monitoring results undertaken by the ACT Government.

[2] The reason for the genus resolution stems from the extensive and high quality data set which precedes the adjusted program. By including genus level identification, the long term integrity of the data record can be maintained.

Table 1-2. Management hypotheses to be tested following impact assessment monitoring for M2G and MPS operations

Hypotheses	Operation(s)
1a: Flow abstraction will not result in the deterioration of the macroinvertebrate community (measured using biological indices) at sites downstream of the abstraction point (Angle Crossing for M2G and downstream of MPS) relative to sites upstream, informed by prevailing conditions in the broader region.	M2G & MPS
1b: Flow discharge to Burra Creek will not result in the deterioration of the macroinvertebrate community (measured using biological indices) at sites downstream of the inflow relative to sites upstream of the abstraction point, and informed by prevailing conditions in the broader region.	M2G
2a: Flow abstraction in the Murrumbidgee River will not result in the development of increased periphyton to the extent that it impacts on the quality of the riffle habitat at sites downstream of the abstraction point (Angle Crossing for M2G and downstream of MPS) compared to sites upstream of the abstraction point, and informed by prevailing conditions in the broader region	M2G & MPS
2b: Flow discharge into Burra Creek will not result in the development of increased periphyton to the extent that it impacts on the quality of the riffle habitat at sites downstream of the abstraction point (Angle Crossing) compared to sites upstream of the abstraction point, and informed by prevailing conditions in the broader region.	M2G
3a: Flow transfer to Burra Creek will not result in bank erosion that is beyond that currently occurring in response to natural high flow events.	M2G
3b: Flow discharge to Burra Creek will not result in changes in macrophyte or riparian vegetation that is beyond that currently occurring in response to natural high flow events.	M2G
4a: Flow abstraction from the Murrumbidgee River will not result in an increased threat to threatened cod species due to decreased pool mixing and consequent water quality impacts.	M2G & MPS
4b: Flow discharge to Burra Creek will not result in the introduction of Carp or Oriental Weatherloach populations (via transfer) in Burra Creek or native fish stranding on drawdown.	M2G

2. Study area

2.1 The Upper Murrumbidgee River

The Murrumbidgee River flows for 1,600 km from its headwaters in the Snowy Mountains to its junction with the Murray River. The catchment area to Angle Crossing is 5,096 km^2. As part of the Snowy Mountains Scheme, the headwaters of the Murrumbidgee River are constrained by the 252 GL Tantangara Dam, which was completed in 1961. The reservoir collects water and diverts it outside the Murrumbidgee catchment to Lake Eucumbene. This has reduced base flows and the frequency and duration of floods in the Murrumbidgee River downstream. The Murrumbidgee River is impounded again at Burrinjuck Dam, after the river passes through the ACT. This region above Burrinjuck Dam is generally referred to as the Upper Murrumbidgee.

Land use varies from National Park in the high country to agricultural use in the valley regions. Land use is dominated by urbanisation between Point Hut Crossing and the North Western suburbs of Canberra near the confluence with the Molonglo River. The major contributing urbanised tributary flowing into the Murrumbidgee River is Tuggeranong Creek, which enters the Murrumbidgee River downstream of Point Hut crossing. Annual rainfall in the Upper Murrumbidgee River catchment ranges from greater than 1400 mm in the mountains, to an average annual rainfall of 675 mm at Lobb's Hole (570985).

2.1.1 Hydrology of the Upper Murrumbidgee River

Prior to spring 2010, drought was the most significant impact on catchment quality within the upper Murrumbidgee catchments. During this period, more than 80% of catchments had been drought-affected since late 2002. Some of the effects of this were drought-induced land degradation, increased stress on surface and groundwater resources, increased soil erosion and a shift from mixed farming and cropping, to grazing and reduced stock numbers. In the spring of 2010, the drought broke in the ACT and surrounding NSW regions and frequent high flow events occurred throughout the following twelve months, resulting in an upward trend in the mean monthly base flows (Figure 2-1). There was a decline in base flow between November 2012 and May 2013 following a particularly dry summer and autumn. Flows remained stable during 2014-15. However, since a spike in 2016, base flows have generally declined and continue to decline (Figure 2-1).

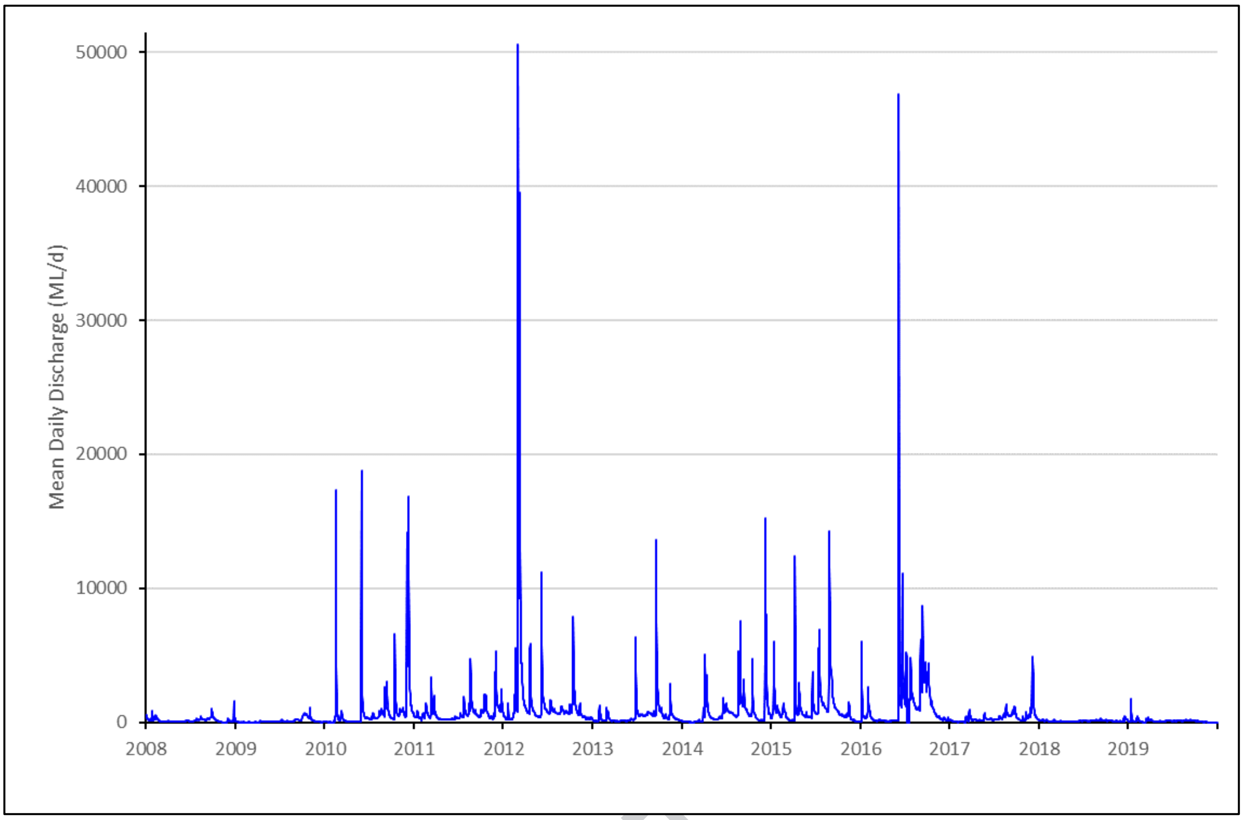

Figure 2-1. Discharge rate (ML/d) of the Murrumbidgee River at Lobb's Hole (410761) from 20008 to 2019

2.2 Burra Creek

Burra Creek is a small intermittent stream, which flows north to north-east along the western edge of the Tinderry Range into Googong Reservoir. The majority of its catchment is pastoral and small rural holdings with the Tinderry Range being natural dry sclerophyll forest. Burra Creek is characterised by emergent and submerged macrophyte beds with limestone bedrock and frequent pool-riffle sequences throughout its length. During low flow periods, the main channel is commonly choked with macrophytes. Burra Creek is within a large macro-channel in the lower reaches both upstream and downstream of London Bridge (a natural limestone arch). When Googong Reservoir is at >80% capacity, the lower sections of Burra Creek become inundated by the reservoir.

2.2.1 Hydrology of Burra Creek

Flow conditions have varied considerably since the inception of the MEMP in late 2008 (Figure 2-2). In 2008, mean daily flow was 0.15 ML/d and this was followed by an equally dry year in 2009 when the mean daily flow was 0.18 ML/d. In early 2010 there were a few rainfall events and this pattern continued throughout most of the year resulting in an upward trend of daily mean flows, which reached an average of 23.4 ML/d. 2011 was a moderately dry year and mean flows fell back to less than 5 ML/d until March 2012, which saw period of large rainfall events. These rainfall events resulted in another upward trend in average flows until early spring 2012 (Figure 2-2). Summer in 2019 was the driest since 2009 (Figure 2-2).

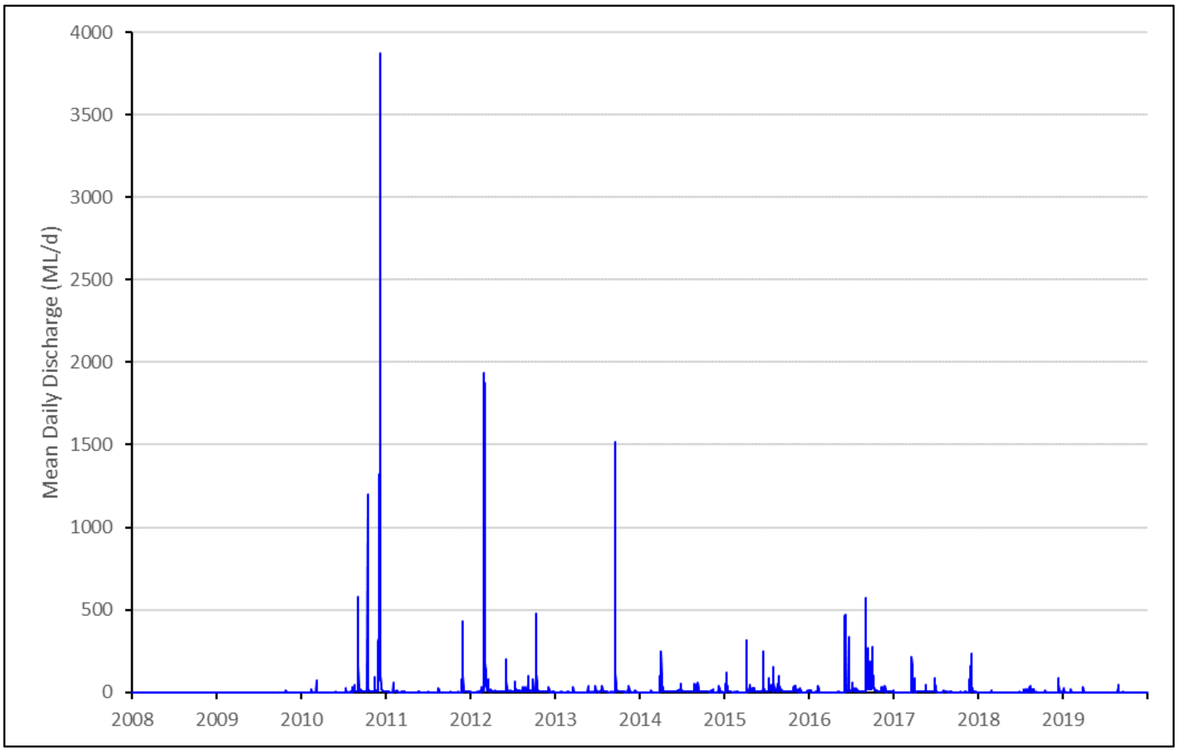

Figure 2-2. Discharge rate (ML/d) of Burra Creek at the Burra Road weir (410774) from 2008 to 2019

3. Methods

3.1 Study sites

Table 3-1 presents the study sites sampled for the autumn 2019 and spring 2019 monitoring events. The table also identifies the monitoring and investigations that were undertaken at each site which are discussed further below. The locations of the sites are shown in Figure 3-1 to Figure 3-3. It should be noted that impact monitoring for Component 3 was not required to be undertaken in spring 2019.

Upstream (control) and downstream (impact) sites relative to the respective infrastructure formed the basis of the 2019 impact monitoring of the MEMP. These sites are a subset of existing sites, which were previously sampled as part of the original MEMP program (2009-2014), as well as the sites modified in response to program review recommendations (Jacobs, 2014). These sites were chosen based on several criteria, which included:

- Safe access and approval from land owners
- Representative habitats (i.e. riffle / pool sequences). If both habitats were not present then sites with riffle zones took priority as they are the most likely to be affected by abstractions
- Sites which have historical ecological data sets (e.g. Keen, 2001) took precedence over new sites allowing for comparisons through time to help assess natural variability through the system. This is especially important in this program, because there is less emphasis on the reference condition, and more on comparisons between and among sites of similar characteristics in the ACT and surrounds over time.

Table 3-1. Sampling locations, details and investigations undertaken during the autumn and spring 2019 impact monitoring

Component		Site Code	Location	Purpose	Alt. (m)	Land use	Latitude	Longitude	Water quality	Macro-invertebrate	Periphyton	Geo-morphology	Riparian Vegetation	Fish
Component 1 (M2G)	Angle Crossing	MUR 17	~950 m upstream Angle Crossing	Control	597	Recreation Grazing	-35.586453	149.112817	✓	✓	✓			
		MUR 18	~600 m upstream Angle Crossing	Control	597	Grazing	-35.587542	149.109902	✓	✓	✓			
		MUR 19	Immediately downstream Angle Crossing	Impact	596	Recreation Grazing	-35.583027	149.109486	✓	✓	✓	✓		
		MUR 20	~400 m downstream Angle Crossing	Impact	595	Recreation Grazing	-35.580979	149.111303	✓	✓	✓			
Component 2 (M2G)	Burra Creek	BUR 1a	Upstream Burra Rd	Control	801	Grazing	-35.597819	149.227547				✓		
		BUR 1b	Upstream Williamsdale Rd	Control	798	Grazing	-35.597536	149.227023	✓	✓	✓			
		BUR 1d	Upstream Williamsdale Rd	Control	748	Grazing	-35.555963	149.222150	✓	✓	✓			
		BUR 2	Downstream Williamsdale Rd	Impact	746	Grazing	-35.553320	149.225228	✓	✓	✓	✓	✓	
		BUR 2a	Downstream Williamsdale Rd	Impact	748	Grazing	-35.554345	149.224477	✓	✓	✓	✓		
		Pool 29	Googong Foreshore upstream London Bridge	Impact	688	Recreation	-35.531316	149.245800				✓	✓	
		BUR 2c	Googong Foreshore upstream London Bridge	Impact	668	Recreation	-35.518833	149.261250				✓	✓	
Component 3 (MPS)	Murrumbidgee Pump Station	MUR 28up	Upstream MPS (upstream Cotter River)	Control	462	Grazing	-35.324382	148.950381	✓	✓	✓			
		MUR 28down	Upstream MPS (downstream Cotter River)	Control	462	Grazing	-35.324699	148.950417	✓	✓	✓			
		MUR 935	Downstream of MPS (Casuarina Sands)	Impact	461	Grazing	-35.319483	148.950211	✓	✓	✓			
		MUR 936	Downstream of MPS	Impact	460	Recreation	-35.317535	148.961213	✓	✓	✓			

Paper Size ISO A4

0 0.055 0.11 0.165 0.22

Kilometers

N

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

GHD

Icon Water
Murrumbidgee Ecological Monitoring Program

Murrumbidgee to Googong
Impact Monitoring Sites

Project No. 2316216
Revision No. 1
Date 15/05/2019

FIGURE 3-1

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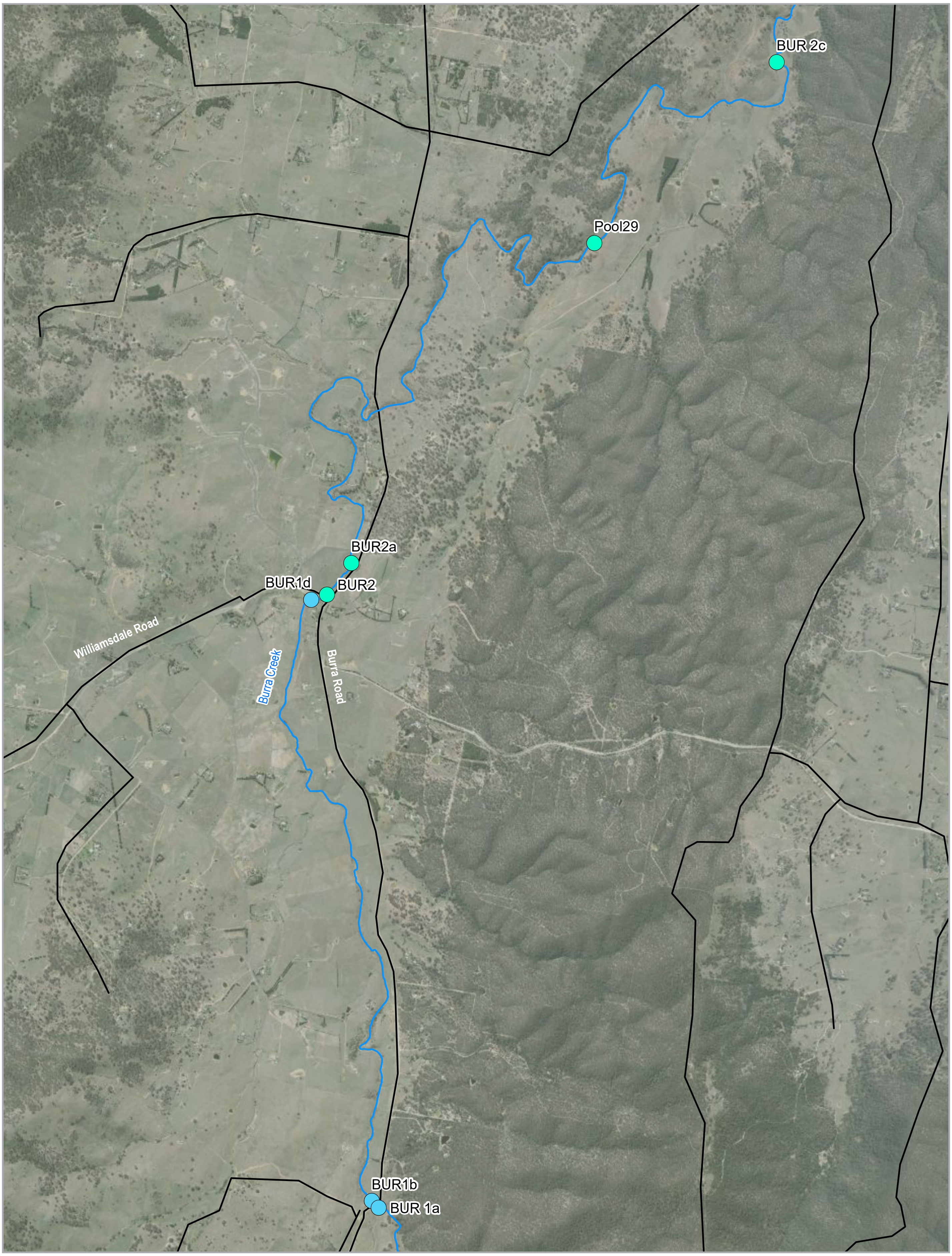

Paper Size ISO A4

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Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

N

GHD

Icon Water
Murrumbidgee Ecological Monitoring Program

Murrumbidgee to Gogong Impact Monitoring Sites

Project No. 2316216
Revision No. 2
Date 24/07/2020

FIGURE 3-2

N:\AU\Canberra\Projects\23\16216\GIS\Maps\Working\BurraCreek_B.mxd
Print date: 24 Jul 2020 - 10:07

Data source: © Department of Customer Service 2020;Imagery NSW imagery webmap sixmap. Created by: cjauniau

Paper Size ISO A4

0 0.07 0.14 0.21 0.28

Kilometers

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

N

Icon Water
Murrumbidgee Ecological
Monitoring Program

Murrumbidgee Pump Station
Impact Monitoring Sites

Project No. 2316216
Revision No. 1
Date **15/05/2019**

FIGURE 3-3

G:\23\16216\GIS\Maps\Working\MPS_updates.mxd
Print date: 21 Nov 2019 - 14:58

Data source: . Created by: pjtaylor

3.2 Hydrology and rainfall

River flows and rainfall for the monitoring period were recorded at ALS maintained gauging stations located upstream of Angle Crossing (41001702), at Mt. MacDonald (downstream of the MPS; 410738) and Burra Creek (at Burra Creek weir: 410774). The gauging stations monitor the parameters shown in Table 3-2. Stations were calibrated according to ALS protocols and data were downloaded and verified before quality coding and storage in the ALS database. Water level data were manually verified by comparing data from the gauging station value to the physical staff gauge value and adjusted if required. Rain gauges were also calibrated and adjusted as required. Records were stored using the HYDSTRA© database management system. The ALS gauging station data is presented in this report to indicate trends in water quality.

Table 3-2. River flow monitoring locations and parameters

Site Code	Location/Notes	Parameters*	Latitude	Longitude	Component of the MEMP
41001702	Murrumbidgee River, (U/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5914	149.1204	Angle Crossing (M2G)
410761	Murrumbidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5398	149.1001	Angle Crossing (M2G) / Murrumbidgee Pump Station (MPS)
410774	Burra Creek D/S road bridge	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5425	149.2279	Burra Creek (M2G)
410738	Murrumbidgee River at Mt. MacDonald	WL, Q	-35.2916	148.9552	Murrumbidgee Pump Station (MPS)

** WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (mm) D/S = downstream; U/S = upstream.*

3.3 Water quality

Water temperature, turbidity, dissolved oxygen (DO), electrical conductivity (EC) and pH were measured *in situ* using a laboratory calibrated YSI 556 multi-parameter water quality meter as a part of the ACT AUSRIVAS sampling protocols (Nichols *et al.*, 2000).

Bottled water samples (grab samples) were collected at all sites in accordance with AUSRIVAS protocols (Nichols, *et al.* 2000), and submitted to NATA accredited laboratory ALS for analysis. Samples were analysed for ammonia, oxidised nitrogen (nitrate + nitrite), total nitrogen and total phosphorus.

3.3.1 Data analysis

Water quality parameters were examined for compliance with the Australian New Zealand Guidelines for Fresh and Marine Water Quality healthy ecosystems in upland streams (ANZG 2018), that supersede the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). Summary statistics were calculated for the parameters collected at the gauging stations and time series plots created to assist with the interpretation.

3.4 Macroinvertebrate monitoring

Where habitat conditions permitted, two replicate samples were collected from both riffle and edge habitats at each site. Both habitats were sampled to provide a more comprehensive assessment of each site (Nichols *et al.*, 2000) and potentially allow the program to isolate flow-related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be affected in different ways by changes in flow conditions. Riffle zones, for example, are likely to be one of the first habitats affected by low flows as water abstraction will result in an immediate reduction in flow velocities and inundation level over riffle zones downstream of the abstraction point. Impacts on edge habitat macroinvertebrate assemblages might be less immediate as it may take some time for the reduced flow conditions to cause loss of macrophyte beds and access to trailing bank vegetation habitat. Therefore, monitoring both habitats will allow the assessment of the short-term and longer-term impacts associated with water abstraction.

Samples were collected using the ACT AUSRIVAS protocols outlined in Nichols *et al*. (2000). Sampling nets and all other associated equipment were washed thoroughly between habitats, sites and sampling events to remove any macroinvertebrates retained on them. The samples were placed in separate containers, preserved with 70% ethanol, and clearly labelled inside and out with project information, site code, date, habitat, and sampler details. ACT AUSRIVAS field sheets were also completed at each site.

Processing of samples followed the ACT AUSRIVAS protocols (Nichols *et al*., 2000). In the laboratory, each preserved sample was placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was agitated to evenly distribute the sample, and the contents of randomly selected cells removed and examined under a dissecting microscope until a minimum of 200 animals were counted. All animals within the selected cells were identified. Sample processing was repeated 3 for each sample times to align with the approach used in previous monitoring events.

Macroinvertebrates were identified to genus level (where possible) using taxonomic keys outlined in Hawking (2000) and later publications. Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the data set prior to analysis. Genus identification was recommended by Chessman (2008) from his review of the MEMP project design.

3.4.1 Quality control

A number of Quality Control procedures were undertaken during the macroinvertebrate identification phase of this program including:

- Individuals heavily damaged were not selected during sorting. To overcome losses associated with damage to intact Individuals during sample handling, attempts were made to obtain significantly more than 200 Individuals.
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience.
- When required, taxonomic experts confirmed identification. Reference collections were also used when possible.
- ACT AUSRIVAS QA/QC protocols were followed.
- An additional 5% of samples were re-identified by another senior taxonomist.
- Very small, immature, damaged animals or pupae that could not be positively identified were not included in the data set.

- All procedures were performed by AUSRIVAS accredited staff.

3.4.2 Univariate analysis

The macroinvertebrate data has been analysed using a combination of univariate and multivariate techniques. Univariate metrics are often used in a lines-of-evidence approach in river health assessments and have solid foundations in biomonitoring. The univariate techniques include:

- Taxa Richness
- EPT Richness
- SIGNAL-2 Biotic Index
- ACT AUSRIVAS O/E score and Band.

Taxa Richness & EPT Richness

The total number of taxa (Taxa Richness) and number of pollution-sensitive taxa of the orders Ephemeroptera, Plecoptera and Trichoptera (EPT Richness) were calculated at family and genus levels. Taxa richness was calculated as a means of assessing macroinvertebrate diversity with high taxa richness scores usually, though not always, indicate better ecological conditions. In certain instances, high taxa richness may indicate a response to the provision of new habitat or food resources that might not naturally occur and are the result of anthropogenic activities. EPT taxa are generally considered more sensitive to pollution.

SIGNAL-2

Stream Invertebrate Grade Number – Average Level (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 2003). Each family has been assigned a grade between 1 (most tolerant) and 10 (most sensitive). The SIGNAL index is then calculated as the average grade number for all families present in the sample. The resulting index score can then be interpreted by comparison with other sites, with larger values indicating potential better water quality conditions as the community has higher levels of sensitivity. These grades have been updated and standard errors applied under the SIGNAL-2 model approach developed by Chessman (2003). These changes were introduced to improve the reliability of the SIGNAL index.

AUSRIVAS

AUSRIVAS is a standard approach for assessing the ecological health of freshwaters through biological monitoring and habitat assessment (Nichols et al., 2000). The AUSRIVAS models are a predictive tool that uses site-specific information to predict the macroinvertebrate fauna expected (E) to be present in the absence of environmental stressors. The expected fauna from reference sites with similar sets of predictor variables (physical and chemical characteristics which cannot be influenced by human activities such as altitude) are compared to the observed fauna (O) from monitoring and the ratio derived (O/E) is used to indicate the extent of any impact. The ratio is allocated into Bandwidths (i.e. X, A-D; Table 3-3) which are used to gauge the overall health of that particular site (Coysh *et al*., 2000).

AUSRIVAS are based on the results from both the riffle and edge samples, where available. Using a precautionary approach as recommended by Coysh *et al.* (2000), the overall site condition was based on the farthest Band (from the sub-sample) from reference in a particular habitat at a particular site. For example, a site assessed as a Band-A in the edge and a Band-B in the riffle would be given an overall site assessment of Band-B (Coysh *et al*., 2000).

Table 3-3. AUSRIVAS Band widths and interpretations for the ACT autumn and spring 2019 riffle and edge habitats

Band	RIFFLE O/E Band width	EDGE O/E Band width	Explanation
X	> 1.12	> 1.17	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.88 – 1.12	0.83 – 1.17	Similar to reference. Water quality and / or habitat in good condition.
B	0.64 – 0.87	0.49 – 0.82	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.40 – 0.63	0.15 – 0.48	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	< 0.40	< 0.15	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

3.4.3 Multivariate analyses

Multivariate analyses of macroinvertebrate data were examined separately for riffle and edge habitats. Replicates were examined individually (i.e. not averaged) at all sites as the aim is to examine within-site variation in addition to examining patterns among sites. All multivariate analyses were performed using PRIMER version 7 (Clarke and Gorley, 2006).

Data were square-root transformed to increase the contribution of rare or cryptic taxa in the analyses and a similarity matrix developed based on the Bary-Curtis similarity measure (see Clarke and Warwick, 2001). Non-metric multidimensional scaling (NMDS) ordination plots were produced as a visual representation of similarity amongst samples. The number of dimensions (axes) used in the NMDS procedure was based on the resultant stress levels. The stress level is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions and will increase as the number of dimensions is reduced and can be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964).

The similarity percentages (SIMPER) routine was carried out on the datasets following a significant ANOSIM test to examine which taxa were responsible for, and explained the most variation among statistically significant groupings (Clarke and Warwick, 2001), this was also used to describe groups (i.e. in terms of which taxa characterised each group of sites).

3.5 Photogrammetry

Photogrammetry was used as a means to monitor potential changes in response to the operation of M2G and MPS over and above those occurring naturally. Photogrammetry is an inexpensive and robust alternative to quantitative techniques (O'Connor and Bond, 2007). Using this method, photo points were established at each monitoring location using markers and GPS coordinates. Photographs are taken at the same point on a pre-determined temporal scale or at times triggered by natural or other unforeseen events. The aspect of the photograph is determined by either using secondary or tertiary markers or by using land scape features. The resulting photographs provide a robust and valuable resource to help understand the temporal dynamics of the system and provide a visual reference of habitat in relation to the macroinvertebrates results as a measure of river health. This method was applied to monitor periphyton, vegetation and geomorphology at the relevant sites.

3.5.1 Periphyton

Representative photographs were taken at each site of the substrate using a 1 m x 1 m quadrat for scale. These photographs were considered to be representative of the habitat and site. Semi -quantitative estimates of the proportion of cover were recorded using the ACT AUSRIVAS field sheet methodology (Nichols, *et al.*, 2000). Periphyton has been included in the monitoring program for Angle Crossing (M2G) and the MPS sites as a means of assessing the influence of flow upon the algal communities downstream of the abstraction point compared to upstream. The aim of this monitoring is to determine, during operational pumping, whether algal and periphyton communities downstream of Angle Crossing are increasing compared to upstream sites due to the reduction in flow. Periphyton has been included in the monitoring program for Burra Creek to monitor the effect which flow is having upon the algal communities downstream of the M2G discharge weir. The aim of this monitoring is to determine during operational pumping whether algal communities downstream of the discharge are changing compared to upstream sites due to the alteration of the natural flow regime.

3.5.2 Riparian and instream vegetation

Photographs were taken at existing photo points to record the current extent of riparian and instream vegetation at relevant sites. Three photos were taken at each point, one facing upstream, one facing downstream and another directly across the channel. GPS co-ordinates have been recorded for all photo points, while some sites also have survey pegs inserted to assist in locating the exact location.

The use of photogrammetry for monitoring the change in the vegetation communities and coverage at the Burra Creek sites is considered to be an efficient method for assessing whether the maintenance pumping is having a significant impact (Hall, 2001). These photo points will be used for comparison to future photo points, or with photos and observations recorded before and after the use of the M2G pipeline for operational purposes.

3.5.3 Geomorphology

Photographs were taken at each of the geomorphology sites. Geomorphological features of interest have already been recorded (GHD, 2015c) and this report, represents a continuation of the methods that have already been used in monitoring geomorphology in the context of the MEMP.

To capture changes in the morphology as effectively as possible, the photos were taken from the existing photo points. Both survey pegs and GPS co-ordinates have been used to accurately record the position of each photo point. Three photos were taken at each point, one facing upstream, one facing downstream and another directly across the channel, with these photo points chosen to ensure all geomorphological features identified at each site have been adequately recorded.

The use of photogrammetry at previously identified cross-sections along Burra Creek are considered to be a robust method for monitoring of potential changes in bank erosion and slumping. The photo points collected between autumn 2015 and autumn 2018 will be used for comparison to future photo points, or with photographs and observations recorded before and after the use of the M2G pipeline for operational purposes.

3.6 Temporal changes and reporting

Previous sentinel monitoring included photogrammetry of geomorphology and vegetation every two years, with macroinvertebrates and periphyton every three years (Table 3-4). Impact monitoring includes both photogrammetry and macroinvertebrate monitoring regardless of previous schedule. As previous monitoring schedules were not synchronised, this report presents photogrammetry from 2015, 2017 and 2019, and macroinvertebrates and periphyton from 2015, 2018, and 2019, and discusses any findings from these records.

Table 3-4 Monitoring schedule of the photogrammetry and sentinel, macroinvertebrate monitoring

Component	A15	S15	A16	S16	A17	S17	A18	S18	A19	S19
Photogrammetry (Vegetation & geomorphology)	✓	✓			✓	✓			✓	✓
Macroinvertebrates & periphyton	✓	✓					✓	✓	✓	✓

3.7 Licences and permits

All sampling was carried out with current scientific research permits under section 37 of *the Fisheries Management Act 1994 NSW* (permit number P01/0081(C)). All GHD aquatic ecology field staff hold current ACT and NSW AUSRIVAS accreditation.

4. Results

4.1 Component 1: Angle Crossing (M2G)

Monitoring of Angle Crossing sites as part of the M2G component was completed on 7 May (autumn) and 30 - 31 October (spring) 2019. During monitoring, weather conditions were generally fine with temperatures ranging between 8 - 16°C in autumn and 15 - 33°C in spring (at Canberra Airport weather station, 070351 - BoM, 2019).

4.1.1 Rainfall and hydrology

Total rainfall during autumn 2019 exceeded 135 mm upstream of Angle Crossing and downstream at Lobb's Hole, which was greater than the 80.6 mm and 102.4 mm during autumn 2018 for these two sites respectively (Figure 4-1 and **Error! Reference source not found.**). Monthly autumn rainfall for these two sites was above the historical mean of 48.6 mm during March and May, but was less than 7 mm during April. Total rainfall during spring 2019 was 82.3 mm upstream of Angle Crossing and 67.6 mm at Lobb's Hole which was similar to the 73.6 mm and 77.8 mm recorded during spring 2018 (Figure 4-2 and **Error! Reference source not found.**). In autumn 2019, the monthly rainfall upstream of Angle Crossing and at Lobb's Hole was well below the historic mean of 61.2 mm.

During both autumn and spring 2019, there were no major differences in flow of the Murrumbidgee River upstream of Angle Crossing and downstream at Lobb's Hole (Figure 4-3 and Figure 4-4). During autumn 2019, flow was characterised by three major spikes with the highest reaching approximately 425 ML/d in March. This was followed by a general downward trend in April and slight increase in May following rainfall events (see Figure 4-3 and **Error! Reference source not found.**). Mean monthly flow during autumn 2019 exceeded 84 ML/d at both sites in all months and was greater than flow during autumn 2018 that ranged from 47.3 to 81.5 ML/d.

During spring 2019, flow displayed an overall downward trend despite a number of flow peaks in response to rainfall events (see Figure 4-4 and **Error! Reference source not found.**). Flows of approximately 5 ML/d in late November reflect the low rainfall recorded in spring. Mean daily flow was noticeably less upstream of Angle Crossing and at Lobb's Hole during spring 2019 compared to 2018.

Table 4-1. Autumn and spring 2019 rainfall and flow summaries, upstream Angle Crossing (41001702) and Lobb's Hole (410761)

		Upstream Angle Crossing (41001702)		Downstream Angles Crossing @ Lobb's Hole (410761)	
		Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
Autumn	March	77.4	103.4	80.3	103.4
	April	3.2	105.7	6.4	103.9
	May	55.0	85.0	52.2	84.0
	Total rainfall	135.6		138.9	
Spring	September	31.8	139.0	30.4	137.7
	October	25.4	72.9	16.9	76.1
	November	25.1	16.5	20.3	18.2
	Total rainfall	82.3		67.6	

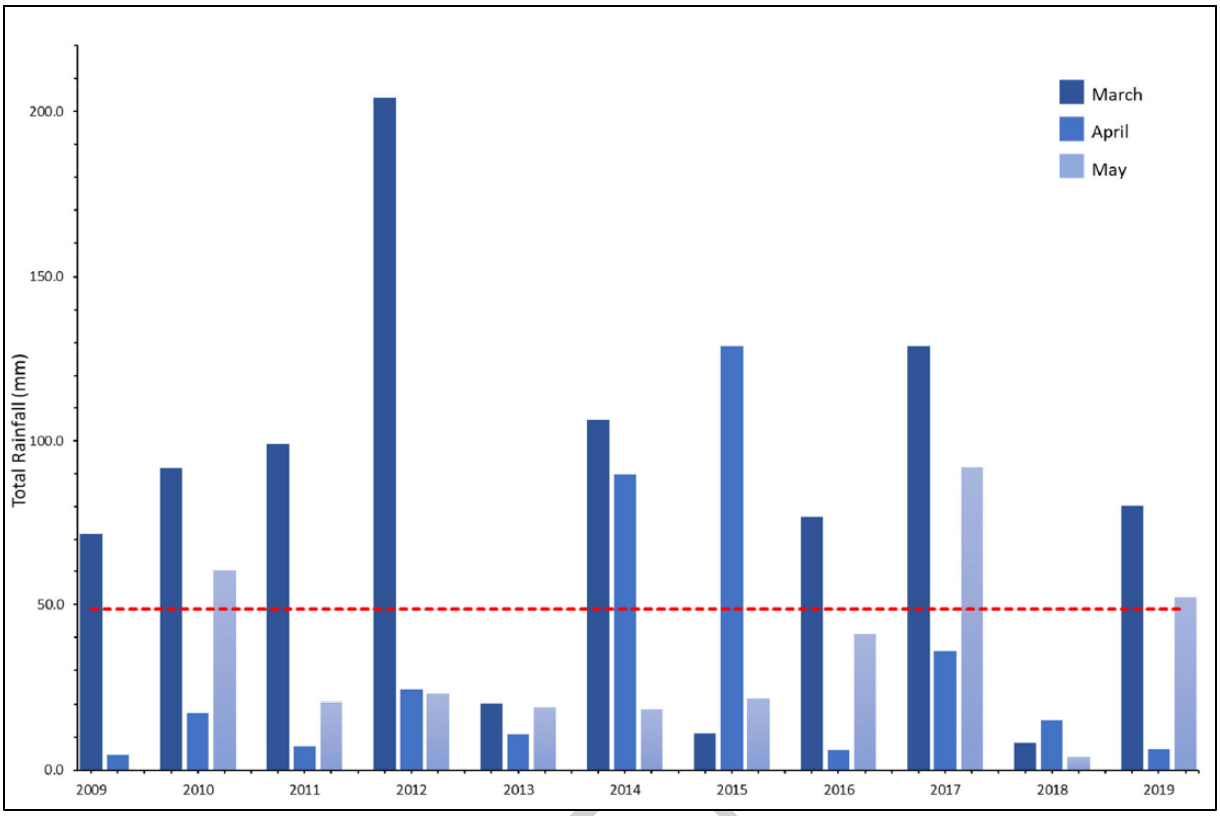


Figure 4-1. Annual comparison of autumn rainfall recorded at Lobb's Hole (570985). Red line shows mean monthly autumn rainfall 2009-2019

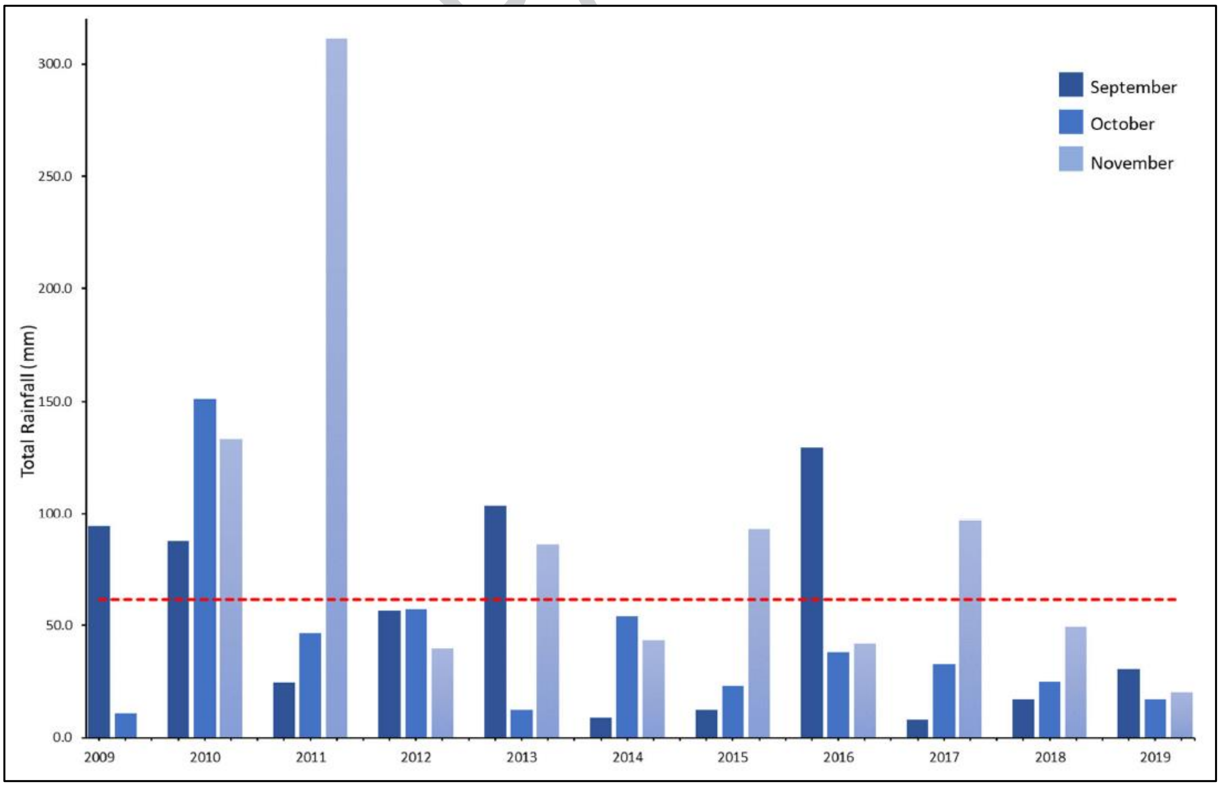


Figure 4-2. Annual comparison of spring rainfall recorded at Lobb's Hole (570985). Red line shows mean monthly spring rainfall 2009-2019

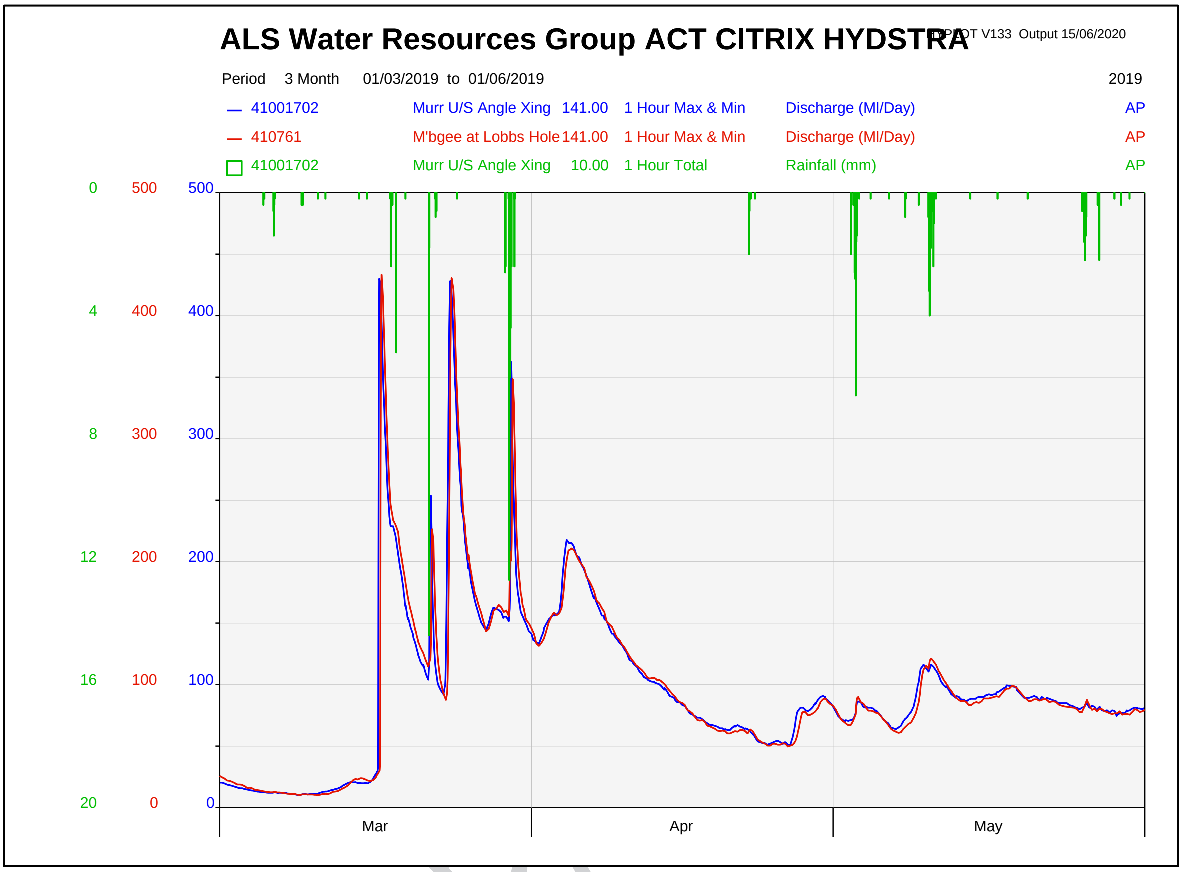


Figure 4-3. Autumn 2019 rainfall and hydrograph of the Murrumbidgee River upstream (41004702) and downstream (410761) of Angle Crossing

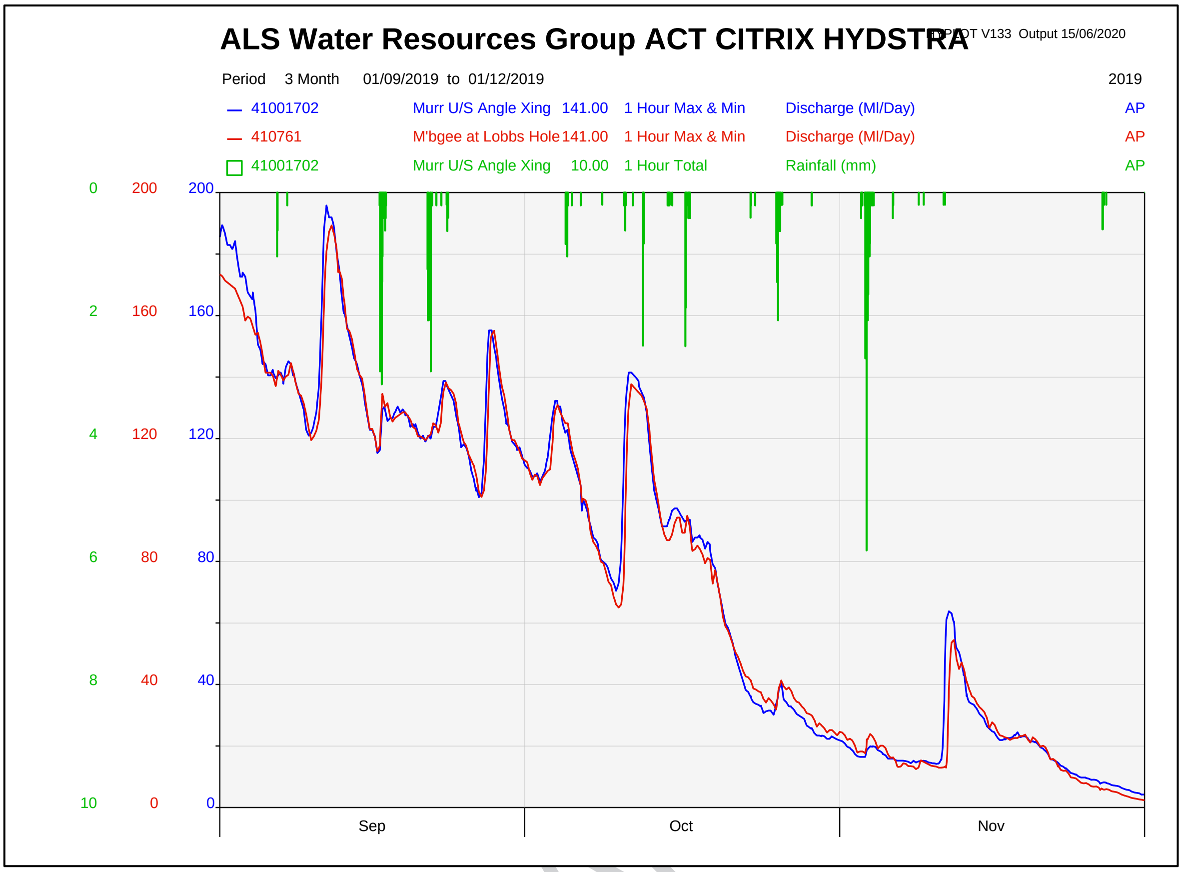


Figure 4-4. Spring 2019 rainfall and hydrograph of the Murrumbidgee River upstream (41004702) and downstream (410761) of Angle Crossing

4.1.2 Water quality

In-situ water quality parameters and grab sample results are presented in Table 4-2 and provide a snapshot of conditions during the monitoring events. During autumn 2019, all sites had elevated concentrations of nutrients which were above ANZG (2018) guidelines. Notably, total nitrogen concentrations at all sites during autumn were nearly twice as high as the guideline value. However, oxidised forms of nitrogen were below laboratory detection limits at all sites except the downstream location MUR19.. Temperature, EC, pH and DO were similar across all locations, with pH often exceeded the ANZG (2018) guideline at all sites and DO was also less than guideline expectations. Turbidity was low at all sites and within water quality guidelines, with MUR18 being much lower than other sites.

Continuous monitoring measured at gauging stations in autumn 2019 is presented in Figure 4-5 (upstream Angle Crossing) and Figure 4-6 (downstream of Angle Crossing). There was minimal variation upstream and downstream of Angle Crossing with both gauging stations showing similar peaks and troughs for all parameters. Typically, water temperature was warmest in March with a gradual decrease through to cooler May temperatures. The pH was also highest during March, but overall between 7.8 and 8.4. Turbidity was normally 10 NTU or less. However, turbidity had more exaggerated peaks and troughs upstream compared to downstream, with peaks greater than 100 and up to 250 NTU, whereas downstream peaks were between 60 and 80 NTU. Overall, EC was slightly higher in March than April or May, but a trough of lower EC was observed late March. DO was relatively stable across the three months, between 80 and 90 % saturation. The physio-chemical parameters recorded by the stations indicate that *in situ* measurements during the autumn 2019 aquatic sampling event at Angle Crossing were in line with the expected trends.

During spring 2019, similar patterns but lower concentrations were recorded for all parameters. Nutrients were elevated at all sites, but MUR19 did not show an increased NOx concentration compared to other locations as was observed in autumn 2019. The pH and DO was not within ANZG (2018) guideline limits at all sites, with the exception for the DO reading at MUR18. Turbidity again was within the guideline limits, and notably lower at MUR18.

Continuous monitoring measured at gauging stations in spring 2019 is presented in Figure 4-7 (upstream Angle Crossing) and Figure 4-8 (downstream of Angle Crossing). As per autumn 2019, trends in water quality observed upstream of Angle Crossing were similar downstream in spring 2019. Water temperatures were coolest in September with a gradual increase through to November. The pH was slightly higher in September with increased variation through to November. Turbidity was typically less than 20 NTU, with some spikes in concentration observed upstream but not downstream. EC was observed to be slightly lower downstream but on the whole showed similar trends to upstream, increasing from September to November. DO was also slightly lower downstream compared to upstream but showed also similar trends to upstream. DO was more stable in September, but moving through to November there was larger variation in DO concentrations.

Table 4-2. *In-situ* water quality results from Angle Crossing 2019. Red cells outside ANZG (2018) default guideline range

Location	Site	Sampling period	Date	Time	Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	pH	D.O. (% Sat.)	D.O. (mg/L)	Alkalinity (mg/L)	NO_x (mg/L)	TP (mg/L)	TN (mg/L)
ANZG (2018) default guideline values						30-350	2-25	6.5-8.0	90-110			0.015	0.02	0.25
Upstream	MUR 17	Autumn	7/5/2019	0900	12.8	97	8.6	8.2	78.4	8.3	78	<0.05	0.03	0.43
		Spring	31/10/2019	0900	18.9	84	15.2	8.1	88.6	8.0	45	<0.05	0.03	0.33
Upstream	MUR 18	Autumn	7/5/2019	1130	13.9	126	20.5	8.6	84.6	8.7	80	<0.05	0.03	0.44
		Spring	31/10/2019	1130	21.5	88	4.9	8.3	96.5	8.8	50	<0.05	0.03	0.35
Downstream	MUR 19	Autumn	7/5/2019	1330	13.4	98	17.6	7.9	84.6	8.8	90	0.08	0.03	0.41
		Spring	30/10/2019	1420	19.7	84	20.1	8.1	83.7	7.6	50	<0.05	0.03	0.33
Downstream	MUR 20	Autumn	7/5/2019	1600	13.7	122	17.0	8.0	88.0	9.1	90	<0.05	0.02	0.40
		Spring	30/10/2019	1305	21.1	93	14.8	8.3	88.6	8.0	60	<0.05	0.02	0.31

Note: Water Temperature (Temp.), Electrical Conductivity (EC), Dissolved Oxygen (D.O.), percentage saturation (% Sat.), Nitrite + Nitrate as N (NOx), Total Nitrogen as N (TN), Total Phosphorus as P (TP)

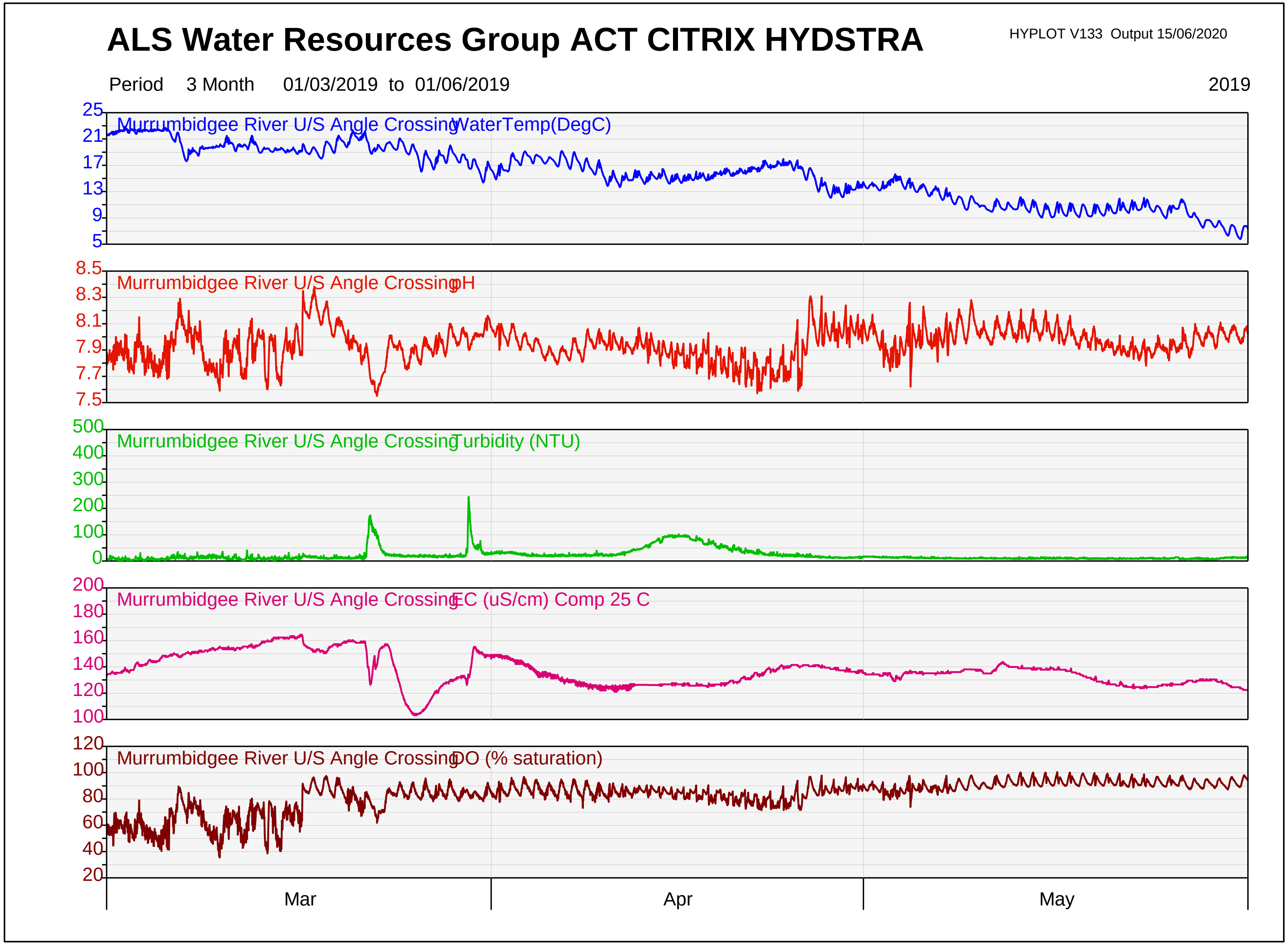


Figure 4-5. Continuous water quality records from upstream Angle Crossing (41001702) for autumn 2019

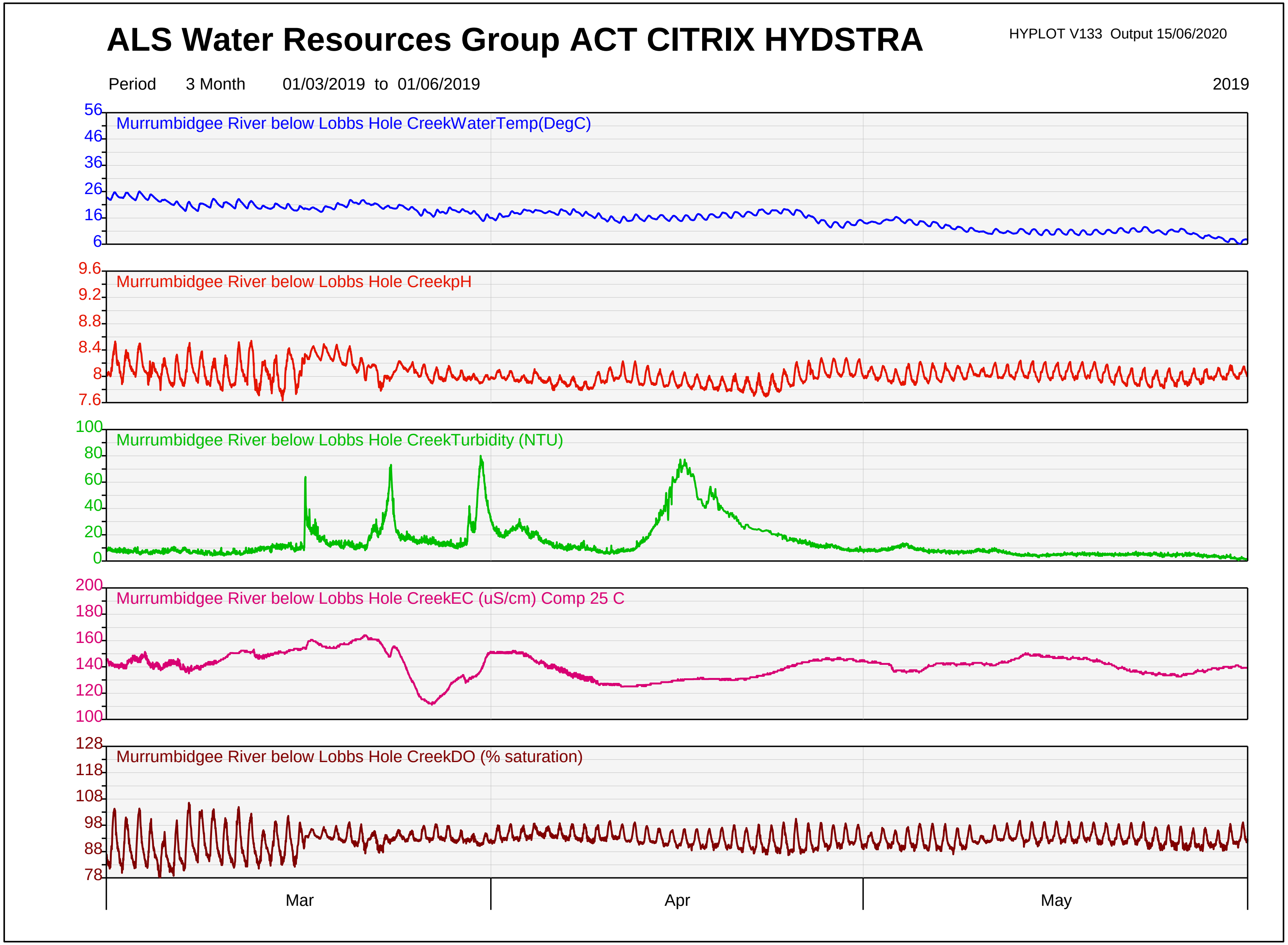


Figure 4-6. Continuous water quality records from Lobb's Hole (410761) (downstream Angle Crossing) for autumn 2019

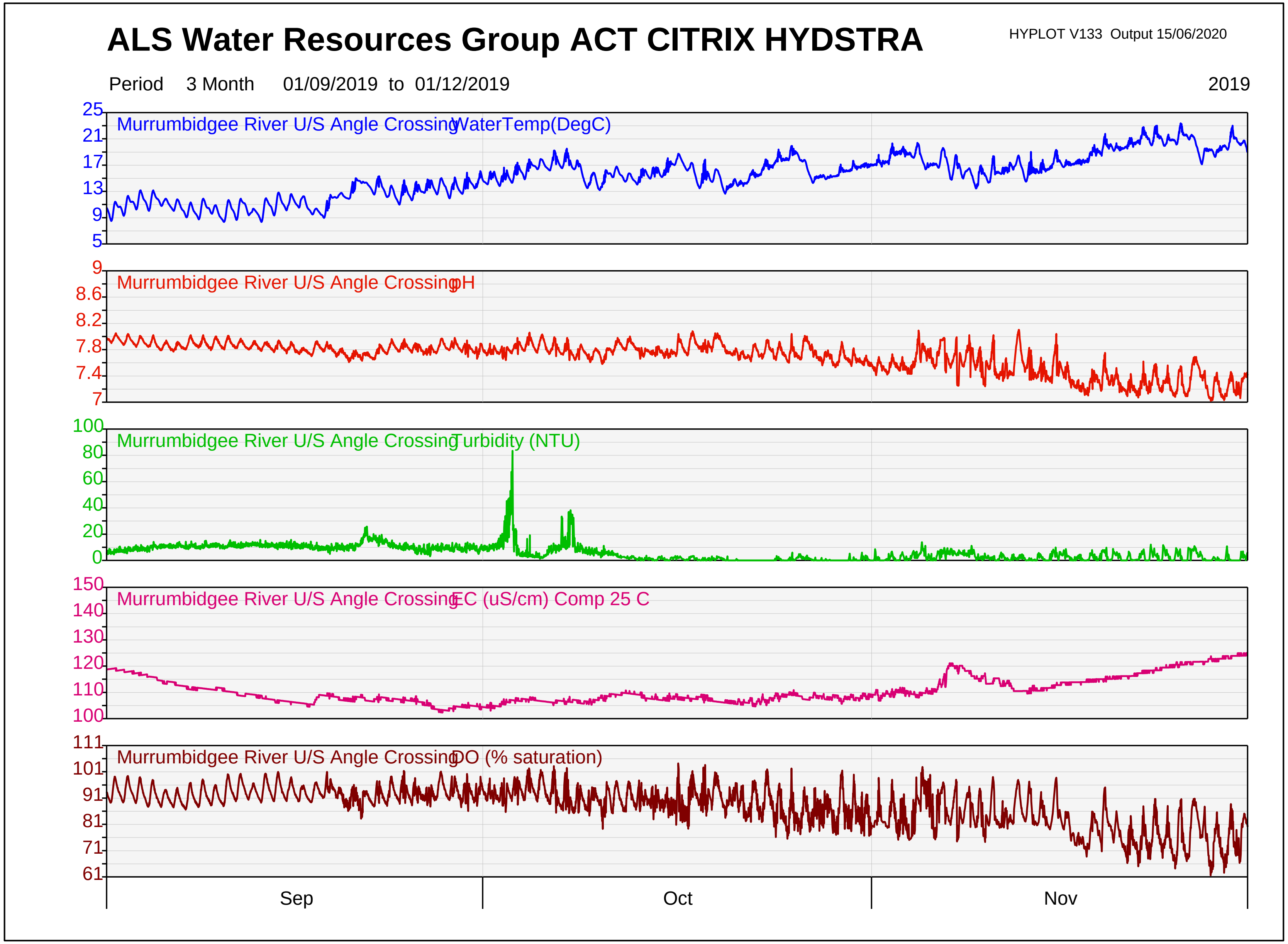


Figure 4-7. Continuous water quality records from upstream Angle Crossing (41001702) for spring 2019

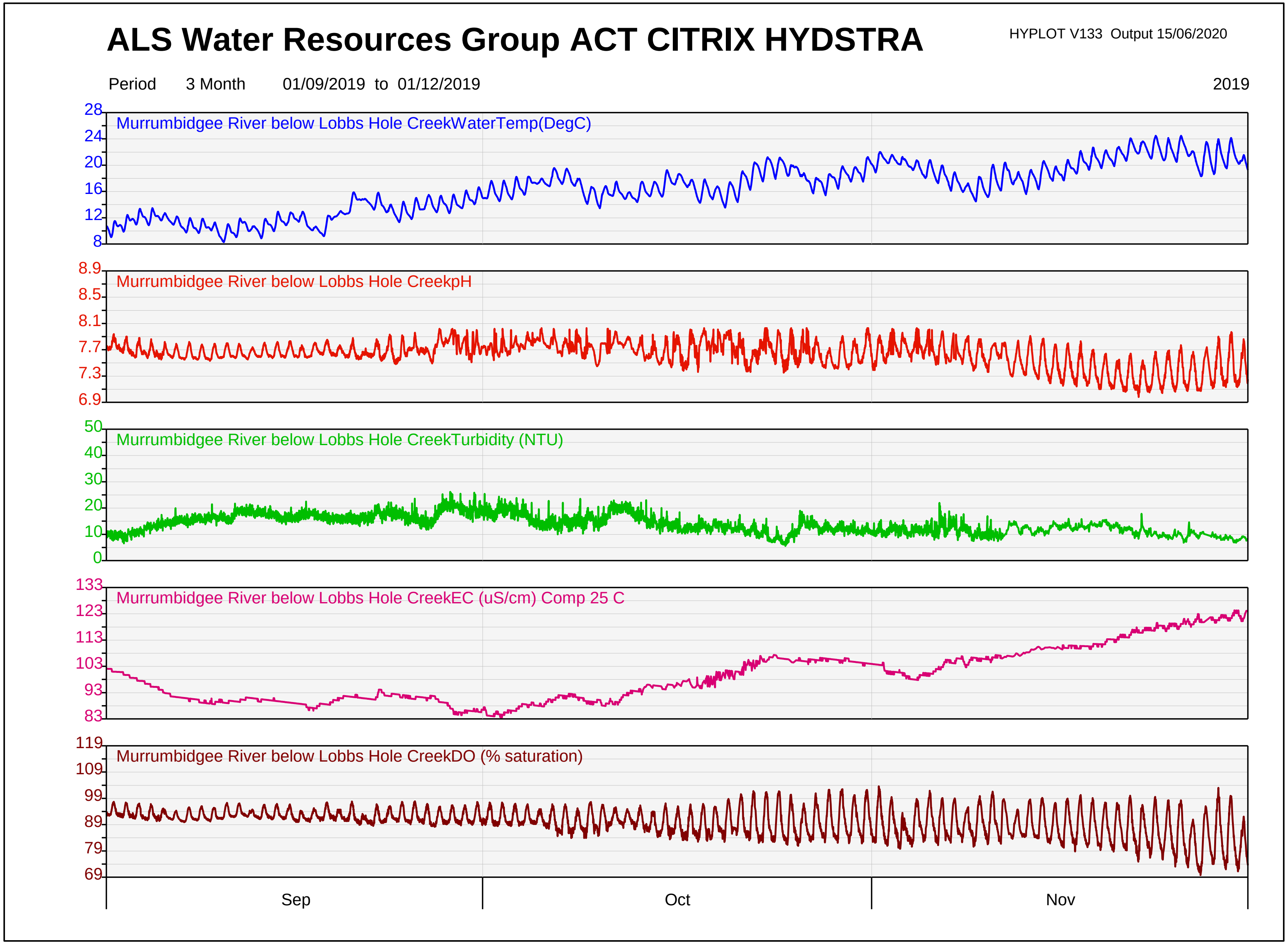


Figure 4-8. Continuous water quality records from Lobb's Hole (410761) (downstream Angle Crossing) for spring 2019

4.1.3 Periphyton

Photographs of periphyton at the Angle crossing monitoring sites are presented in Plate 4-1. Periphyton coverage for reach and riffle habitats at Angle Crossing was recorded as part of the AUSRIVAS habitat assessment presented in Appendix A.

MUR17 - Periphyton coverage at MUR17 during autumn 2019 was approximately 35-65% for the reach and 35-65% for the riffle habitat. During spring 2019, periphyton coverage was approximately 65-90% for the reach, 65-90% at the riffle, >90% in the edge habitat. The most abundant macrophyte in both seasons was *Myriophyllum sp.*

MUR18 - The periphyton coverage in autumn 2019 was <10% for the reach and <10% for the riffle habitat. Spring periphyton coverage was approximately 35-65% for the reach and 65-90% for the edge habitat. The most abundant macrophyte in both seasons was *Myriophyllum sp.*

MUR19 - The periphyton coverage in autumn 2019 was approximately 35-65% for the reach and 35-65% for the riffle habitat. The spring periphyton coverage was approximately 35-65% for the reach, 65-90% for the riffle and 65-90% for the edge habitat. *Myriophyllum sp.* was observed as the most abundant macrophyte in autumn 2019 however *Triglochin sp*. Was most abundant macrophyte during spring.

MUR20 - The periphyton coverage in autumn 2019 was approximately 35-65% for the reach and 35-65% for the riffle habitat based on the AUSRIVAS assessment method (Appendix A). Spring periphyton coverage as approximately 35-65% for the reach, 65-95% for the riffle and >90% for the edge habitat. *Myriophyllum sp*. was the most abundant macrophyte during both autumn and spring.

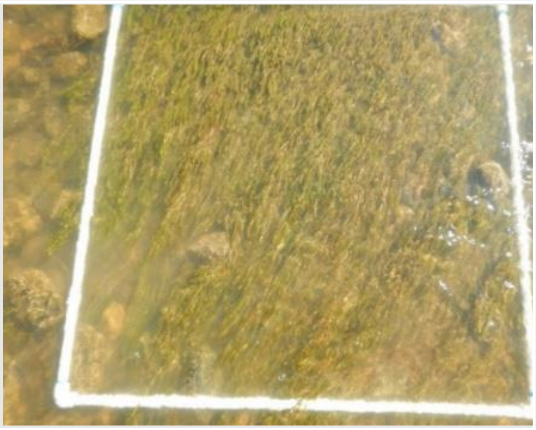
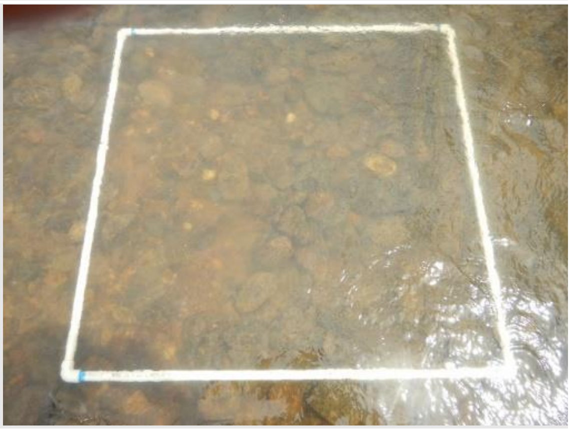
Site	Autumn	Spring
MUR17		
MUR18		
MUR19		
MUR20		

Plate 4-1. Photos showing the periphyton coverage in the riffle at Angle Crossing sites in autumn and spring 2019

4.1.4 Geomorphology

Geomorphological features at Angle Crossing (MUR19) observed in 2019 have remained relatively unchanged compared to autumn and spring 2017 (GHD, 2017), which is the previous point of reference. Plate 4-2 to Plate 4-6 show some degree of seasonal variation in water level, which was lower during spring 2019 compared to autumn. Changes in bed and bar exposure associated with water levels changes can been seen. Vegetation dieback and recruitment can also be observed in varying degrees. However, the river banks have remained stable at each of the photo points.

Plate 4-2. Geomorphology photo point 1 at Angle Crossing MUR 19 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-3. Geomorphology photo point 2 at Angle Crossing MUR 19 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

Plate 4-4. Geomorphology photo point 3 at Angle Crossing MUR 19 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-5. Geomorphology photo point 4 at Angle Crossing MUR 19 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-6. Geomorphology photo point 5 at Angle Crossing MUR 19 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

4.1.5 Macroinvertebrates

There is minimal edge habitat in this reach of the Murrumbidgee River and therefore no edge samples were collected in autumn and only 3 in spring.

The total taxa richness scores for autumn and spring 2019 calculated for samples from the Murrumbidgee River M2G sites are presented in Table 4-3. During autumn 2019, total taxa richness ranged from 13 to 19 families at family level resolution and 19 to 26 at genus level resolution in the riffle habitat. There was no pattern in diversity in riffle habitat upstream or downstream of Angle Crossing during autumn 2019.

In spring 2019, riffle habitat diversity was slightly higher compared to autumn. At family level resolution, total taxa richness ranged from 17 to 20 and at genus level resolution from 21 to 25. Similar to autumn, there was no pattern upstream or downstream of Angle Crossing in the riffle habitat. Edge samples, had comparable diversity to riffle habitat. However, the highest diversity of all sites, seasons and habitat at the Murrumbidgee River M2G was found at MUR17, with 31 taxa at genus level resolution.

The EPT Richness results for autumn and spring 2019 are presented in Table 4-4. In autumn 2019, similar EPT scores in riffle habitats were calculated for all sites at M2G with slightly higher diversity at genus resolution compared to family. The number of EPT taxa was similar in spring 2019 for riffle and edge habitats.

Table 4-3. Number of taxa at family and genus level from riffle and edge habitats in autumn and spring 2019

Total Richness	Sample number	Autumn 2019				Spring 2019			
		Riffle		Edge		Riffle		Edge	
Site		Family	Genus	Family	Genus	Family	Genus	Family	Genus
MUR 17	1	18	22	NS	NS	19	24	24	31
MUR 17	2	13	19	NS	NS	19	25	NS	NS
MUR 18	1	14	20	NS	NS	20	24	22	28
MUR 18	2	18	23	NS	NS	20	24	NS	NS
MUR 19	1	17	23	NS	NS	17	21	21	28
MUR 19	2	16	21	NS	NS	20	25	NS	NS
MUR 20	1	19	26	NS	NS	19	28	NS	NS
MUR 20	2	19	25	NS	NS	17	24	NS	NS

NS = No sample taken

Table 4-4. Number of EPT taxa at family and genus level from riffle and edge habitats

EPT taxa	Sample number	Autumn 2019				Spring 2019			
		Riffle		Edge		Riffle		Edge	
Site		Family	Genus	Family	Genus	Family	Genus	Family	Genus
MUR 17	1	7	10	NS	NS	7	11	9	14
MUR 17	2	6	11	NS	NS	7	12	NS	NS
MUR 18	1	6	10	NS	NS	8	11	6	12
MUR 18	2	8	11	NS	NS	7	11	NS	NS
MUR 19	1	7	11	NS	NS	8	11	8	15
MUR 19	2	7	10	NS	NS	8	12	NS	NS
MUR 20	1	7	12	NS	NS	8	15	NS	NS
MUR 20	2	8	12	NS	NS	6	12	NS	NS

The SIGNAL-2 and AUSRIVAS scores for riffle habitat in autumn and spring 2019 are presented in Table 4-5. SIGNAL-2 scores in autumn were similar at all sites, with minor variation between samples and sub-sample replicates. The SIGNAL-2 scores in autumn are suggestive of moderate pollution impacts. In spring, were generally found to be higher at all sites, with scores indicating mild to moderate pollution impacts. In both autumn and spring 2019, SIGNAL-2 scores were similar upstream and downstream of Angle Crossing.

AUSRIVAS scores in autumn 2019, were either 0.78 or 0.89 at all sub-sample replicates, placing the sites in either Band A, at reference condition or Band B, poorer than reference condition. In spring 2019, scores ranged from 0.77 to 1.00, again placing sites in Band A or Band B. The overall assessment for riffle habitat in both seasons placed all sites in Band B indicating water quality and/or habitat disturbance that is impacting macroinvertebrate communities.

Table 4-6 presents AUSRIVAS Bands for Angle Crossing since 2012, indicating that these sites are typically placed in Band B, and on occasion Band A during spring. The results of the 2019 monitoring are in line with previous AUSRIVAS scores.

Table 4-5. Riffle habitat AUSRIVAS and SIGNAL 2 scores for autumn and spring 2019

Site	Sample	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment	
			Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
MUR 17	1	1	4.5	5.3	0.89	0.82	A	B	**B**	**B**
		2	4.1	4.7	0.78	0.75	B	B		
		3	4.1	5.4	0.78	0.82	B	B		
	2	1	4.3	5.2	0.89	1.00	A	A		
		2	4.1	5.3	0.78	0.93	B	A		
		3	4.3	5.2	0.89	1.00	A	A		
MUR 18	1	1	4.1	5.0	0.78	0.85	B	B	**B**	**B**
		2	4.1	5.3	0.78	0.93	B	A		
		3	4.1	4.9	0.78	0.93	B	A		
	2	1	4.1	5.3	0.78	0.77	B	B		
		2	4.1	4.7	0.78	0.70	B	B		
		3	4.6	5.2	0.89	0.85	A	B		
MUR 19	1	1	4.5	5.2	0.89	0.93	A	A	**B**	**B**
		2	4.1	5.1	0.78	0.85	B	B		
		3	4.1	5.2	0.78	0.93	B	A		
	2	1	4.5	5.2	0.89	0.92	A	A		
		2	4.5	4.9	0.89	0.77	A	B		
		3	4.5	5.3	0.89	0.85	A	B		
MUR 20	1	1	4.5	4.9	0.89	0.85	A	B	**B**	**B**
		2	4.1	4.9	0.78	0.85	B	B		
		3	4.1	4.9	0.78	0.85	B	B		
	2	1	4.6	5.3	0.89	0.82	A	B		
		2	4.5	5.2	0.89	0.97	A	A		
		3	4.6	5.0	0.89	0.90	A	A		

Table 4-6. Overall site assessments for Angle Crossing sites since 2012

	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Spring 2014	Autumn 2015	Spring 2015	Autumn 2018	Spring 2018	Autumn 2019*	Spring 2019*
MUR 17											B	B
MUR 18	B	B	B	B	B	B	B	A	B	A	B	B
MUR 19	B	B	B	B	B	A	B	A	B	B	B	B
MUR 20											B	B

*Overall assessment based on riffle habitat only

The NMDS ordination of macroinvertebrate community samples from riffle habitats from the sentinel monitoring (2015 and 2018) and impact monitoring (2019) are presented in Figure 4-9. Note that each point on the NMDS represents a multivariate macroinvertebrate sample (i.e. all taxa collected and their abundances) and those samples close together have a more similar community composition than those further apart. The spread of samples on the ordination highlights the following patterns; 1) the community composition in 2015 differs to 2018 and 2019, and 2) within each year there are clear differences in the community composition between autumn and spring. Furthermore, within each season there was no clear separation between samples collected upstream and downstream of the M2G abstraction.

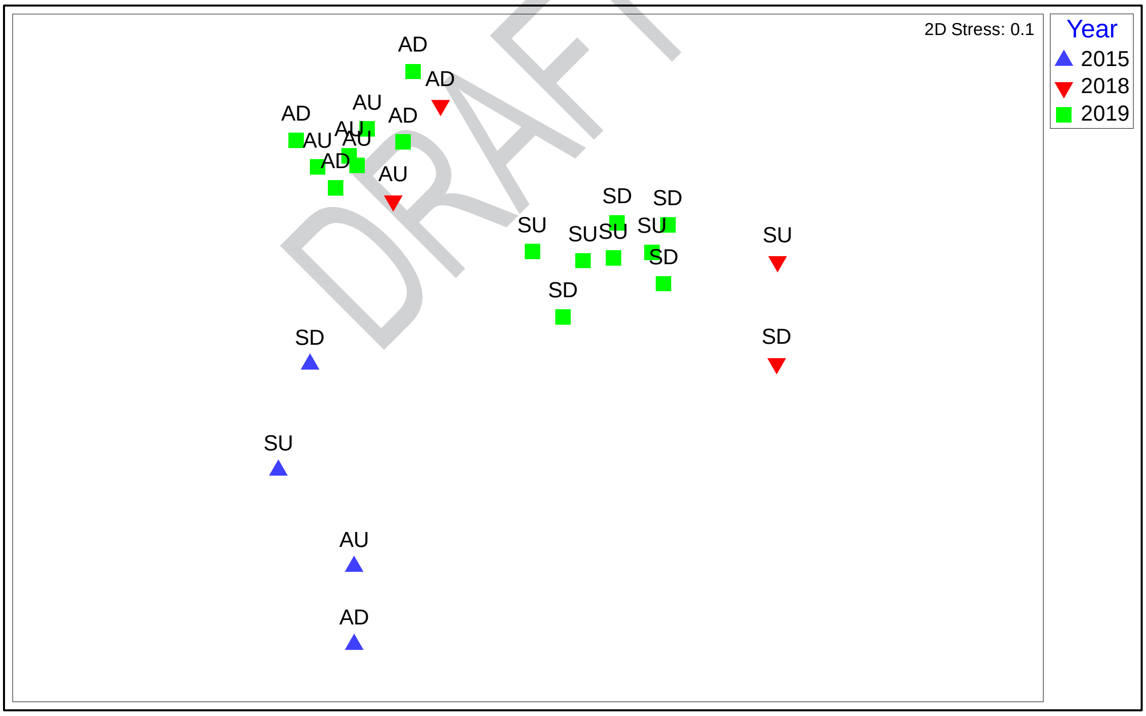


Figure 4-9. MDS ordination of macroinvertebrate communities associated with riffle habitats. A = autumn and S = spring; U = upstream and D = downstream

The low samples sizes for the sentinel monitoring (2015 and 2018) limited the power of statistical tests for differences (i.e. a single sample upstream or downstream of the abstraction within each season x year). However, for 2019 the patterns on the NMDS were confirmed by a one-way ANOSIM that detected significant differences between seasons (Global R = 0.996, P = 0.001). During autumn 2019 there were no significant differences in community composition upstream and downstream of the abstraction (Global R = 0.323, P = 0.086) but significant differences were detected in spring (Global R = 0.521, P = 0.029).

Those taxa that contributed to the differences upstream and downstream of the M2G abstraction are included in Figure 4-10. Overall there were similar taxa upstream and downstream of the abstraction point during 2019. Taxa absent downstream were *Antocha* cranefly larvae, whereas *Irapacaenis* mayfly larvae were absent upstream.

Blackfly larvae (Simuliidae) contributed most to the differences with higher average abundances upstream compared to downstream. Several individuals in the Simuliid family were immature and could not be identified further than family level resolution. Those that could be identified further were allocated to the genus *Austrosimulium* that were also more abundant upstream of the abstraction. Other taxa that were more abundant upstream include midgefly larvae (Orthocladiinae, Chironominae), worms (Oligochaeta), cranefly larvae (*Antocha*) and mayfly larvae (Baetidae, *Offadens*) and stonefly larvae (*Dinotoperla*). Alternatively, water mites (Acarina), caddisfly larvae (*Oxyethira*, *Cheumatopsyche*, *Hellyethira*.), mayfly larvae (Caenidae, *Irapacaenis*), bivalve molluscs (*Corbicula*) and riffle beetles (*Simsonia* sp.) were more abundant downstream.

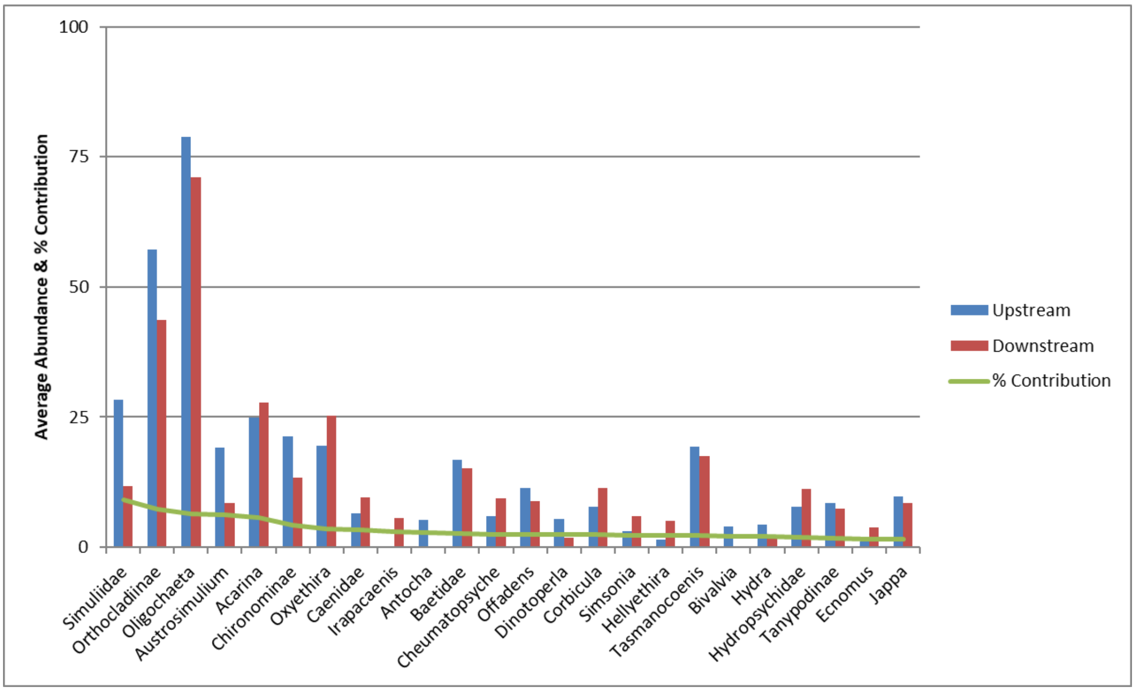


Figure 4-10. 2019 riffle habitat SIMPER analyses identifying those taxa that contributed most to the dissimilarity between upstream and downstream locations associated with Angle Crossing. Taxa that contributed to 80% of the dissimilarity are included and the average dissimilarity between samples was 24.61%. Note that abundances are square-root values

4.1.6 Fish

The 2019 fish monitoring of the Murrumbidgee River surveyed fish populations at ten sites on the Murrumbidgee River in the ACT region. Four sites (Scottsdale, Lawler Rd, Prutties and Angle Crossing) were upstream of the M2G extraction point, and six downstream. The river section is known to support a number native and alien fish species, including threatened species under the ACT *Nature Conservation Act 2015* (NT Act), NSW *Fisheries Management Act 1991* (FM Act), and *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) identified in Table 4-7.

A total of 655 fish were caught using boat electrofishing, backpack electrofishing, overnight netting with fyke nets and bait traps in 2019. Both native and alien species were observed across all sites (see Figure 4-11). Of note, Redfin distribution was observed to have expanded 20 km upstream. This pest species has not been previously recorded above Gigerline Gorge for the past 25 years and poses a threat native species (particularly Macquarie Perch).

Murray Cod were recorded at all sites and were the only cod species recorded in the 2019 survey. Juveniles (<150 mm) were predominantly recorded upstream of Kambah Pool (particularly at Point Hut Crossing, Angle Crossing and Prutties), and in low abundance downstream. The overall number of juveniles (<150 mm) recorded in 2019 was approximately three times greater than 2017 and 2015 surveys (see Figure 4-12), suggesting good species recruitment. There was also an overall increase of fish in the 150-250 mm in size class, indicating successful breeding from 2017 to 2018.

Three records of Trout cod (*Maccullochella macquariensis*) had previously been recorded at Tharwa Sandwash and Lawler Road sites in the 2017 survey. It was identified that the hybridisation of Trout Cod and Murray Cod was an emerging issue for the recovery of this endangered native species.

Table 4-7. Threatened species status of fish identified in 2019 monitoring

Species	NC Act	FM Act	EBPC Act
Macquarie Perch (*Macquaria australasica*)	E	E	E
Murray Crayfish (*Euastacus armatus*)	V	V	
Murray Cod (*Maccullochella peelii*)	SPS		V

CE- Critically Endangered, E- Endangered, V- Vulnerable, P- Protected and SPS- Special Protection Status

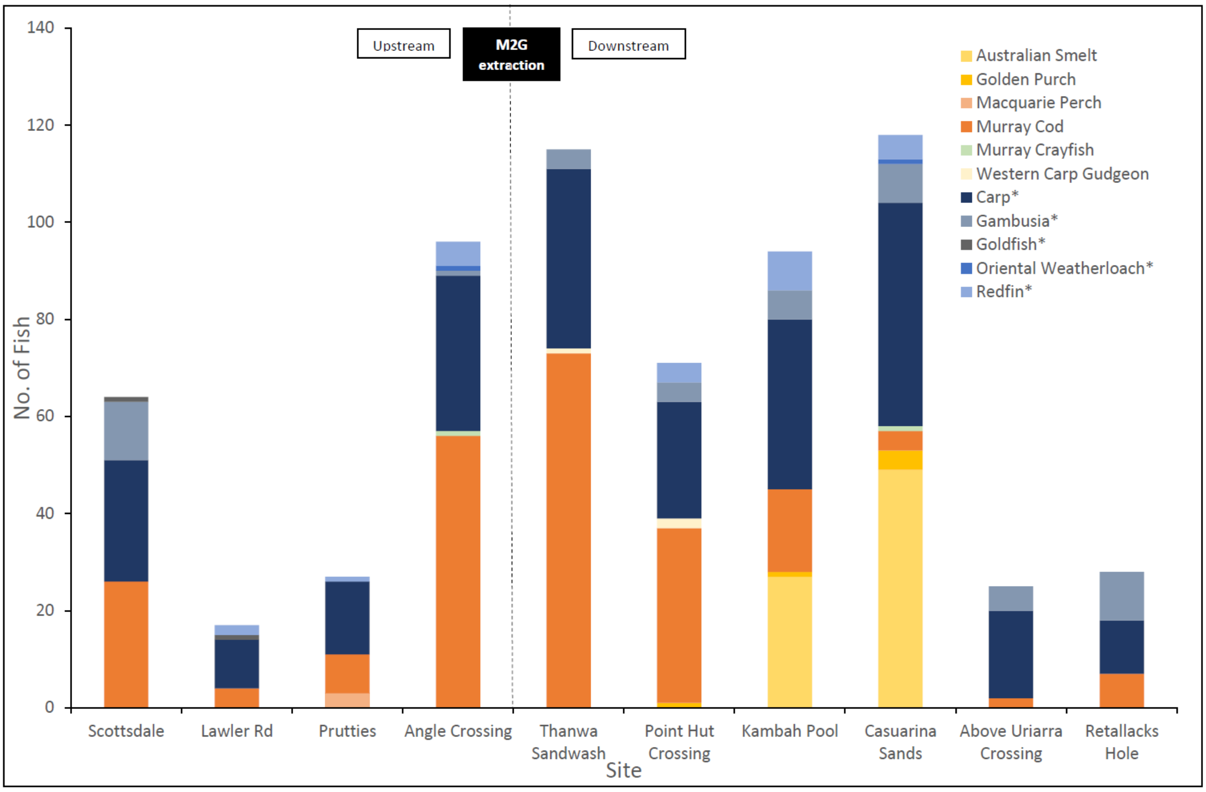


Figure 4-11. Number of fish caught in 2019 Murrumbidgee River Monitoring program (alien species)

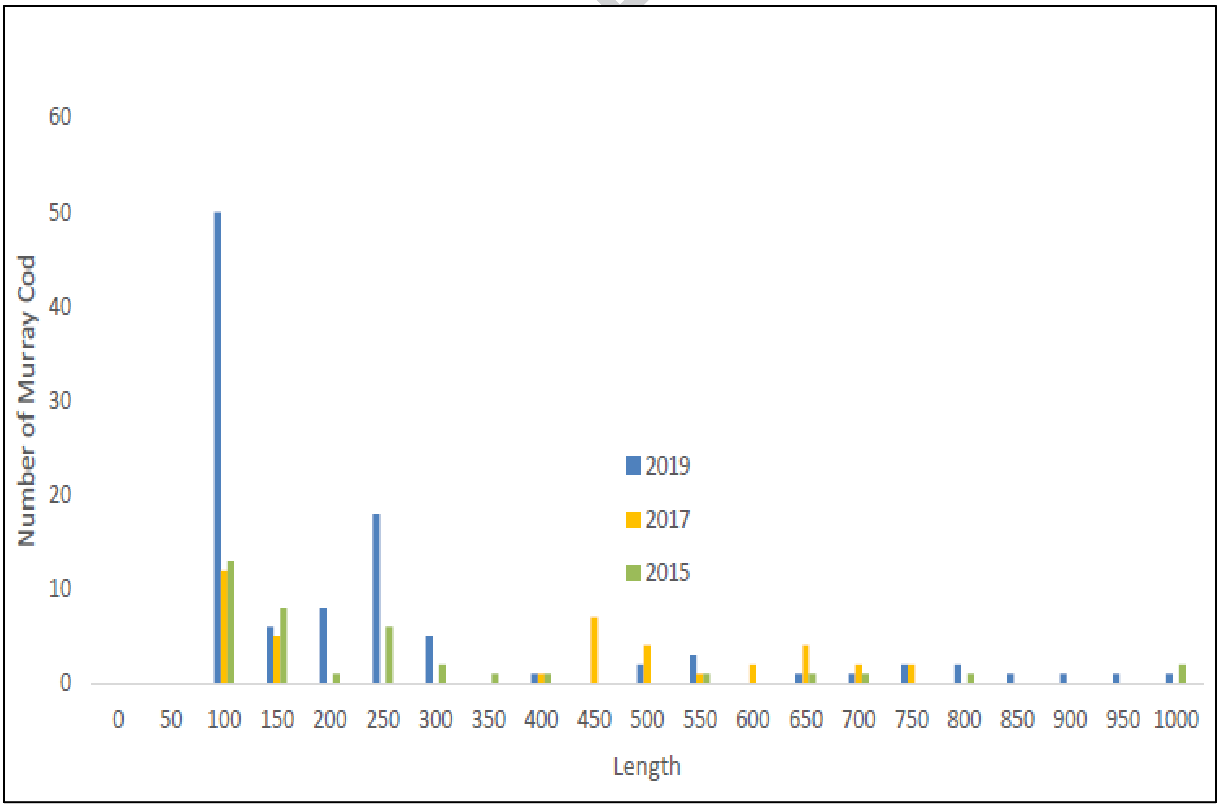


Figure 4-12 Length frequency of Murray Cod from 2015, 2017 and 2019 monitoring surveys (extract from *2019 Fish Monitoring of the Murrumbidgee River* report)

4.2 Component 2: Burra Creek (M2G)

Monitoring of Burra Creek sites as part of the M2G component was completed on 4 - 5 May (autumn), and 31 October and 1 November (spring) 2019. There was 17.8 mm of rainfall at Burra Creek (570951) on the first day of autumn monitoring, otherwise all other weather conditions during 2019 were fine. Temperature ranged between 4.9 - 19°C in autumn and 7 - 31.7 °C in spring (at Canberra Airport weather station, 070351 - BoM, 2018).

4.2.1 Rainfall and hydrology

Total rainfall at Burra Creek during autumn 2019 was 144.2 mm, a noticeable increase from 37.8 mm recorded the previous autumn in 2018 (Figure 4-13 and Table 4-8). April was the driest autumn month with only 5.8 mm of rainfall while both March and May were above the historical mean of 48.1 mm. Spring 2019 had a total rainfall of 88.5 mm, the lowest recorded in the last 10 years at Burra Creek. Rainfall was below the historical mean of 63.9 mm in all months during spring 2018 and 2019 (Figure 4-14).

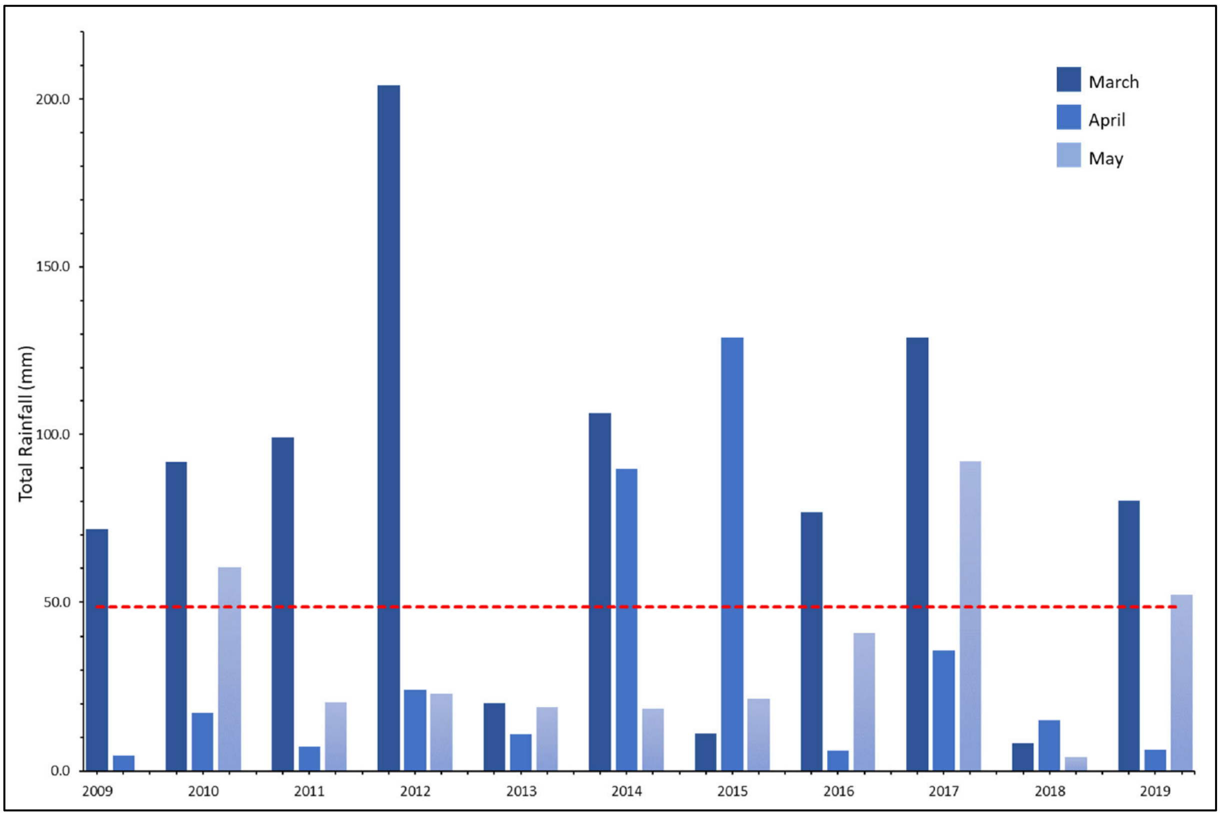


Figure 4-13. Annual comparisons of autumn rainfall recorded at Burra Creek (570951). Red line shows mean autumn rainfall 2009-2019

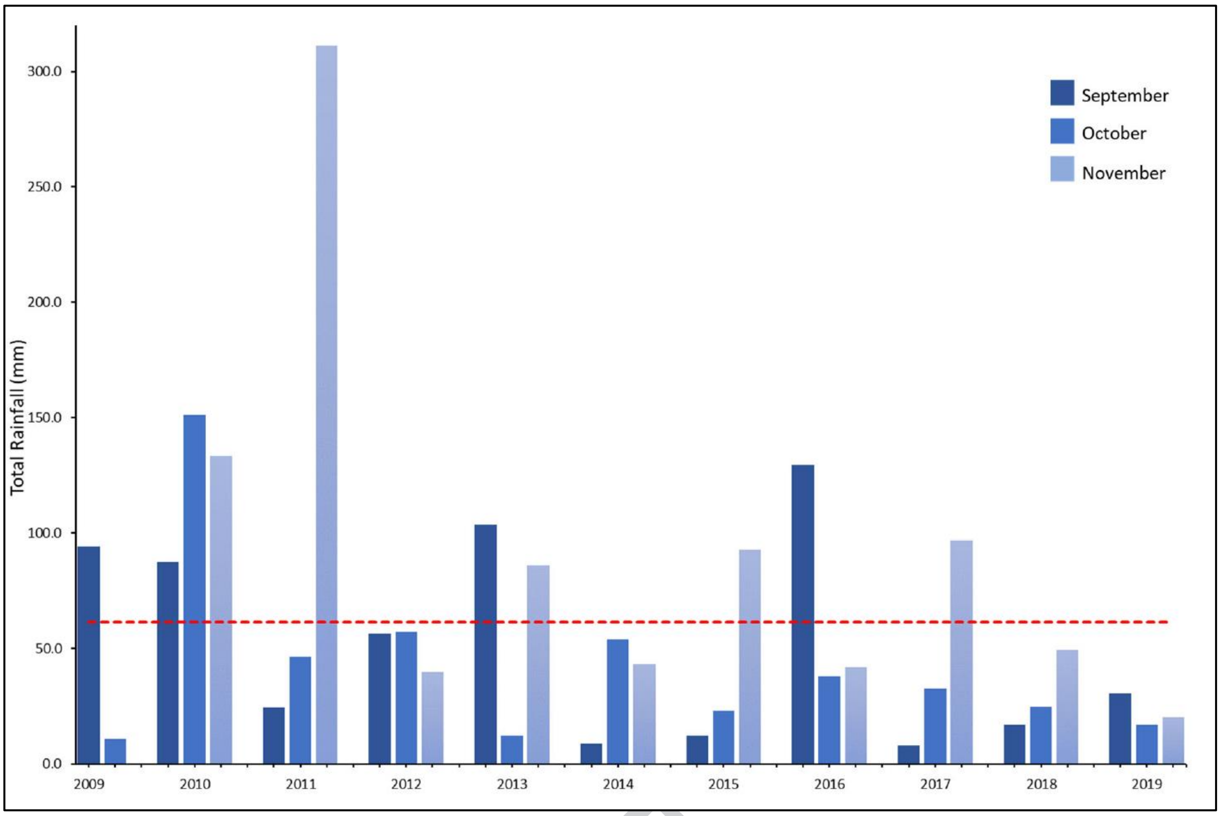


Figure 4-14. Annual comparisons of spring rainfall recorded at Burra Creek (570951). Red line shows mean spring rainfall 2009-2019

Burra Creek during 2019 was characterised by low flows in both autumn (max. mean daily flow 1.4 ML/d) and spring (max. mean daily flow 1.0 ML/d), with one major spike in March of approximately 92 ML/d, and two small peaks in September and November that were both approximately 2.7 ML/d (Figure 4-15 and Figure 4-16). During spring 2019, there was a decreasing trend in flow from September to November that is likely due to reduced rainfall (Table 4-8). Overall, flow during both autumn and spring 2019 were comparable to 2018 with the exception of the March spike.

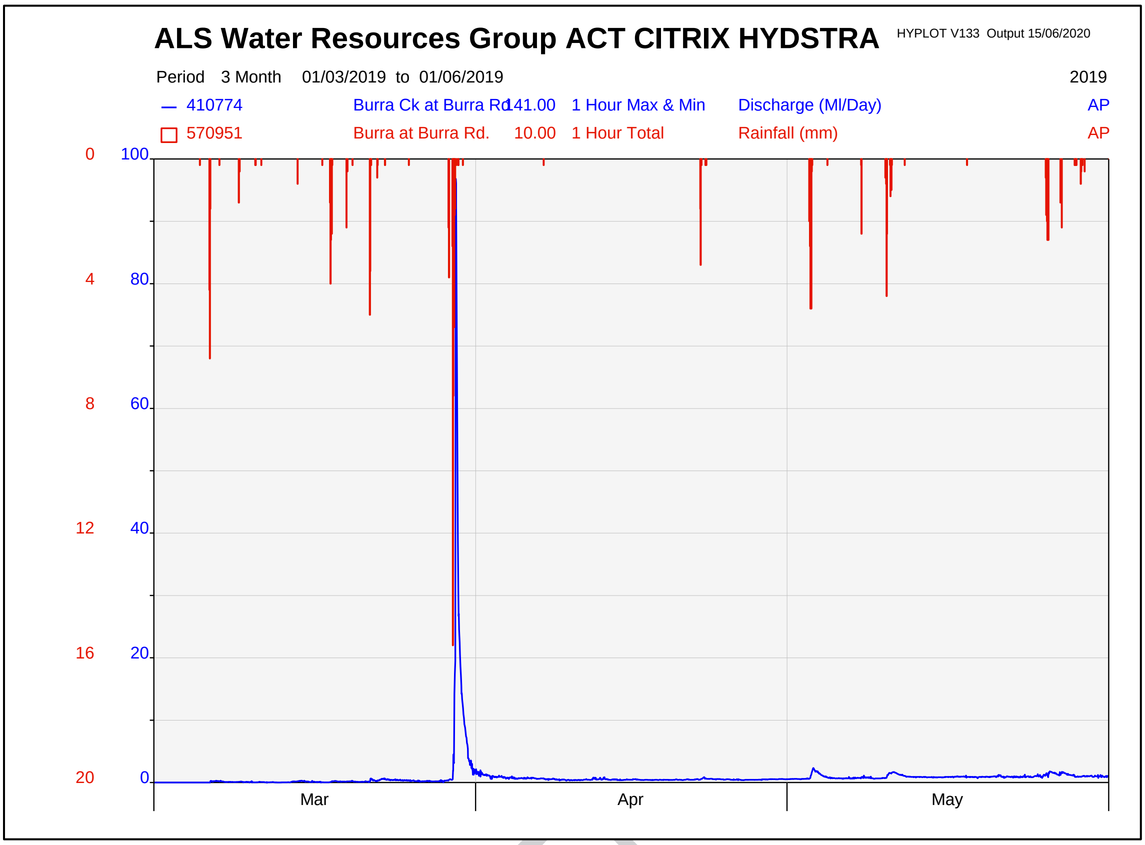


Figure 4-15. Autumn 2019 rainfall and hydrograph from Burra Creek (410774)

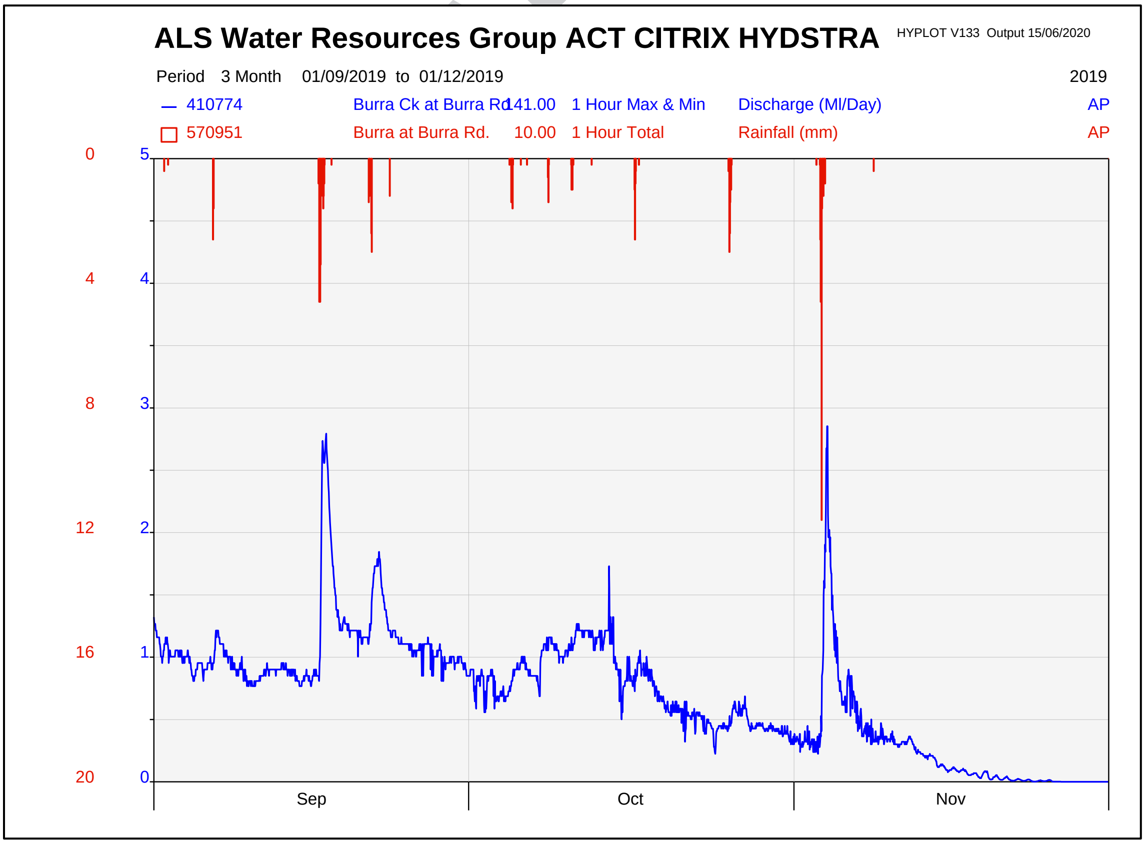


Figure 4-16. Spring 2019 rainfall and hydrograph from Burra Creek (410774)

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Table 4-8. Autumn and spring 2019 rainfall and flow summaries, upstream Burra Creek (570951)

		Burra Creek (410774)	
		Total Rainfall (mm)	Mean Flow (ML/d)
Autumn	March	86.6	1.4
	April	5.8	0.5
	May	51.8	0.8
	Total rainfall	144.2	
Spring	September	39.0	1.0
	October	23.4	0.6
	November	26.0	0.2
	Total rainfall	88.5	

4.2.2 Water Quality

Water quality measured *in situ* during the autumn and spring 2019 sampling events is presented in Table 4-2. The results for autumn 2019 suggest all locations had similar conditions for EC, turbidity, pH and DO. Dissolved oxygen levels were low and below ANZG (2018) guidelines. EC was above the guideline at all sites except BUR1b, which incidentally was the only site where turbidity was elevated above the guideline. The pH was also above the guideline at all sites during autumn 2019. Total nitrogen concentrations were higher upstream compared to downstream during autumn 2019. NOx was variable at all locations, and below laboratory detection limits at BUR1b and BUR2.

Continuous monitoring measured at the Burra Creek gauging station is presented in Figure 4-17 for autumn 2019 and Figure 4-18 for spring 2019. The data from the gauging station indicates the measurements recorded *in situ* during both autumn and spring 2019 aquatic sampling are not unusual to trends observed in Burra Creek. During autumn, water temperatures were highest in March and gradually decreased through to May where water temperature was approximately 15 degrees Celsius. The pH was highest in early to mid-March. However, in late March there was a drop in pH which corresponded with a drop in EC and increase in turbidity. Apart from this spike in late March, turbidity was generally low with occasionally peaks. The continuous monitoring suggest the turbidity reading of 30 NTU recorded *in situ* at BUR 1b in autumn 2019 is likely to be from a local runoff source. EC was typically in the range of 400 to 500 µS/cm in March, and following the drop in late March which saw EC fall to less than 200 µS/cm, EC gradually increased back to early March concentrations by May.

In spring 2019, there were no considerable spikes or troughs in water quality as observed in autumn 2019. Water temperature was 10 degrees Celsius or less during September with a slight increase through to November and greater variation than autumn 2019. The pH was fairly stable across the three months of spring and similar to April and May. Turbidity was consistently low through spring 2019, with only a few spikes where turbidity increased. EC was similar to autumn 2019, with concentrations typically in the range of 400 to 500 µS/cm. DO % saturation indicated a wide variation in measurements throughout spring 2019.

Table 4-9. *In-situ* water quality results from Burra Creek 2019. Red cells outside ANZG (2018) default guideline range

Location	Site	Sampling period	Date	Time	Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	pH	D.O. (% Sat.)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L)	TP (mg/L)	TN (mg/L)
ANZG (2018) default guideline values						30-350	2-25	6.5-8	90-110			0.015	0.02	0.25
Upstream	BUR 1b	Autumn	8/05/2019	1000	9.7	261	30.7	8.2	61.8	7.04	230	<0.05	<0.01	0.30
		Spring	31/10/2019	1330	20.7	556	7.2	8.0	70.6	6.3	215	<0.05	0.02	0.58
Upstream	BUR 1d	Autumn	8/05/2019	1130	9.7	359	13.6	8.1	60.2	6.83	240	0.07	<0.01	0.21
		Spring	31/10/2019	1430	17.1	418	9.2	8.2	67.8	6.35	210	<0.05	0.01	0.23
Downstream	BUR 2	Autumn	8/05/2019	1330	10.5	373	8.6	8.1	74.6	8.08	250	<0.05	0.01	0.18
		Spring	1/11/2019	900	16.2	415	11.3	8.1	47.9	4.69	210	ND	0.03	0.38
Downstream	BUR 2a	Autumn	8/05/2019	1520	11.1	388	13.1	8.2	67.6	7.4	260	0.10	<0.01	0.18
		Spring	1/11/2019	1015	16.4	430	14.2	8.1	50.4	4.95	240	ND	0.36	0.03

Note: Water Temperature (Temp.), Electrical Conductivity (EC), Dissolved Oxygen (D.O.), percentage saturation (% Sat.), Nitrite + Nitrate as N (NOx), Total Nitrogen as N (TN), Total Phosphorus as P (TP)

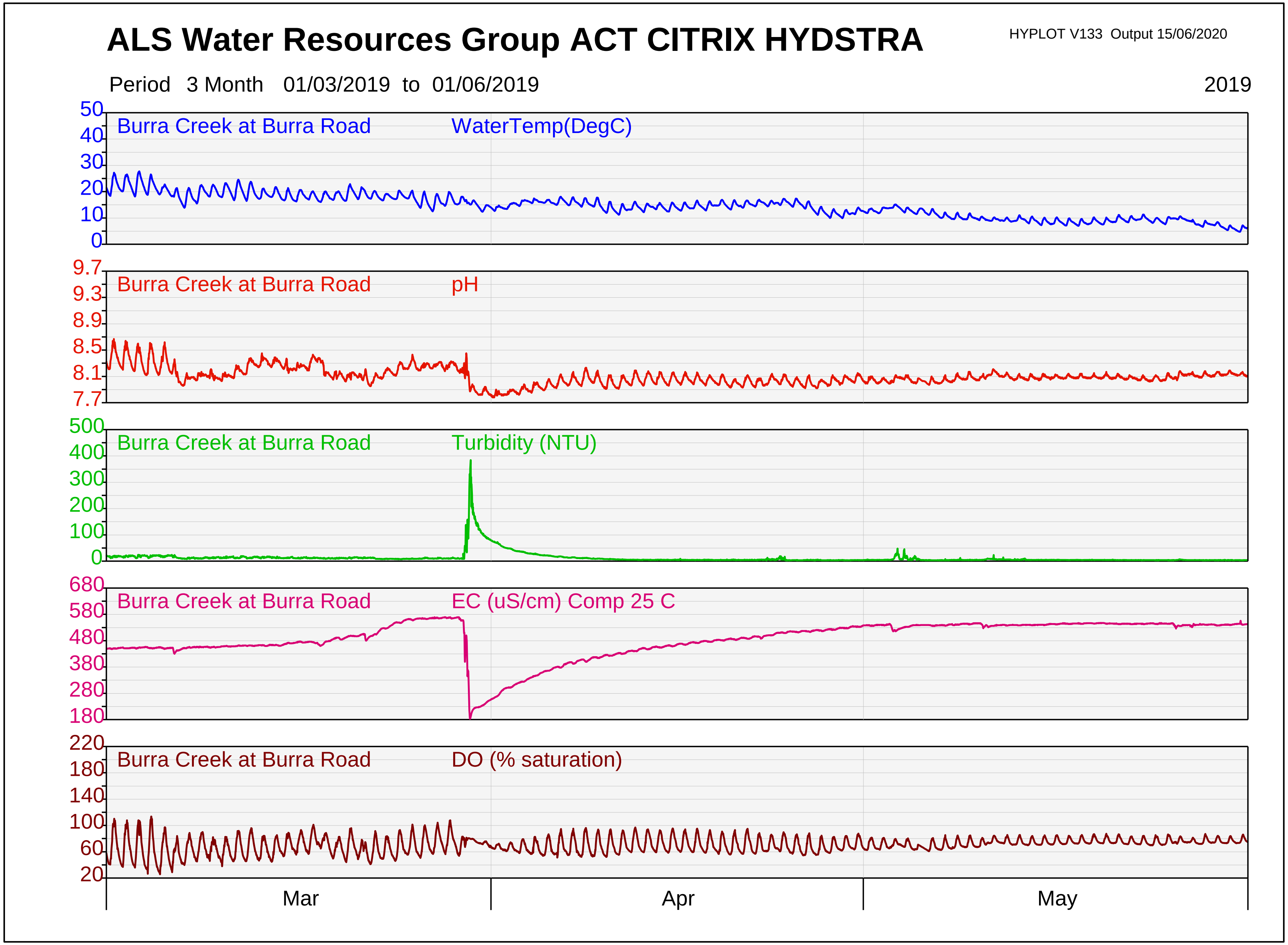


Figure 4-17. Continuous water quality records from upstream Burra Creek at Burra Road (410774) for autumn 2019

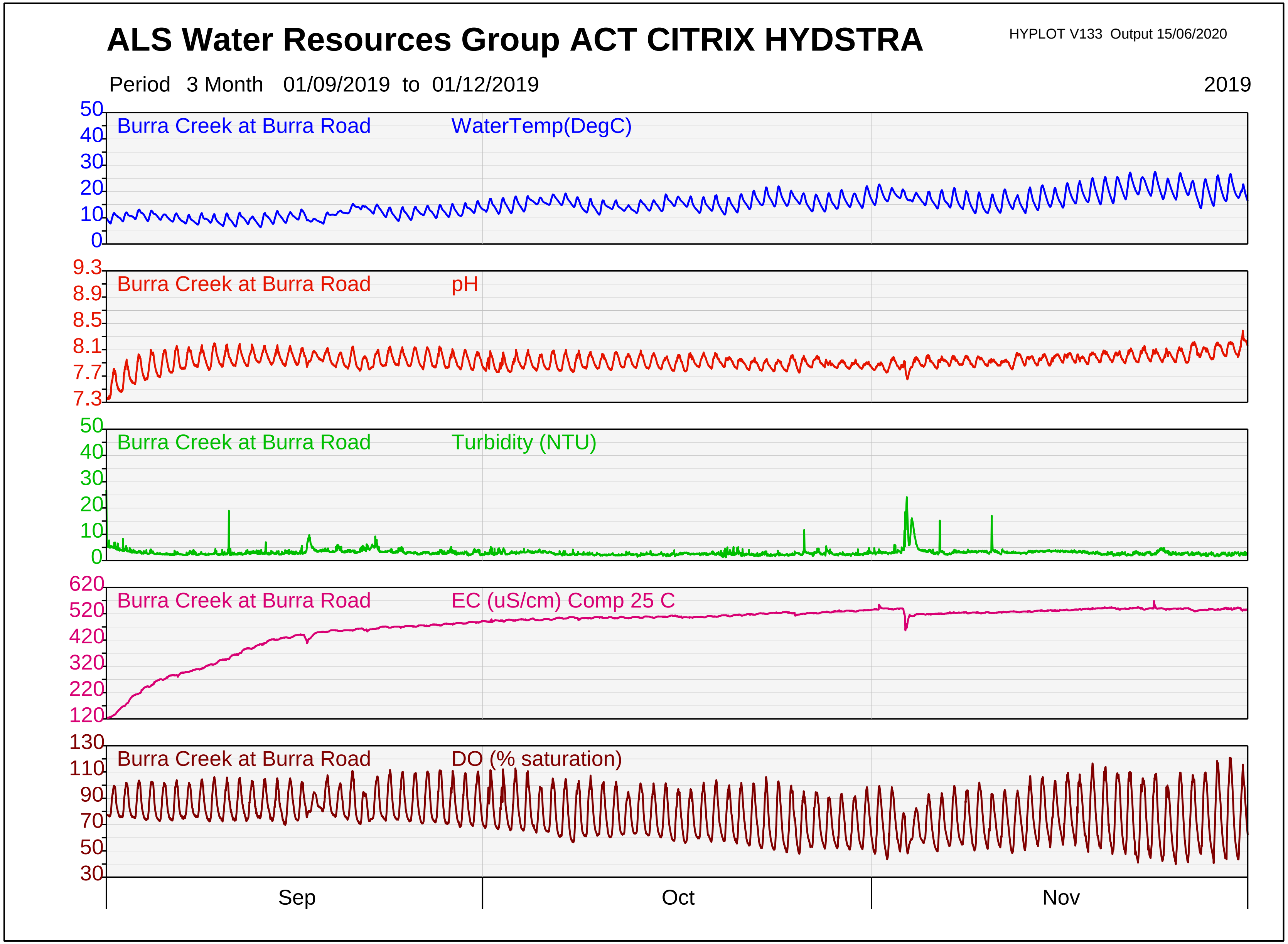


Figure 4-18. Continuous water quality records from upstream Burra Creek at Burra Road (410774) for spring 2019

4.2.3 Periphyton

Periphyton coverage for reach and edge habitats at Burra Creek was recorded as part of the AUSRIVAS habitat assessment presented in Appendix A. Photographs of periphyton in Burra Creek are presented in Plate 4-7.

BUR 1b

Periphyton coverage in autumn and spring at BUR1b was both approximately 65-90% in the reach, and 65-90% in the edge habitat. No riffle was present in spring and the predominant macrophyte observed was *Typha sp*.

BUR 1d

Both autumn and spring periphyton coverage at BUR 1d was approximately 35-65% in the reach, and 65-90% in the edge habitat. Stream levels were observed to be very low in spring 2019 with a high level of filamentous algae and macrophytes present were dominated by *Phragmites sp.*

BUR 2

The periphyton coverage in autumn 2019 at BUR 2 was estimated as 65-90% in edge habitat and 35-65% for the study reach. *Myriophyllum sp.* was observed as a submerged macrophyte. The spring periphyton coverage was approximately 65-90% in the reach and edge habitats. *Myriophyllum sp.* and *Phragmites sp.* were the predominant macrophytes observed at this site.

BUR 2a

In autumn 2019, the periphyton coverage at BUR 2a was estimated to be >90% in edge habitat and 65-90% for the study reach. Spring periphyton coverage was approximately 65-90% at the reach and >90% at the edge habitat. High levels of silt were noted and the predominant macrophyte was *Myriophyllum sp* in spring.

Site	Autumn 2019	Spring 2019
BUR 1b		
BUR 1d		
BUR 2		
BUR 2a		

Plate 4-7. 3 Photos showing the periphyton coverage at Burra Creek sites in autumn and spring 2019

4.2.4 Vegetation

BUR 2

Minimal change was observed in vegetation at site BUR 2 between autumn and spring 2019. The site has large *Populus* sp. (Poplar) located immediately downstream of the causeway and a couple of *Populus* sp. (approx.3- 4 m tall) growing across the site. In term of emergent macrophytes, *Phragmites australis* (Common Reed) is dominant throughout. However, *Cyperus sp*. and *Juncus sp*. are also present. Photos taken in 2019 are presented in Plate 4-11 through to Plate 4-13.

Downstream of Pool 29

There is evidence of some slight growth in the limited vegetation presented Downstream of Pool 29, with some shrubs and grasses/weeds growing between autumn and spring 2019. There are three trees present at the site, a native *Acacia dealbata* (Silver Wattle) on the right bank and introduced *Populus* sp. (Poplar) and *Salix* sp. (Willow) on the left bank. The large vegetated bank-attached point bar on the right bank is dominated by weeds with dense patches of *Rubus fruiticosus* (Blackberry) along the water's edge, and other common weeds across the bar including *Hypericum perforatum* (St. John's Wort), *Conyza* sp.(Fleabane), *Verbascum* sp. (Mullein) and various thistles. There is also considerable coverage by grasses, including native *Poa* spp. and introduced *Phalaris* sp. (Canary Grass) and *Paspalum dilatatum* (Caterpillar Grass), throughout the macro channel. Three vegetation photo points were collected at the site downstream of Pool 29 during autumn and spring 2019 and are presented in Plate 4-16 through to Plate 4-18.

BUR 2c

Between autumn and spring 2019, there was no significant difference or growth in vegetation at the site. Site BUR 2c has limited vegetation close to the creek despite the wider surrounds having numerous large *Eucalyptus* spp. The banks and channel were bare in some sections. However, the site does have sections covered by grasses, mostly *Poa* spp., and weeds such as *Verbascum* sp. (Mullein), *Hypericum perforatum* (St. John's Wort), *Rubus fruiticosus* (Blackberry) and various thistle species. Several small *Populus* sp. (Poplar) and *Salix* sp. (Willow) are present within the macro-channel while two larger *Populus* sp. (approximately 3-4 m tall) are the largest vegetation within the channel. Instream vegetation is dominated by *Typha orientalis* (Broad leaf Cumbungi) with numerous large stands visible from all photo points, while *Schoenoplectus validus* (Great Bulrush) is also present in smaller patches. Four vegetation photo points were collected at BUR 2c in both autumn and spring 2019 and are presented in Plate 4-19 through to Plate 4-22.

4.2.5 Geomorphology

BUR 1a

The conditions at BUR 1a have remained relatively unchanged since 2017 with the site characterised by a large-macro channel with a small inset low flow channel set along the right side of the macro-channel. Large sections of the site show evidence of erosion and bank slumping however no significant changes have been recorded since spring 2017. Three photo points were assessed during spring 2019 at BUR 1a and are presented in Plate 4-8 through to Plate 4-10 .

BUR 2

While no large scale changes have been observed since 2017, the pool downstream of the drop off has a vertical bank on the right hand side which shows evidence of small scale erosion and potential for bank slumps, particularly vulnerable during periods of high flow. The other areas downstream of the causeway are well protected by the large established *Salix* sp. (Willow). The discharge pool has shown no geomorphological changes since spring 2017. Photo points were assessed at BUR 2 during autumn and spring 2019 and are presented in Plate 4-11 through to Plate 4-13.

BUR 2a

Consistent with previous monitoring (GHD, 2015c) the steep right bank at BUR 2a has shown no signs of erosion. Similar to BUR 1c, this reach is a depositional zone with blanketing silt across all habitats. Photo points assessed at BUR 2a during autumn and spring 2019 and are presented in Plate 4-14 through to Plate 4-15.

Downstream of Pool 29

The large eroding sections of bank downstream of pool 29 show no signs of bank slumps or large scale movement since spring 2017. The large macro-channel has had no major changes to its morphology since the previous visit during spring 2017, while the vegetated point bar upstream of the riffle habitat and lateral bank attached bar adjacent to the riffle appear to have neither increased nor decreased in size. The formed vegetated island in the riffle habitat also appears stable. Three photo points were assessed downstream of Pool 29 during autumn and spring 2019 and are presented in Plate 4-16 through to Plate 4-18.

BUR 2c

Compared to all other geomorphology sites in 2019, BUR 2c was the only site which showed some signs of change since spring 2017. The large steep right banks (looking downstream) have previously been identified as an area for high erosion potential (GHD, 2015c) and are visible in Photo Point 2 (Plate 4-20) where bank slumping and erosion has occurred since the previous monitoring period. Other than the changes along these steep bank sections the rest of the site has remained relatively unchanged. Four photo points were collected at BUR 2c during autumn and spring 2019 and are presented in Plate 4-19 through to Plate 4-22.

BUR 1a

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-8. Geomorphology photo point 1 at BUR 1a showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-9. Geomorphology photo point 2 at BUR 1a showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-10. Geomorphology photo point 3 at BUR 1a showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

BUR 2

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-11. Vegetation extent and geomorphology photo point 1 at BUR 2 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

Plate 4-12. Vegetation extent and geomorphology photo point 2 at BUR 2 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-13. Vegetation extent and geomorphology photo point 3 at BUR 2 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

BUR 2a

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-14. Geomorphology photo point 1 at BUR 2a showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

Plate 4-15. Geomorphology photo point 2 at BUR 2a showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

Downstream of Pool 29

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-16. Vegetation extent and geomorphology photo point 1 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-17. Vegetation extent and geomorphology photo point 2 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-18. Vegetation extent and geomorphology photo point 3 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

BUR 2c

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-19. Vegetation extent and geomorphology photo point 1 at BUR 2c showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-20. Vegetation extent and geomorphology photo point 2 at BUR 2c showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-21. Vegetation extent and geomorphology photo point 3 at BUR 2c showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

	Autumn 2019	Spring 2019
a		
b		
c		

Plate 4-22. Vegetation extent and geomorphology photo point 4 at BUR 2c showing upstream (a), downstream (b) and across the channel (c) during autumn and spring 2019

4.2.6 Macroinvertebrates

There were no riffle samples collected at Burra Creek during 2019 due to low flows, which resulted in the absence of riffle habitat. The total taxa richness scores for Burra Creek in 2019 are presented in Table 4-10 and Table 4-11.

During autumn 2019, diversity of taxa in edge habitat was higher and particularly high at BUR1b which notably was very diverse at genus level resolution. Generally, genus level resolution did indicate greater diversity than family level at all sites in autumn 2019. However, the same trends at each site were observed regardless. Diversity was similar in spring 2019. However, BUR1b did stand out from the other sites with higher diversity. In both seasons, site BUR1D had slightly lower diversity than the remaining sites.

The EPT richness scores for Burra Creek in 2019 are presented in Table 4-10 and Table 4-11. The number of EPT taxa in autumn 2019 ranged from 3 to 8 and family level resolution and 4 to 10 at genus level. The lowest EPT scores were at BUR1D and the highest at BUR1b and BUR2. In spring, EPT scores were slightly less than autumn.

Table 4-10. Number of taxa at family and genus level from riffle and edge habitats

Total Richness	Sample number	Autumn 2019				Spring 2019			
		Riffle		Edge		Riffle		Edge	
Site		Family	Genus	Family	Genus	Family	Genus	Family	Genus
BUR1D	1	NS	NS	18	21	NS	NS	17	20
BUR1D	2	NS	NS	17	21	NS	NS	21	24
BUR1b	1	NS	NS	33	41	NS	NS	25	27
BUR1b	2	NS	NS	36	49	NS	NS	31	34
BUR2	1	NS	NS	29	35	NS	NS	28	30
BUR2	2	NS	NS	29	36	NS	NS	24	29
BUR2A	1	NS	NS	28	32	NS	NS	26	30
BUR2A	2	NS	NS	27	36	NS	NS	26	30

Table 4-11. Number of EPT taxa at family and genus level from riffle and edge habitats

EPT taxa	Sample number	Autumn 2019				Spring 2019			
		Riffle		Edge		Riffle		Edge	
Site		Family	Genus	Family	Genus	Family	Genus	Family	Genus
BUR1D	1	NS	NS	3	4	NS	NS	5	6
BUR1D	2	NS	NS	4	6	NS	NS	5	7
BUR1b	1	NS	NS	8	10	NS	NS	6	7
BUR1b	2	NS	NS	8	10	NS	NS	7	9
BUR2	1	NS	NS	8	10	NS	NS	6	7
BUR2	2	NS	NS	7	8	NS	NS	6	8
BUR2A	1	NS	NS	6	9	NS	NS	6	8
BUR2A	2	NS	NS	5	8	NS	NS	7	9

AUSRIVAS & SIGNAL-2

The SIGNAL2 and AUSRIVAS scores for edge habitat samples collected in autumn 2019 and spring 2019 are presented in Table 4-12. SIGNAL-2 scores in autumn indicated that macroinvertebrate communities were impaired by severe to moderate water quality and/or habitat impacts with scores ranging between 3.7 and 4.5. In spring 2019, SIGNAL-2 were comparable to autumn with scores ranging from 3.5 to 4.6 and again suggestive of severe to moderate pollution impacts.

AUSRIVAS results in autumn indicated that most sites were either Band A, similar to reference condition or Band B, poorer than reference condition. There was one exception to this, in which a sub-sample replicate from a BUR2a sample scored as Band C, much poorer than reference condition. The reason for this variation in the sample is unclear. However, the conservative approach is to assess this habitat based on the lowest sub-sampled AUSRIVAS score.

AUSRIVAS scores in spring 2019, were generally higher than autumn with more sites placed in Band A. Generally, the AUSRIVAS results suggest slightly better conditions in spring compared to autumn and that site BUR1b had the most optimum conditions of all sites on Burra Creek in 2019.

Table 4-13 presents the AUSRIVAS bands since 2012 and show that spring results are typically higher than autumn results, similar to what has been found in 2019. Historically, it can also be seen that sites generally fall in to Band A or Band B, with one exception in spring 2015, where BUR1c was found to be in Band X, above reference condition.

Table 4-12. Edge habitat AUSRIVAS and SIGNAL-2 scores for autumn and spring 2019

Site	Sample	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment	
			Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
BUR 1b	1	1	4.2	4.3	0.83	0.94	A	A	**B**	**B**
		2	4.5	4.6	0.64	0.94	B	A		
		3	4.0	3.5	0.77	0.70	B	B		
	2	1	3.9	4.7	0.89	0.82	A	B		
		2	4.1	4.3	0.83	0.94	A	A		
		3	3.9	4.4	0.83	1.05	A	A		
BUR 1d	1	1	3.7	4.3	0.58	0.94	B	A	**B**	**B**
		2	4.3	4.0	0.58	0.94	B	A		
		3	4.3	4.4	0.68	1.05	B	A		
	2	1	4.3	3.7	0.78	0.82	B	B		
		2	4.3	4.3	0.78	0.70	B	B		
		3	4.3	4.5	0.78	0.94	B	A		
BUR 2	1	1	3.7	3.5	0.68	0.89	B	A	**B**	**B**
		2	4.0	4.3	0.78	0.78	B	B		
		3	4.4	4.3	0.88	0.66	A	B		
	2	1	4.3	4.3	0.78	0.78	B	B		
		2	4.3	4.3	0.78	0.89	B	A		
		3	4.3	4.0	0.78	1.00	B	A		
BUR 2a	1	1	4.5	4.3	0.48	0.94	C	A	**C**	**B**
		2	4.2	4.3	0.80	0.82	B	B		
		3	4.4	4.3	0.72	0.94	B	A		
	2	1	4.2	4.3	0.80	0.82	B	B		
		2	4.0	4.6	0.56	0.94	B	A		
		3	3.8	4.5	0.72	0.94	B	A		

Table 4-13. Overall site assessments for Burra Creek sites since 2012

	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Spring 2014	Autumn 2015	Spring 2015	Autumn 2018	Autumn 2019*	Spring 2019*
BUR 1b										B	B
BUR1d	B	B	B	B	B	A	B	X	B	B	B
BUR2	B	A	B	A	B	A	B	A	B	B	B
BUR2a										C	B

* Overall assessment based on riffle habitat only

The NMDS ordination of macroinvertebrate community samples from edge habitats from the sentinel monitoring (2015 and 2018) and impact monitoring (2019) are presented in Figure 4-19. Note that each point on the NMDS represents a multivariate macroinvertebrate sample (i.e. all taxa collected and their abundances) and those samples close together have a more similar community composition than those further apart. The spread of samples on the ordination highlights the following patterns; 1) the community composition in 2015 differs to 2018 and 2019, 2) within 2018 and 2019 there are clear differences in the community composition between autumn and spring, 3) within 2015 there is some suggestion that upstream sites differ to downstream sites, and 4) within 2018 there is some suggestion that upstream sites differ to downstream sites although the seasonal variation was greater than any location differences.

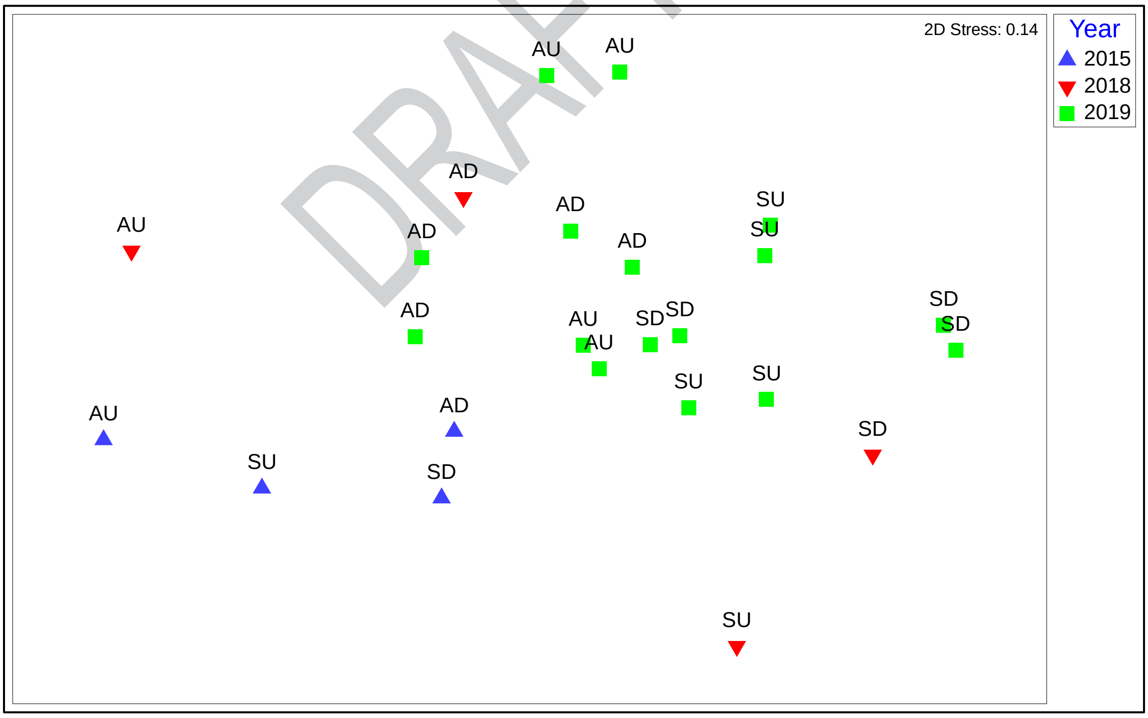


Figure 4-19. MDS ordination of macroinvertebrate communities associated with edge habitats associated with Burra Creek. A = autumn and S = spring; U = upstream and D = downstream

The low samples sizes for the sentinel monitoring (2015 and 2018) limited the power of statistical tests for differences (i.e. a single sample upstream or downstream of the abstraction within each season x year). However, for 2019 the patterns on the NMDS were confirmed by a one-way ANOSIM that detected significant differences between seasons (Global R = 0.475, P = 0.001). However, there were no significant differences in community composition upstream and downstream of the discharge during autumn 2019 (Global R = 0.031, P = 0.400) or spring (Global R = 0.021, P = 0.514).

Although no statistical tests for differences could be undertaken for 2015 and 2018, SIMPER analyses were completed to examine those taxa that contributed to the differences in macroinvertebrate composition upstream and downstream of the discharge point into Burra Creek (Figure 4-20 and Figure 4-21).

Overall there were similar taxa upstream and downstream of the discharge point during 2015. Taxa absent downstream were immature blackfly larvae (Simuliidae) although more mature individuals of the genus *Austrosimulium* were present. Mayfly larvae (*Offadens*) were also absent downstream although other mayfly larvae genera were present. Similarly, immature caddisfly larvae (Hydroptilidae) were absent upstream but more mature individuals of the genus *Hellyethira* were present. Stonefly larvae (*Dinotoperla*) were also absent upstream as were water scavenger beetles (*Hydrochus*). Overall, there were higher abundances of most taxa downstream of the discharge point including worms (Oligochaeta), backswimmers (Notonectidae), midgefly larvae (Orthocladiinae, Chironominae, Tanypodinae), biting midgefly larvae (Ceratopogoninae), mayfly larvae (Baetidae, *Austrophlebioides* sp., Leptophlebiidae), caddisfly larvae (*Triplectides*, *Hellyethira*, Hydroptilidae), water mites (Acarina), water boatmen (*Micronecta*), predacious diving beetles (*Necterosoma*) and stonefly larvae (*Dinotoperla*). The only taxa more abundant upstream were molluscs (*Ferrissia*, Lymnaeidae), mayfly larvae (*Atalophlebia*, *Offadens*), blackfly larvae (Simuliidae), immature dragonflies (Epiprocta) and marsh beetles (Scirtidae).

During 2018, predacious diving beetles (*Necterosoma*) was the only taxa not present downstream of the discharge point compared to upstream. However, several taxa were absent upstream including predacious diving beetles (*Sternopriscus*) and mayfly larvae (*Atalophlebia*, *Centroptilum*). Furthermore, most taxa were in greater abundances downstream including midgefly larvae (Orthocladiinae, Chironominae, Tanypodinae), mayfly larvae (*Cloeon*, *Atalophlebia*, *Centroptilum*), amphipods (*Austrocholtonia*), predacious diving beetles (*Antiporus*, *Sternopriscus*) and caddisfly larvae (*Hellyethira*).

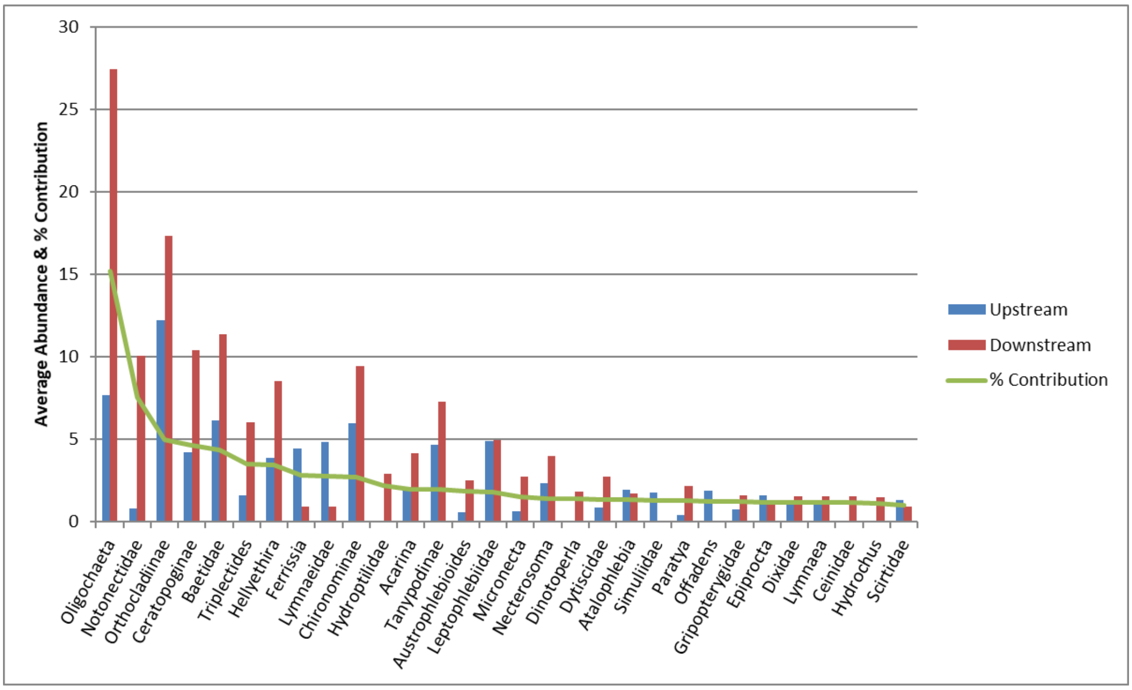


Figure 4-20. 2015 edge habitat SIMPER analyses identifying those taxa that contributed most to the dissimilarity between upstream and downstream locations. Taxa that contributed to 80% of the dissimilarity are included and the average dissimilarity between samples was 49.55%. Note that abundances are square-root values

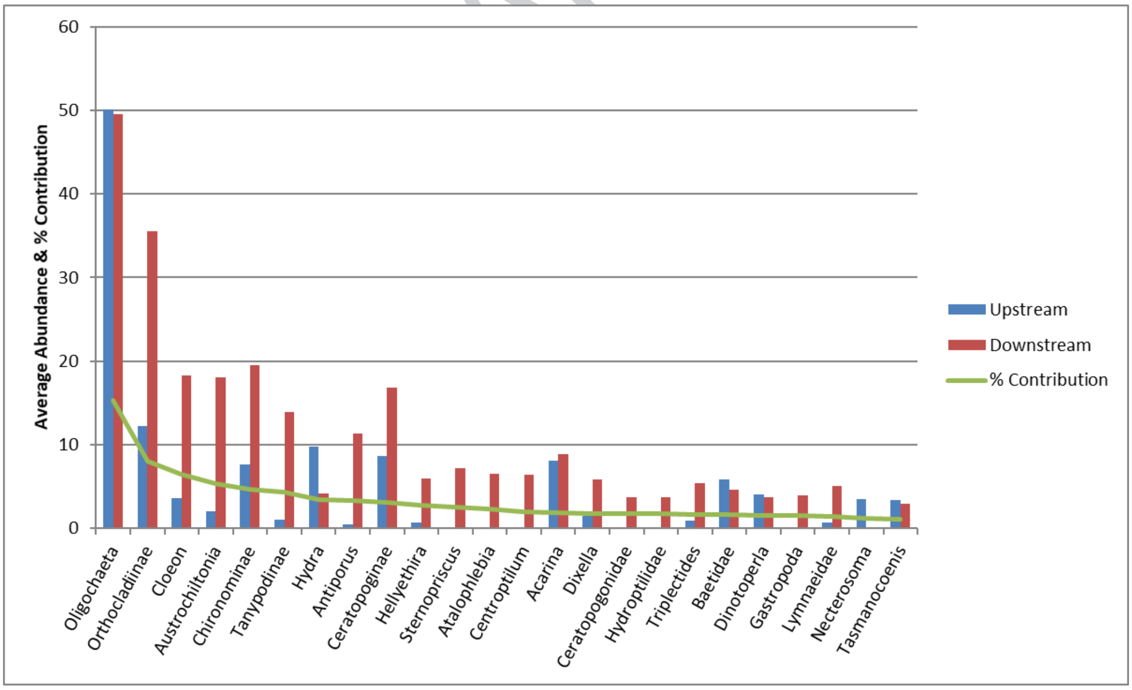


Figure 4-21. 2018 edge habitat SIMPER analyses identifying those taxa that contributed most to the dissimilarity between upstream and downstream locations. Taxa that contributed to 80% of the dissimilarity are included and the average dissimilarity between samples was 49.55%. Note that abundances are square-root values

4.3 Component 3: Murrumbidgee Pump Station (MPS)

Monitoring of sites related to the MPS component were only undertaken in spring 2019 (20 November) and therefore, there are no autumn 2019 results presented in this report. At the time of spring monitoring weather conditions were generally fine with temperatures ranging between 8.4 - 31.4°C (at Canberra Airport weather station, 070351 - BoM, 2018).

4.3.1 Rainfall and hydrology

As outlined in Section 4.1.1, total rainfall during autumn 2019 exceeded 135 mm upstream of Angle Crossing and downstream at Lobb's Hole, which was greater than the 80.6 mm and 102.4 mm during autumn 2018 for these two sites respectively. Monthly autumn rainfall for these two sites was above the historical mean of 48.6 mm during March and May, but was less than 7 mm during April. Total rainfall during spring 2019 was 82.3 mm upstream of Angle Crossing and 67.6 mm at Lobb's Hole which was similar to the 73.6 mm and 77.8 mm recorded during spring 2018. In all months, the monthly autumn 2019 rainfall upstream of Angle Crossing and at Lobb's Hole was well below the historic mean of 61.2 mm.

During spring 2019, flow displayed an overall downward trend despite a number of flow peaks in response to rainfall events (see Figure 4-22 and Table 4-14). Flows of approximately 5 ML/d in at Lobb's Hole and around 50 ML/d at Mount McDonald late November reflect the low rainfall recorded in spring. Mean daily flow was greater at Mount McDonald than Lobb's Hole in all spring months, in part due to the contribution from the Cotter River (Figure 4-23). Mean daily flow during spring 2019 was noticeably lower that spring 2018, particularly during November. The influence of reduced flow in habitat conditions in the Murrumbidgee River are demonstrated by historical photos taken in 2015 and 2018 (see Figure 4-24 and Figure 4-25).

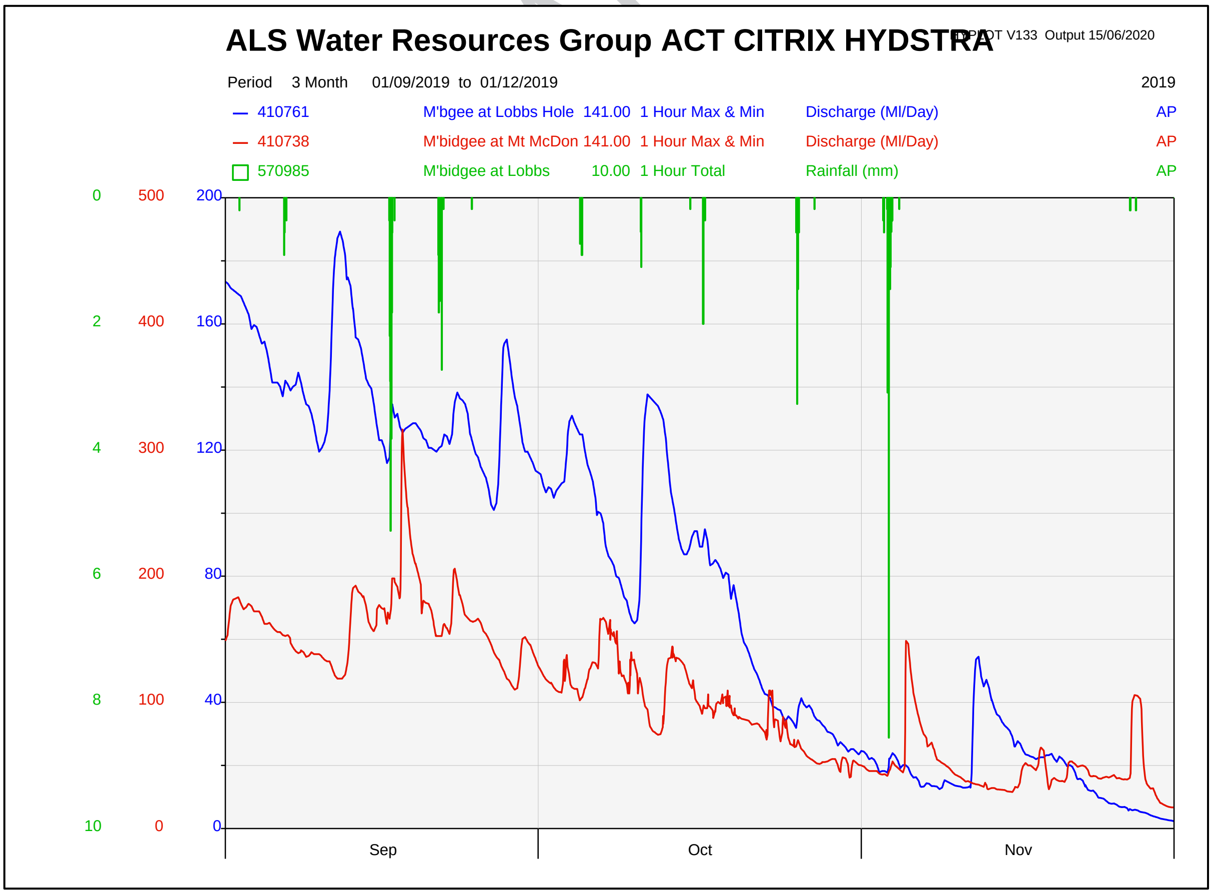


Figure 4-22. Spring 2019 rainfall and hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738)

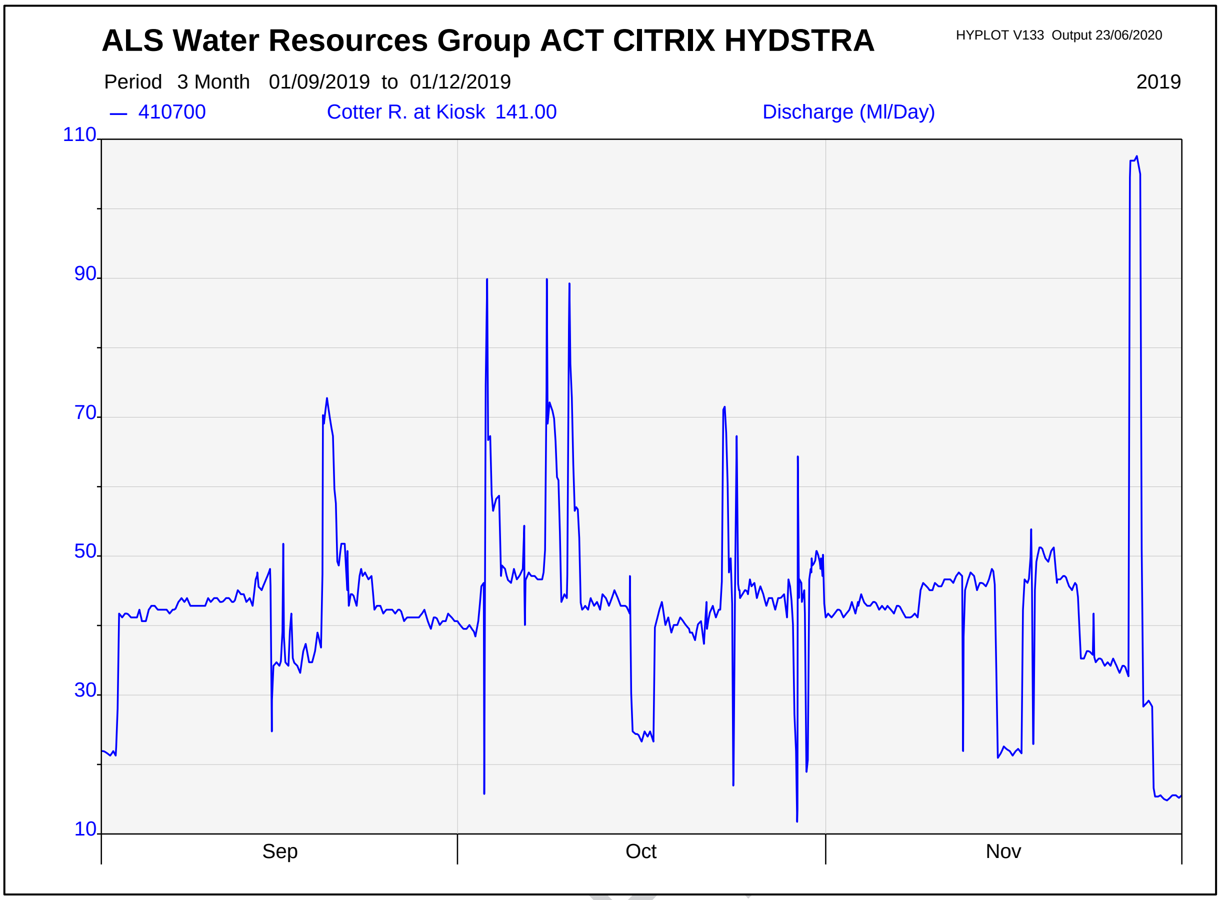


Figure 4-23. Spring 20109 hydrograph for the Cotter River downstream of the Cotter Dam (410700)

Table 4-14. Spring rainfall and flow summaries upstream of the MPS at Lobb's Hole and downstream at Mount McDonald

	Lobb's Hole (410761)		Mt. MacDonald (410738)	Cotter River at Kiosk (410700)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)	Mean Flow (ML/d)
September	30.4	137.7	161.8	44.0
October	16.9	76.1	96.9	47.3
November	20.3	18.2	47.8	34.1
Spring total rainfall	67.6			

Figure 4-24. The Murrumbidgee River upstream of the Cotter Road bridge and the MPS in autumn 2015 (top – 510 ML/d)) and 2018 (bottom – 108 ML/d). Flow is mean daily flow recorded at Mt. MacDonald (410738)

Figure 4-25. Murrumbidgee River downstream of Cotter Road bridge in autumn 2015 (top – 510 ML/d) and 2018 (bottom – 108 ML/d). Flow is mean daily flow recorded at Mt. MacDonald (410738)

4.3.2 Water quality

Water quality recorded during spring 2019 is presented in Table 4-15 providing a snap shot of conditions. EC, and turbidity were below the ANZG (2018) guideline at the Murrumbidgee pump station sites. At upstream sites, pH and TN were above the guideline value and TP reached the guideline concentration. Downstream, pH was lower and compliant. However, dissolved oxygen concentrations were slightly below the guideline value requirement. Similar to the upstream sites, TN was elevated above the guideline value and TP reached the guideline concentration. NOx was above the guideline at one downstream site.

Continuous monitoring data for the Murrumbidgee Pump Station is obtained from the gauging station on the Murrumbidgee River at Lobb's Hole (D/S of Angle Crossing). This station is also used for continuous monitoring data for Component 1 and therefore for a description of continuous water quality for component 3 refer to section 4.1.2 and Figure 4-8. On the whole, the data from the gauging station indicates that the measurements recorded *in situ* during spring 2019 aquatic sampling are not unusual to trends observed in the Murrumbidgee River.

Table 4-15 *In-situ* water quality results from Murrumbidgee Pump Station spring 2019 sampling

Location	Site	Sampling period	Date	Time	Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	pH	D.O. (% Sat.)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L)	TP (mg/L)	TN (mg/L)
ANZG (2018) default guideline values						30-350	2-25	6.5-8	90-110			0.015	0.02	0.25
Upstream	MUR 28 up	Spring	20/11/2019	1100	21.9	131	11.6	8.26	93.4	9.60	80	<0.05	0.02	0.39
	MUR 28 down	Spring	20/11/2019	1130	20.4	110	9.2	8.15	93.6	9.36	80	<0.05	0.02	0.35
Downstream	MUR 935	Spring	20/11/2019	1010	18.9	110	8.4	7.41	89.1	8.36	90	0.08	0.02	0.35
	MUR 936	Spring	20/11/2019	850	20.5	77	8.0	7.85	88.7	8.07	100	<0.05	0.02	0.27

Note: Water Temperature (Temp.), Electrical Conductivity (EC), Dissolved Oxygen (D.O.), percentage saturation (% Sat.), Alkalinity (Alk.), Nitrite + Nitrate as N (NOx), Total Nitrogen as N (TN), Total Phosphorus as P (TP)

4.3.3 Periphyton

Periphyton coverage for reach and riffle habitats at MPS was recorded as part of the AUSRIVAS habitat assessment presented in Appendix A. Photographs of periphyton in the Murrumbidgee River are presented in Plate 4-23.

MUR 28 up / down

Spring periphyton coverage in the reach habitat of both MUR 28 up and MUR 28 down was approximately 35-65%. It was noted that there was very low flow at these sites.

MUR 935

In spring 2019, periphyton cover was approximately 35-65% in the reach habitat. It was noted that river flow was very at the time of sampling and the riffle habitat was poor. Persicaria *sp.* was the dominant macrophyte species observed in spring.

MUR 936

Periphyton coverage at MUR 936 in spring was approximately 35-65% in the reach habitat. The macrophyte habitat was dominated *Persicaria sp.*

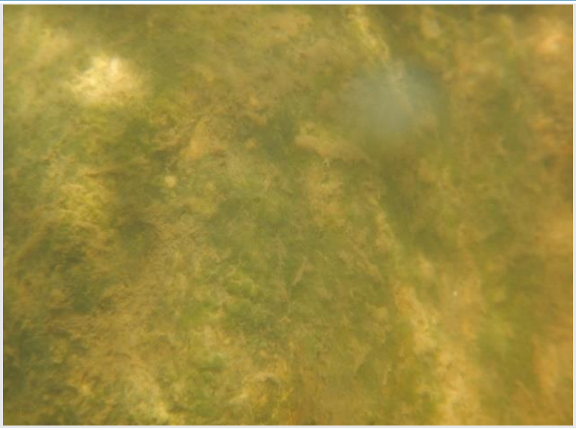
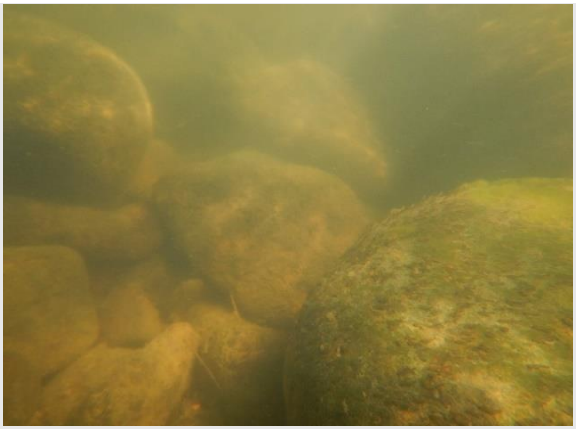
Site	Spring 2019
MUR 28 up	
MUR 28 down	
MUR 935	
MUR 936	

Plate 4-23. Photos showing periphyton coverage in the Murrumbidgee River

4.3.4 Macroinvertebrates

There is minimal edge habitat in this reach of the Murrumbidgee River and therefore no edge samples were collected in spring 2019.

The total taxa richness calculated for the Murrumbidgee Pump Station in spring 2019 is presented in Table 4-16. There was no pattern in diversity upstream or downstream of the pump station during spring 2019. At family level resolution, diversity ranged from 20 to 25 families. Genus level, indicated greater diversity with scores ranging from 25 to 33.

The number of EPT richness calculated for spring 2019 samples is presented in Table 4-17. Similar to total taxa richness, there was no pattern in EPT scores upstream or downstream of the pump station, with family level scores ranging from 7 to 0 families. Twice as many EPT taxa were identified using genus level resolution with scores ranging from 11 to 15.

Table 4-16. Number of taxa at family and genus level from riffle and edge habitats

Total Richness	Sample number	Spring 2019			
		Riffle		Edge	
Site		Family	Genus	Family	Genus
MUR28down	1	24	29	NS	NS
MUR28down	2	25	33	NS	NS
MUR28up	1	20	26	NS	NS
MUR28up	2	21	29	NS	NS
MUR935	1	22	28	NS	NS
MUR935	2	23	27	NS	NS
MUR936	1	20	25	NS	NS
MUR936	2	22	28	NS	NS

Table 4-17. Number of EPT taxa at family and genus level from riffle and edge habitats

EPT taxa	Sample number	Spring 2019			
		Riffle		Edge	
Site		Family	Genus	Family	Genus
MUR28down	1	9	13	NS	NS
MUR28down	2	8	15	NS	NS
MUR28up	1	7	13	NS	NS
MUR28up	2	7	15	NS	NS
MUR935	1	8	12	NS	NS
MUR935	2	9	12	NS	NS
MUR936	1	7	11	NS	NS
MUR936	2	7	11	NS	NS

AUSRIVAS & SIGNAL-2

The SIGNAL-2 and AUSRIVAS scores calculated for riffle habitat at the Murrumbidgee Pump Station samples for spring 2019 samples is presented in Table 4-18. The SIGNAL-2 scores indicate moderate to mild pollution impacts, with scores ranging between 4.7 and 5.4. There was no discernible pattern of scores along the study reach. AUSRIVAS scores were between 0.78 and 1.05 which places sites in either Band B, poorer than reference condition and Band A, similar to reference condition. The overall AUSRIVAS assessment for riffle habitat in spring 2019 places all sites in Band B.

Overall AUSRIVAS site assessment results since 2011 are presented in Table 4-19. Historically, sites at MPS typically fall in to Band B, with exception sin autumn 2015 and autumn 2018. The results of spring 2019 are therefore similar to other spring results.

Table 4-18. Riffle habitat AUSRIVAS and SIGNAL-2 scores for spring 2019

Site	Sample	Rep.	SIGNAL-2	AUSRIVAS O/E score	AUSRIVAS Band	Overall habitat assessment
			Spring	Spring	Spring	Spring
MUR 28 up	1	1	5.1	0.82	B	B
		2	5.4	0.82	B	
		3	5.0	0.82	B	
	2	1	5.0	0.82	B	
		2	4.9	0.90	A	
		3	5.0	0.82	B	
MUR 28 down	1	1	5.0	0.82	B	B
		2	5.0	0.82	B	
		3	5.4	1.05	A	
	2	1	4.9	0.90	A	
		2	5.3	0.82	B	
		3	5.3	0.90	A	
MUR 935	1	1	4.7	0.78	B	B
		2	5.3	0.93	A	
		3	4.7	0.78	B	
	2	1	5.0	0.85	B	
		2	4.7	0.78	B	
		3	5.3	0.93	A	
MUR 936	1	1	4.7	0.78	B	B
		2	5.0	0.85	B	
		3	5.0	0.85	B	
	2	1	5.0	0.85	B	
		2	5.3	0.93	A	
		3	5.3	0.93	A	

Table 4-19 Overall AUSRIVAS assessments for MPS sites since 2011

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Autumn 2015	Spring 2015	Autumn 2018	Spring 2019*
MUR 28	B	B	B	B	B	A	B	A	B
MUR 935	B	B	NRA	B	B	A	B	A	B

NRA = no reliable assessment, Bands were significantly different between habitat.

* Overall assessment based on riffle habitat only

The NMDS ordination of macroinvertebrate community samples from riffle habitats from the sentinel monitoring (2015 and 2018) and impact monitoring (2019) are presented in Figure 4-26. Note that each point on the NMDS represents a multivariate macroinvertebrate sample (i.e. all taxa collected and their abundances) and those samples close together have a more similar community composition than those further apart. The spread of samples on the ordination highlights two obvious patterns; 1) the community composition in 2015 differs to 2018 and 2019, and 2) within 2015 and 2018 there are clear differences in the community composition between autumn and spring. Furthermore, within each season there was no clear separation between samples collected upstream and downstream of the MPS abstraction.

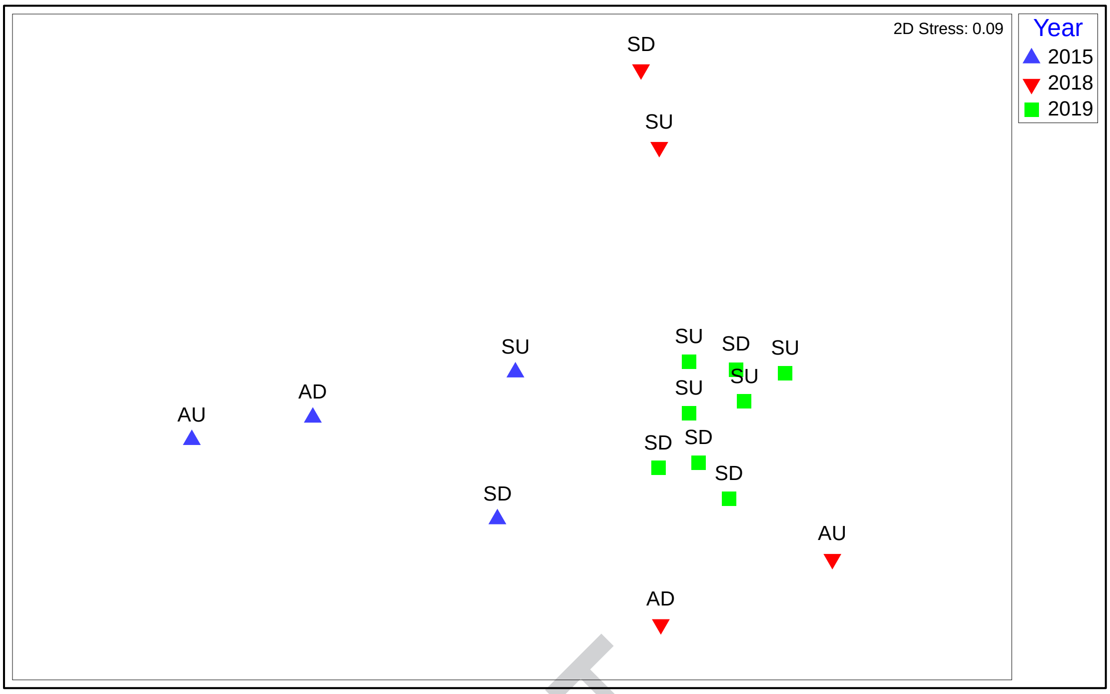


Figure 4-26. MDS ordination of macroinvertebrate communities associated with riffle habitats. A = autumn and S = spring; U = upstream and D = downstream

The low samples sizes for the sentinel monitoring (2015 and 2018) limited the power of statistical tests for differences (i.e. a single sample upstream or downstream of the abstraction within each season x year). However, for spring 2019 the patterns on the NMDS were confirmed by a one-way ANOSIM that detected no significant differences in community composition upstream and downstream of the abstraction (Global R = 0.323, P = 0.086). Given there were no obvious or statistical differences upstream and downstream of the abstraction point, no SIMPER analyses have been undertaken.

5. Discussion

5.1 Component 1: Angle Crossing (M2G)

5.1.1 Rainfall and hydrology

The 2019 impact monitoring occurred during a period of reduced rainfall, particularly during spring. Although the long-term mean monthly rainfall was exceeded in some months, in general the typical conditions during the MEMP monitoring program has been low rainfall. Weather conditions during monitoring in autumn and spring 2019 were comparable to previous years.

Flow in the Murrumbidgee River reflects rainfall patterns in the region. Prior to spring 2010, drought conditions had a significant impact and more than 80% of catchments in the region had been drought-affected since late 2002. In the spring of 2010, the drought broke in the ACT and surrounding NSW regions and frequent high flow events occurred in the Murrumbidgee River in response to rainfall events. However, since 2016, base flows have generally declined and continue to decline. During the 2019 impact monitoring, flow was generally lower than long-term average in both autumn and spring. Average daily flow was 97.2 ML/d during autumn and 120 ML/d during spring.

Overall, the sentinel monitoring during 2015 were comparable to 'normal' base flow conditions whereas flow was lower during sentinel monitoring during 2018 and 2019 impact monitoring.

5.1.2 Water quality

During the current mode of operation of the M2G, there was little difference in water quality upstream and downstream of the abstraction point.

Water quality results from both autumn and spring 2019 highlight that the Murrumbidgee River has high nutrient loads - nitrogen and phosphorous exceeded the ANZG (2018) guidelines at all sites, and total nitrogen concentrations were nearly twice as high as the guideline value in autumn 2019. Phosphorus and nitrogen were also above water quality guidelines in 2018 monitoring. Nutrient enrichment can lead to algal blooms and excessive growth of macrophytes, and it is noted that estimations of periphyton coverage were on the higher side of the rating scale during 2019. Elevated phosphorus concentrations have been shown to originate upstream of the ACT (GHD, 2013). Elevated pH and low dissolved oxygen often failed to meet the ANZG (2018) guidelines. However, turbidity was low and within guidelines during monitoring.

Continuous monitoring data from Angle Crossing indicates that turbidity can have considerable peaks in concentrations triggered by rainfall and high flow events.

5.1.3 Periphyton

The periphyton coverage in the Murrumbidgee River was reasonably consistent upstream and downstream of the M2G abstraction point, with the exception of MUR18 which had very low coverage in autumn 2019 compared to other sites. During spring, coverage of periphyton was high in edge habitats. The results align with previous findings and relate to low flows experienced in the Murrumbidgee River and do not indicate the current level of operation of the M2G is influencing the algal communities downstream of the abstraction point compared to upstream.

5.1.4 Geomorphology

Minimal change in geomorphology has been observed in the Murrumbidgee River in recent years since 2015 and this trend continued during 2019. Seasonal variation was visible in 2019 and although individual high flow events can result in significant changes in the study reach

(GHD, 2014c; GHD, 2015c), there was no evidence of bank erosion, incising or scouring that and the banks appeared stable.

5.1.5 Macroinvertebrate communities and river health assessment

Due to the habitat conditions in the Murrumbidgee River, there was limited edge habitat available to sample and the assessment of river health is based primarily on riffle habitat. Overall, there were no distinctive patterns in the macroinvertebrate indices that would indicate differences between upstream and downstream of the abstraction point. Across both seasons family richness ranged from 13 to 20 and genus richness from 19 to 28 and generally there was greater diversity during spring. EPT taxa were relatively diverse at all sites in both seasons. The taxa richness and EPT richness values suggest that the community in the Murrumbidgee River is relatively healthy and not subject to severe impairment.

SIGNAL-2 scores were higher in spring than autumn, suggesting moderate pollution impacts in autumn, and mild to moderate pollution in spring. The AUSRIVAS results suggest that all sites are significantly impaired resulting in loss of taxa. SIGNAL-2 is more a reflection of water quality while AUSRIVAS is more relates to habitat conditions. Consequently, both the relatively high nutrient levels in the Murrumbidgee River and low flows may be contributing to a decline in the overall health of the macroinvertebrate community. The multivariate community analyses also detected significant changes in the community composition between autumn and spring. Furthermore, given there were some differences in the community composition upstream and downstream of the abstraction point during spring in the absence of abstraction, it is likely that habitat conditions are contributing to these differences. That is, although the overall health of the community did not differ upstream and downstream (as determined by SIGNAL-2 and AUSRIVAS) the abundances of individual taxa may have varied due to habitat availability.

Overall, the results suggest that the macroinvertebrate community in the Murrumbidgee River are subjected to some level of disturbance from water quality, and the composition is influenced by habitat conditions. However, given that there is a general increase in river health during the more productive spring period, any impacts are not limiting the seasonal dynamics of the community. Importantly, this is the case both upstream and downstream of the abstraction point and any differences observed during operation mode must consider this natural and broad-scale variation.

5.2 Component 2: Burra Creek (M2G)

5.2.1 Rainfall and hydrology

The 2019 impact monitoring occurred during a period of reduced rainfall, particularly during spring. Although the long-term mean monthly rainfall was exceeded in some months, in general low rainfall has been a regular occurrence during the life of the MEMP since 2009. Weather conditions during monitoring in autumn and spring 2019 were comparable to previous years and not expected to influence the results.

Flow in the Burra Creek River reflects changing rainfall patterns in the region. Prior to spring 2010, drought conditions had a significant impact and more than 80% of catchments in the region had been drought-affected since late 2002. In the spring of 2010, the drought broke in the ACT and surrounding NSW regions and frequent high flow events occurred in Burra Creek in response to rainfall events. However, since around mid-2016, base flows have generally remained low. During the 2019 impact monitoring, flow was generally lower than long-term conditions in both autumn and spring. Average daily flow was 0.9 ML/d during autumn, and 0.6 ML/d in spring.

Overall, the sentinel monitoring during 2015 were comparable to ‘normal’ base flow conditions while sentinel monitoring during 2018, and the impact monitoring during 2019 was lower.

5.2.2 Water quality

Water quality results from both autumn and spring 2019 highlight that Burra Creek often has high nutrient loads. Oxidised forms of nitrogen often exceeded the ANZG (2018) guidelines, as did total nitrogen and total phosphorous although not as often. Nutrients have historically shown to increase with decreasing flow and following runoff events. Electrical conductivity (EC) and pH also regularly exceeded the ANZG (2018) guidelines. EC has historically exceeded the ANZG (2018) and therefore, the high levels are not unusual. Dissolved oxygen and also did not meet water quality guideline levels, likely influenced by the low flow conditions.

Continuous monitoring data from Burra Creek indicates that turbidity can have considerable peaks in concentrations triggered by rainfall and high flow events – high flows resulted in increases in turbidity and decreases in EC due to dilution. Importantly, during the current mode of operation of the M2G, there was little difference in water quality downstream of the discharge point than has been observed in previous years. However, the discharge of water from the Murrumbidgee River may be expected to increase nutrient loads, decrease EC and increase turbidity and dissolved oxygen once operation and pumping becomes more consistent.

5.2.3 Periphyton

In both spring and autumn, periphyton coverage was typically observed to be mid to very high at each site. Edge habitat had similar high coverage and is likely to be related to the very low flow conditions. During 2018 sampling, periphyton coverage was also noted to be very high in Burra Creek, a notable increase since 2015. However, algal communities downstream of the discharge are similar to upstream and there does not appear to be evidence that any alteration of the natural flow regime is having a detectable impact.

5.2.4 Vegetation

Across all sites monitored for changes in vegetation on Burra Creek, there was minimal change between autumn and spring 2019. Sites have been photographed since 2015. However, since the last photo in 2017, change in vegetation has not been significant. There evidence of new growth, notably at Downstream Pool 29 and somewhat at BUR 2c. Encroachment from vegetation and macrophytes at Burra Creek has previously been noted and thought to impact habitat and water quality. However, the 2019 results do not indicate any significant increases in encroachment.

5.2.5 Geomorphology

The photogrammetry assessment of Burra Creek in 2015, 2017 and 2019 has identified several reaches where bank erosion is considered severe. Land use and a lack of riparian vegetation in many areas is contributing to bank instability and an increased risk of erosion. Erosion hotspots include sites upstream of the discharge point on Burra Creek.

The reach adjacent to the discharge point and immediately downstream has been stabilised with boulders as part of the infrastructure works and this will limit the risk of erosion at BUR 2. No change in bank conditions have been observed since 2017. Summarily, there has been little change in bank conditions further downstream at BUR 2s, in part due to the morphology of this area (deep pool to attenuate high flows) and stable banks in some areas due to presence of large boulders. However, there is some potential for erosion under high flows on the right bank (looking downstream).

Downstream of Pool 29, there has also been little change in bank condition since 2017. This could be attributed to the low flows that have occurred in Burra Creek in recent years. Further evidence of this is the established sand bars and vegetated islands within the channel. Further downstream at BUR 2c, there has been some bank slumping since 2017. For both of these sites, there is a high risk of further bank erosion under high flows.

5.2.6 Macroinvertebrates and river health assessment

Due to the lack of riffle habitat conditions in Burra Creek, the assessment of river health is based primarily on edge habitat. Overall, there were no distinctive patterns in the health of the macroinvertebrate communities upstream and downstream of the discharge point as determined by the univariate indices. Across both seasons family richness ranged from 17 to 36 and genus richness from 20 to 49 and generally, there was a decrease in diversity during spring. EPT taxa was relatively diverse at all sites in both seasons. The taxa richness and EPT richness values suggest that the community in Burra Creek is relatively healthy and not subject to severe anthropogenic pollution or other impacts. The lower diversity in spring is likely attributable to the lower flows in this season.

There was no clear pattern in SIGNAL-2 scores between seasons. The SIGNAL-2 scores suggest Burra Creek is subjected to severe to moderate water quality and/or habitat impacts. Alternatively, there was some suggestion that AUSRIVAS scores increased during spring although overall, AUSRIVAS suggest that all sites are significantly impaired with water quality and/or habitat potentially impacted resulting in loss of taxa. SIGNAL-2 is more a reflection of water quality while AUSRIVAS is more relates to habitat conditions. Consequently, the relatively high nutrient, electrical conductivity and pH, combined with low dissolved oxygen may be impacting on the community in both seasons, leading to the lack of patterns in SIGNAL-2 scores. However, although there was a decrease in diversity in spring AUSRIVAS scores increased. This may be due to the lack of riffle habitat in Burra Creek resulting in no significant impact to edge habitat during the low spring flows. The multivariate community analyses also detected significant changes in the community composition between autumn and spring but not differences upstream and downstream of the discharge point.

Overall, the results suggest that the macroinvertebrate community in Burra Creek are subjected to some level of disturbance from water quality, and the composition is influenced by habitat conditions. However, given that there a general change in river health between autumn and spring, any impacts are not limiting the seasonal dynamics of the community. Importantly, this is the case both upstream and downstream of the abstraction point and any differences observed during operation mode must consider this natural and broad-scale variation. Furthermore, future discharges into Burra Creek may increase the overall health of the waterways, provided flows are not too extreme and provide additional riffle habitat.

5.3 Component 3: Murrumbidgee Pump Station (MPS)

5.3.1 Rainfall and hydrology

The 2019 impact monitoring occurred during a period of reduced rainfall, particularly during spring. Although the long-term mean monthly rainfall was exceeded in some months, in general low rainfall has been a regular occurrence during the life of the MEMP since 2009. Weather conditions during monitoring in spring 2019 were comparable to previous years and not expected to influence the results.

Flow in the Murrumbidgee River reflects changing rainfall patterns in the region. Prior to spring 2010, drought conditions had a significant impact and more than 80% of catchments in the region had been drought-affected since late 2002. In the spring of 2010, the drought broke in the ACT and surrounding NSW regions and frequent high flow events occurred in the

Murrumbidgee River in response to rainfall events. However, since 2016, base flows have generally declined and continue to decline. During the spring 2019 impact monitoring, flow was generally lower than long-term conditions and flows of approximately 5 ML/d in at Lobb's Hole and around 50 ML/d at Mount McDonald late November reflect the low rainfall. Flow was greater at Mount McDonald than Lobb's Hole in all spring months, in part due to the contribution from the Cotter River.

Overall, the sentinel monitoring during 2015 were comparable to 'normal' base flow conditions while sentinel monitoring during 2018, and the impact monitoring during 2019 was lower.

5.3.2 Water quality

Water quality results from spring 2019 highlight that the Murrumbidgee River has high total nitrogen loads that exceeded the ANZG (2018) guidelines at all sites. Total phosphorus reached the ANZG (2018) guideline at all sites. Upstream of the MPS, pH was high and above the guideline and historically pH has been high at these sites. Dissolved oxygen was slight lower than the ANZG (2018) at downstream sites.

Continuous gauge monitoring data the Angle Crossing indicates that turbidity can have considerable peaks in concentrations triggered by rainfall and high flow events. Importantly, during the current mode of operation of the MPS, there was little difference in water quality upstream and downstream of the abstraction point. Furthermore, apart from a slight decrease in electrical conductivity, there were no noteworthy differences in water quality downstream fo the Cotter River at MUR28 down compared to MUR 28 up. This suggests that these two site should be suitable as replicate upstream control sites to assess potential changes in flow due to abstraction of water by the MPS.

5.3.3 Periphyton

Periphyton coverage at the Murrumbidgee Pump Station was estimated to be similar at all sites in spring 2019 indicating that abstraction and reduction in flow was not impacting the algal communities. The results are slightly lower estimates than those observed in 2018, despite very low flows being noted in this study reach.

5.3.4 Macroinvertebrates and river health assessment

Due to the habitat conditions in the Murrumbidgee River, there was no edge habitat available to sample and the assessment of river health is based primarily on riffle habitat. Overall, there were no distinctive patterns in the health of the macroinvertebrate communities upstream and downstream of the abstraction point as determined by the univariate indices. During spring 2019, family richness ranged from 20 to 25 and genus richness from 25 to 33. EPT taxa was relatively diverse at all sites. The taxa richness and EPT richness values suggest that the community in the Murrumbidgee River is relatively healthy and not subject to severe anthropogenic pollution or other impacts.

The SIGNAL-2 results suggest moderate to mild pollution impacts while the AUSRIVAS results suggest that all sites are significantly impaired with water quality and/or habitat potentially impacted resulting in loss of taxa. SIGNAL-2 is more a reflection of water quality while AUSRIVAS is more relates to habitat conditions. Consequently, the relatively high nitrogen levels in the Murrumbidgee River and low flows may both be contributing to a decrease in the overall health of the macroinvertebrate community. The multivariate community analyses also detected no significant differences upstream and downstream of the abstraction point.

Overall, the results suggest that the macroinvertebrate community in the Murrumbidgee River are subjected to some level of disturbance from water quality, and the composition is influenced by habitat conditions. Importantly, this is the case both upstream and downstream of the abstraction point and any differences observed during operation mode must consider this natural and broad-scale variation. Furthermore, given that there were no major differences downstream of the confluence of the Cotter River compared to upstream, the changes in flow at the downstream sites were not dramatic enough to lead to changes in the community composition. Based on this, abstraction from the Murrumbidgee River during the operation mode of the MPS may not influence the overall health of the macroinvertebrate community unless it reached some threshold level where decreased flow contributes to a loss of water quality and/or habitat, beyond that observed upstream of the Cotter River.

6. Conclusion

The purpose of the sentinel monitoring in 2015 and 2018, and this first round of impact monitoring in 2019, is to provide a broad scale assessment of control and impact sites related to the Angle Crossing abstraction point (M2G), the discharge weir in Burra Creek and the MPS. Specifically, the monitoring prior to ongoing operation modes is to *“provide confidence that the condition of the potential impact sites is broadly similar to non-impact sites across time”.* The data generated through the historical monitoring also provides comprehensive baseline data that can be compared to conditions during the operation mode. Under the current modes of operation, the major conclusions from the monitoring are:

- A drier climate has resulted in low flows in the Murrumbidgee River and Burra Creek in recent years.
- Low flows reduces available habitat in the Murrumbidgee River and Burra Creek. Although there is a loss of riffle habitat in Burra Creek during low flow periods, the general health of the two waterways has not dramatically changed over time.
- Both the Murrumbidgee River and Burra Creek have high nutrient loads.
- There has been no increase in the occurrence of periphyton in the Murrumbidgee River and Burra Creek over time.
- There has been no dramatic changes in riparian or instream vegetation in Burra Creek.
- There are several areas prone to bank erosion and slumping in Burra Creek that are likely to be at greater risk during high flows.
- The macroinvertebrate communities in the Murrumbidgee River and Burra Creek are generally reflective of mild to moderate pollution impacts and/or significant impairment with water quality and/or habitat potentially impacted resulting in loss of taxa.
- Despite the condition of the macroinvertebrate community, the composition still displays a high level of seasonal variation. This suggests that any impairment is not sufficient to mask natural variability.
- Fish surveys in the Murrumbidgee River determined there is a relatively diverse community, although this is also composed of several exotic species. However, 2019 results suggest there has been successful breeding events by Murray Cod and evidence of recruitment of juveniles.
- There were limited differences between control and impact sites for all aspects of the waterways monitored. Consequently, the MEMP should allow for an assessment of the influence of the operation modes once they are implemented.
- It is recommended that a low range analytical testing method should be used for NOx analysis to provide a level of reporting appropriate for comparison against ANZG guidelines (i.e.LOR <0.015mg/L).

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Appendices

Appendix A - AUSRIVAS habitat information

Appendix A1. AUSRIVAS habitat information collected on site during autumn 2019

Site Code	BUR1b	BUR 1d	BUR 2	BUR 2a	MUR17	MUR18	MUR19	MUR 20
Date	8/05/2019	8/05/2019	8/05/2019	8/05/2019	7/05/2019	7/05/2019	7/05/2019	7/05/2019
Time	1030	1130	1300	1400	0930	1130		1430
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	Upstream of Williamsdale Road	Upstream of Williamsdale Road	Downstream Williamsdale Rd	Downstream Williamsdale Rd	Upstream of Angle Crossing	Upstream of Angle Crossing	Downstream of Angle Crossing	Downstream of Angle Crossing
Weather	fine	fine	fine	fine	overcast, drizzle	-	fine	fine
Cloud cover (%)	30	70	60	30	100	-	0	0
Rain during the previous week?	Yes	yes	yes	yes	yes	-	yes	yes
Bank Height (m)	2	2	-	-	5	-	1	1.5
Bank Full Width (m)	30	20	-	-	60	-	80	60
Mode Stream Width (m)	2	2	2	2	15	20	25	20
Length of Reach	300	20	200	200	600	-	800	600
Habitat in Reach								
% Riffle	0	-	0	0	5	20	10	5
% Pool	100	-	85	70	85	80	70	60
% Run	0	-	15	30	10	0	20	35
% Edge	10	-	60	40	10	0	20	5
% Macrophyte	40	-	90	50	10	0	10	0
Mean Riffle Depth (cm)	-	-	0	0	18.6	25	8	24
Mean Riffle Velocity (m/s)	-	-	0	0	0.7	0.7	0.7	0.6
Mean Edge Depth (cm)	-	80	90	88	-	-	-	-
Mean Edge Velocity (m/s)	0.001	0.006	0.005	0.007	-	-	-	-
Riparian Vegetation								

Site Code	BUR1b	BUR 1d	BUR 2	BUR 2a	MUR17	MUR18	MUR19	MUR 20
Date	8/05/2019	8/05/2019	8/05/2019	8/05/2019	7/05/2019	7/05/2019	7/05/2019	7/05/2019
Time	1030	1130	1300	1400	0930	1130		1430
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	Upstream of Williamsdale Road	Upstream of Williamsdale Road	Downstream Williamsdale Rd	Downstream Williamsdale Rd	Upstream of Angle Crossing	Upstream of Angle Crossing	Downstream of Angle Crossing	Downstream of Angle Crossing
Mean Riparian Width (m)	1	10	2	1.5	5	7.5	5	6
% Trees >10m	0	15	5	5	5	15	5	30
% Trees <10m	10	20	5	5	30	20	5	20
% Shrubs	5	70	10	10	60	60	60	50
% Grasses/Ferns/Sedges	90	95	100	100	30	25	30	0
% Shading	<5	6-25	<5	<5	<5	<5	<5	<5
% Native	60	50	60	50	70	70	70	70
% Exotic	40	50	40	50	30	30	30	30
Observations								
Water Odours	normal	normal	normal	normal	normal	normal	normal	normal
Water Oils	none	none	globs	none	none	none	none	none
Turbidity	slight	slight	slight	slight	slight	clear	clear	clear
Plume	lots	some	some	some	some	some	some	some
Sediment Oils	absent	absent	absent	absent	absent	absent	absent	absent
Sediment Odours	normal	normal	normal	normal	normal	normal	normal	normal
Flow Level	low	low	low	low	low	low	low	low
Sediment Deposits	silt, sand	silt	sand, silt	sand, silt	sand	sand	sand	silt, sand
Local Erosion	moderate	moderate	moderate	moderate	moderate	moderate	moderate	moderate
Point Source Pollution	no	no	low level bridge	No	no	no	crossing, M2G	crossing
Non Point Source Pollution	no	agriculture	landuse	landuse	no	agriculture	recreation, toilets	no
Dams/Barriers	no	no	no	no	no	no	no	no
River Braiding	no	no	no	no	no	no	no	

Site Code	BUR1b	BUR 1d	BUR 2	BUR 2a	MUR17	MUR18	MUR19	MUR 20
Date	8/05/2019	8/05/2019	8/05/2019	8/05/2019	7/05/2019	7/05/2019	7/05/2019	7/05/2019
Time	1030	1130	1300	1400	0930	1130		1430
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	Upstream of Williamsdale Road	Upstream of Williamsdale Road	Downstream Williamsdale Rd	Downstream Williamsdale Rd	Upstream of Angle Crossing	Upstream of Angle Crossing	Downstream of Angle Crossing	Downstream of Angle Crossing
Site Classification	broad valley	broad valley	broad valley	broad valley	steep valley	steep valley	steep valley	steep valley
Left Bank Land Use	grazing, residential	grazing, residential, industrial	grazing, residential	grazing, residential	commercial, recreational	grazing	native forest, native grassland (no grazing), recreational	recreational
Right Bank Land Use	Native forest, exotic grassland (no grazing)	grazing, residential	grazing, residential	grazing, residential	exotic grassland, recreational	grazing, commercial, recreational	commercial, recreational	native forest, native grassland, recreational
% Bar Cover	0	0	0	0	0	0	0	0
Reach - Substratum Description								
% Bedrock	15	25	10	10	5	15	5	20
% Boulder	5	10	30	20	15	20	10	10
% Cobble	15	15	10	30	20	25	20	10
% Pebble	10	15	10	5	10	15	15	15
% Gravel	20	10	10	5	5	15	15	10
% Sand	20	15	5	10	35	15	30	20
% Silt	5	10	25	20	10	3	5	15
% Clay	0	0	0	0	0	2	0	0
% Detritus	10	20	20	30	5	25	10	-
% Muck/Mud	10	15	10	20	5	25	10	-
% Periphyton	65 - 90	35-65	35-65	65-90	35-65	< 10	35-65	35-65
% Moss	< 10	<10	<10	<10	< 10	< 10	< 10	< 10
% Filamentous Algae	< 10	10-35	10-35	<10	< 10	10-35	10-35	10-35
% Macrophytes	> 10	<10	10-35	<10	< 10	35-25	35-65	10-35

Site Code	BUR1b	BUR 1d	BUR 2	BUR 2a	MUR17	MUR18	MUR19	MUR 20
Date	8/05/2019	8/05/2019	8/05/2019	8/05/2019	7/05/2019	7/05/2019	7/05/2019	7/05/2019
Time	1030	1130	1300	1400	0930	1130		1430
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	Upstream of Williamsdale Road	Upstream of Williamsdale Road	Downstream Williamsdale Rd	Downstream Williamsdale Rd	Upstream of Angle Crossing	Upstream of Angle Crossing	Downstream of Angle Crossing	Downstream of Angle Crossing
Riffle - Sustratum Description								
% Bedrock	-	-	-	-	0	2	0	30
% Boulder	-	-	-	-	25	10	5	5
% Cobble	-	-	-	-	25	30	0	5
% Pebble	-	-	-	-	15	20	60	15
% Gravel	-	-	-	-	15	15	15	25
% Sand	-	-	-	-	10	10	10	5
% Silt	-	-	-	-	5	10	10	15
% Clay	-	-	-	-	0	3	0	0
% Detritus	-	-	-	-	0	25	5	10
% Muck/Mud	-	-	-	-	0	25	5	10
% Periphyton	-	-	-	-	35-65	< 10	35-65	35-65
% Moss	-	-	-	-	< 10	< 10	< 10	< 10
% Filamentous Algae	-	-	-	-	< 10	10-35	10-35	35-65
% Macrophytes	-	-	-	-	35-65	10-35	35-65	65-90
Edge - Substratum Description								
% Bedrock	5	40	15	15	-	-	-	-
% Boulder	20	10	30	20	-	-	-	-
% Cobble	10	15	15	20	-	-	-	-
% Pebble	5	5	5	2.5	-	-	-	-
% Gravel	5	5	5	2.5	-	-	-	-
% Sand	25	5	5	5	-	-	-	-
% Silt	30	10	20	30	-	-	-	-
% Clay	0	10	5	5	-	-	-	-
% Detritus	40	50	30	40	-	-	-	-
% Muck/Mud	5	10	20	10	-	-	-	-
% Periphyton	65-90	65-90	65-90	>90	-	-	-	-

Site Code	BUR1b	BUR 1d	BUR 2	BUR 2a	MUR17	MUR18	MUR19	MUR 20
Date	8/05/2019	8/05/2019	8/05/2019	8/05/2019	7/05/2019	7/05/2019	7/05/2019	7/05/2019
Time	1030	1130	1300	1400	0930	1130		1430
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	Upstream of Williamsdale Road	Upstream of Williamsdale Road	Downstream Williamsdale Rd	Downstream Williamsdale Rd	Upstream of Angle Crossing	Upstream of Angle Crossing	Downstream of Angle Crossing	Downstream of Angle Crossing
% Moss	< 10	< 10	<10	<10	-	-	-	-
% Filamentous Algae	10-35	10-35	10-35	10-35	-	-	-	-
% Macrophytes	35-65	25-65	35-35	10-35	-	-	-	-
Macrophytes								
Submergent / Floating	yes	yes	yes	yes	yes	yes	yes	yes
Emergent	yes	yes	yes	yes	yes	no	yes	yes
Habitat score	72	67	74	78	102	116	106	98

Appendix A2. AUSRIVAS habitat information collected on site during spring 2019

Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
Weather	fine	fine	fine	fine	fine	fine	fine	fine	fine	fine	fine	fine
Cloud cover (%)	0	0	0	0	0	0	70	30	0	0	0	0
Rain during the previous week?	no	no	no	no	no	no	yes	yes	no	no	no	no
Bank Height (m)	2	2	-	2.4	5	0.5	0.5	1	1	1	1	1.5
Bank Full Width (m)	30	20	-	25	60	70	70	60	60	60	80	70
Mode Stream Width (m)	1	4	1	2	30	20	25	30	25	25	35	15
Length of Reach	30	200	-	250	600	700	700	600	600	600	800	700
Habitat in Reach												
% Riffle	0	0	0	0	5	5	10	4	10	10	<5	<5
% Pool	100	100	100	100	85	80	60	90	70	70	90	58
% Run	0	0	0	0	10	15	30	6	20	20	5	10
% Edge	10	20	50	60	10	20	5	0	10	10	15	70
% Macrophyte	70	15	30	30	5	5	5	< 5	10	10	5	5
Mean Riffle Depth (cm)	60	0	-	-	16.6	7	6	14.3	11	11	9.3	13
Mean Riffle Velocity (m/s)	-	-	-		0.89	0.5	0.5	0.7	0.4	0.4	0.5	0.7
Mean Edge Depth (m/s)	44.6	36	83.3	52	26	34	29.3	21	-	-	-	-
Mean Edge Velocity (m/s)	-	-	0.001	0.001	0.006	0.5	0.1	0.3	-	-	-	-

Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
Riparian Vegetation												
Mean Riparian Width (m)	2	5	12.5	2.5	10	15	15	6	10	10	25	10
% Trees >10m	0	10	5	5	60	30	15	30	30	30	60	70
% Trees <10m	20	5	10	0	40	30	40	70	30	30	60	40
% Shrubs	20	0	15	0	60	60	60	70	20	20	5	10
% Grasses/Ferns/Sedges	80	90	95	95	70	40	60	0	40	40	50	30
% Shading	<5	<5	<5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
% Native	70	60	60	60	70	70	70	60	80	80	80	80
% Exotic	30	40	40	40	30	30	30	40	20	20	20	20
Observations												
Water Odours	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal
Water Oils	sheen	sheen	sheen	sheen	-	none	none	none	none	none	none	none
Turbidity	slight	clear	clear	clear	slight	slight	clear	slight	slight	slight	clear	clear
Plume	lots	some	lots	lots	some	some	some	-	little	little	some	some
Sediment Oils	light	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent
Sediment Odours	anaerobic	anaerobic	normal	normal	normal	normal	normal	normal	normal	normal	normal	normal
Flow Level	No flow	low	low	low	low	low	low	low	low	low	low	low
Sediment Deposits	sand, silt	sand, silt	sand, silt	silt	sand, silt	sand, silt	sand, silt	sand, silt	sand, silt	sand, silt	sand, silt	sand, silt
Local Erosion	moderate	heavy	moderate	moderate	low	moderate	moderate	moderate	some	some	some	some

Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
Point Source Pollution	no	no	M2G, road	crossing	no	no	crossing, M2G	crossing	no	no	no	recreation area upstream
Non Point Source Pollution	no	crossing	traffic	grazing	no	no	toilet	no	agriculture	agriculture	no	no
Dams/Barriers	no	no	no	no	no	no	no	no	no	no	no	no
River Braiding	no	no	no	no	no	no	no	no	no	no	no	yes
Site Classification	broad valley	broad valley	broad valley	broad valley	steep valley	steep valley	steep valley	steep valley	steep valley	steep valley	steep valley	steep valley
Left Bank Land Use	grazing, residential	grazing	grazing, residential	grazing, residential	grazing, native grassland (no grazing)	nature woodland	recreational, grasslands	recreational, native grasslands	forestry, recreational	forestry, recreational	recreational	recreational, forestry
Right Bank Land Use	cropped	grazing	grazing, residential	grazing, residential	industrial, recreational	nature woodland	recreational, industrial, grasslands	native woodland	recreational	recreational	recreational	recreational
% Bar Cover	0	0	0	0	0	0	0	10	0	0	0	15
Reach - Substratum Description												
% Bedrock	10	5	10	10	10	10	5	10	20	20	30	20
% Boulder	20	30	5	5	15	20	5	5	20	20	20	10
% Cobble	25	20	30	20	25	30	20	30	15	15	20	25

Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
% Pebble	10	5	10	10	10	10	30	30	20	20	10	5
% Gravel	10	5	10	10	5	10	25	5	5	5	5	5
% Sand	15	10	5	10	20	15	10	15	15	15	10	20
% Silt	15	20	25	30	10	5	5	5	5	5	10	10
% Clay	5	5	5	5	5	0	0	0	0	0	0	5
% Detritus	-	-	-	-	-	-	7	5	-	-	-	-
% Muck/Mud	-	-	-	-	-	-	7	5	-	-	-	-
% Periphyton	65 - 90	35 – 65	65 - 90	65 - 90	65 - 90	35 – 65	35 - 65	35 – 65	35 - 65	35 - 65	35-65	35-65
% Moss	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
% Filamentous Algae	10 – 35	35 - 65	10 – 35	10 – 35	10 – 35	< 10	10 – 35	< 10	< 10	< 10	< 10	10 – 35
% Macrophytes	35-65	10 – 35	35 - 65	35 - 65	35 - 65	35 - 65	10-35	10 – 35	< 10	< 10	< 10	< 10
Riffle - Sustratum Description												
% Bedrock	-	-	-	-	0	0	0	0	-	-	-	-
% Boulder	-	-	-	-	10	40	5	10	-	-	-	-
% Cobble	-	-	-	-	60	30	35	40	-	-	-	-
% Pebble	-	-	-	-	10	10	35	15	-	-	-	-
% Gravel	-	-	-	-	5	5	10	10	-	-	-	-
% Sand	-	-	-	-	10	10	15	10	-	-	-	-
% Silt	-	-	-	-	5	5	10	15	-	-	-	-
% Clay	-	-	-	-	0	0	0	0	-	-	-	-
% Detritus	-	-	-	-	5	5	5	10	-	-	-	-
% Muck/Mud	-	-	-	-	0	0	0	0	-	-	-	-
% Periphyton	-	-	-	-	< 90	-	65 – 90	65 – 90	-	-	-	-

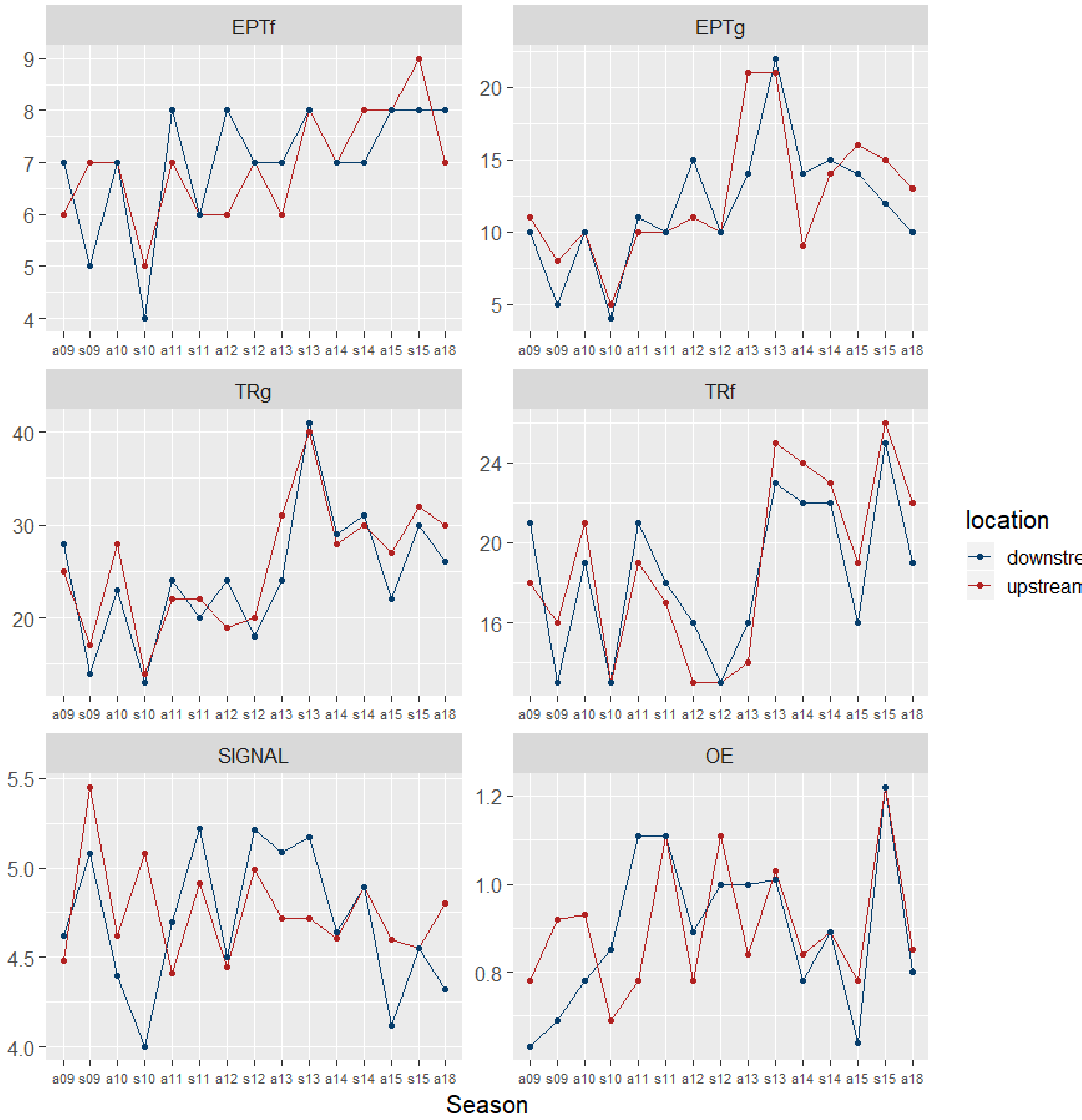
Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
% Moss	-	-	-	-	< 10	-	< 10	< 10	-	-	-	-
% Filamentous Algae	-	-	-	-	10 – 35	-	10 – 35	< 10	-	-	-	-
% Macrophytes	-	-	-	-	35 – 65	-	65 - 90	10 – 35	-	-	-	-
Edge - Substratum Description												
% Bedrock	0	0	0	0	0	0	0	0	-	-	-	-
% Boulder	15	10	0	10	20	5	5	5	-	-	-	-
% Cobble	20	30	30	5	10	5	10	15	-	-	-	-
% Pebble	5	15	5	5	10	10	10	10	-	-	-	-
% Gravel	5	5	5	5	10	10	30	10	-	-	-	-
% Sand	20	5	5	10	10	30	15	30	-	-	-	-
% Silt	30	35	50	60	10	40	30	30	-	-	-	-
% Clay	5	0	5	5	40	0	0	0	-	-	-	-
% Detritus	10	15	30	30	15	10	30	20	-	-	-	-
% Muck/Mud	10	10	10	10	5	10	5	0	-	-	-	-
% Periphyton	65 - 90	65 – 90	65 - 90	> 90	> 90	65 - 90	65-90	> 90	-	-	-	-
% Moss	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-	-	-	-
% Filamentous Algae	35 - 65	35 – 65	10 - 35	35 – 65	10 - 35	35-65	10 - 35	10 - 35	-	-	-	-
% Macrophytes	35 – 65	35 – 65	65 - 90	35 – 65	35 - 65	65-90	35 - 65	35 - 65	-	-	-	-
Macrophytes												
Submergent / Floating	-	yes	yes	yes	yes	yes	yes	yes	-	-	-	-
Emergent	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Site Code	BUR1b	BUR1d	BUR2	BUR2a	MUR17	MUR18	MUR19	MUR20	MUR28 up	MUR28 down	MUR935	MUR936
Date	31/10/2019	31/10/2019	1/11/2019	1/11/2019	31/10/2019	31/10/2019	31/10/2019	30/10/2019	20/11/2019	20/11/2019	20/11/2019	20/11/2019
Time	1330	1430	0900	1015	0940	1045	1520	1305	1100	1100	1010	0850
Season	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring	Spring
River	Burra Creek	Burra Creek	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	upstream Williamsdale Road	downstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	upstream Angle Crossing	upstream Angle Crossing	downstream Angle Crossing	Upstream of MPS (upstream of Cotter River confluence)	Upstream of MPS (downstream of Cotter River confluence)	Casuarina Sands	downstream MPS
Habitat score	72	77	86	83	103	103	104	98	95	95	89	106

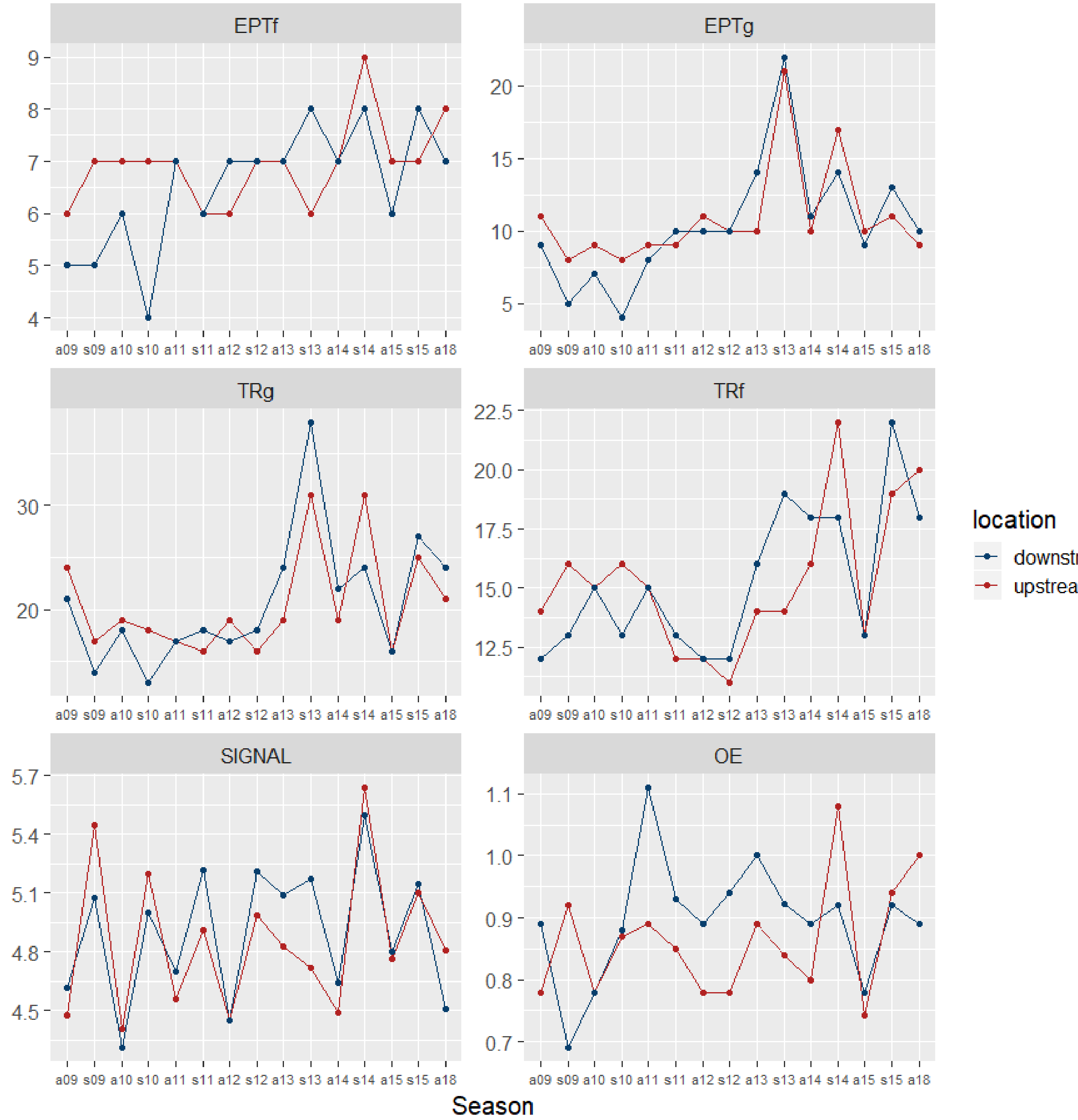
Appendix B - Historical macroinvertebrate indices

NOTE - MPS is not included at this stage due to the large data gaps. Values are means for each location.

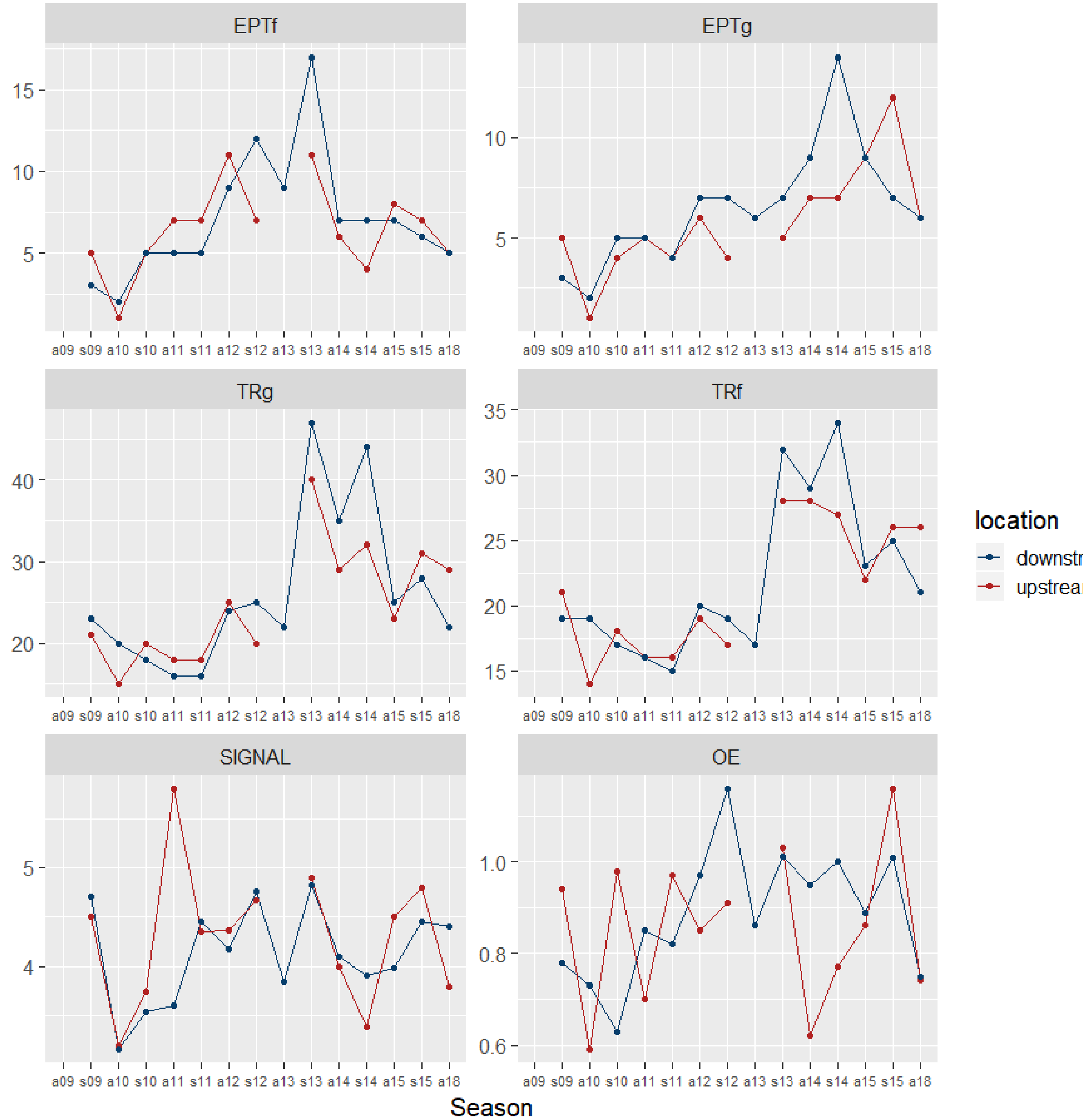
Angle Crossing EDGE - Macroinvertebrate indices between autumn 2009 and autumn 2018



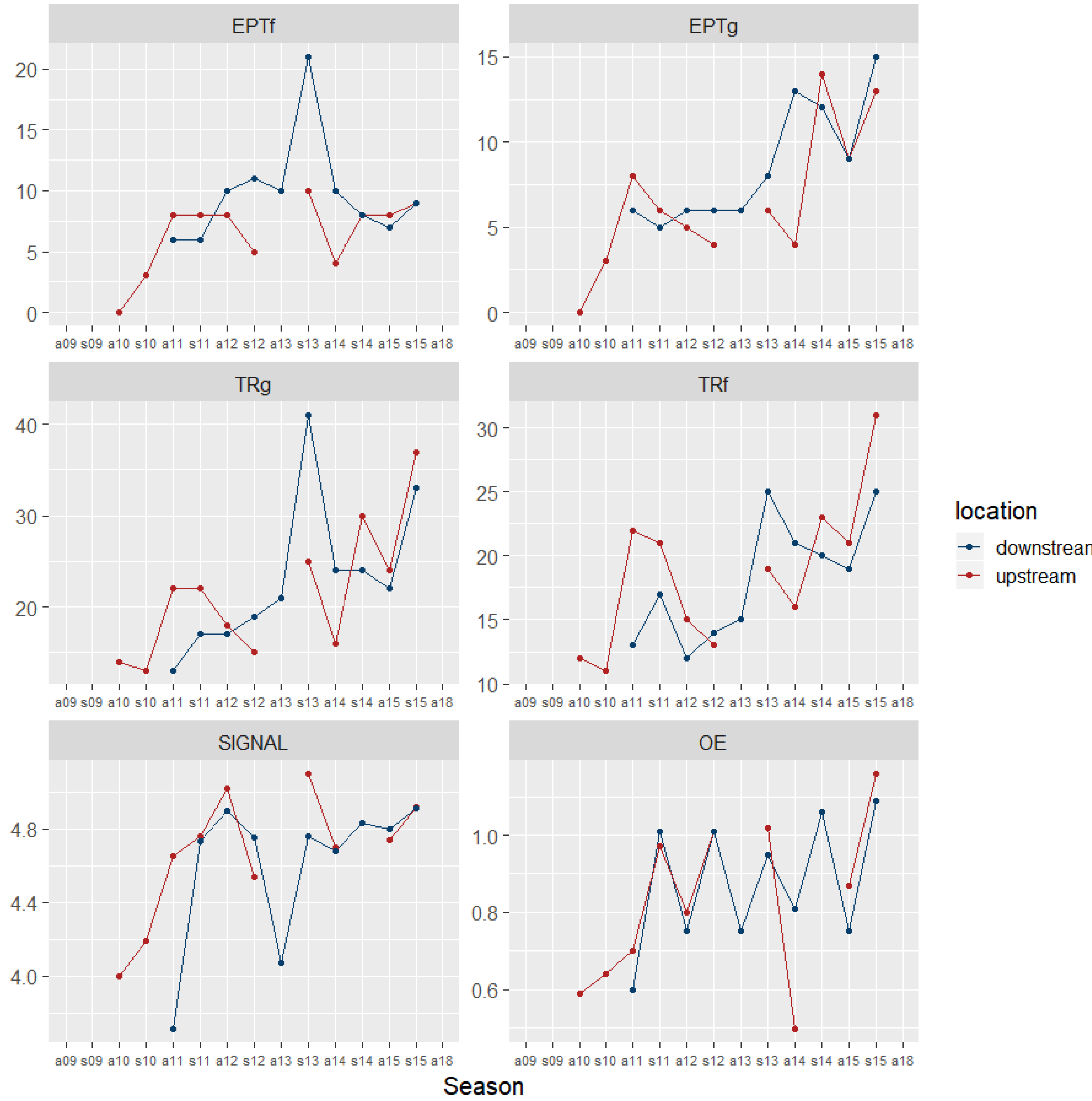
Angle Crossing RIFFLE - Macroinvertebrate indices between autumn 2009 and autumn 2018



Burra Creek EDGE - Macroinvertebrate indices between autumn 2009 and autumn 2018



Burra Creek RIFFLE- Macroinvertebrate indices between autumn 2009 and autumn 2018



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