Icon Water

Murrumbidgee Ecological Monitoring Programme

Sentinel Monitoring - autumn 2015

August 2015

Executive summary

The Murrumbidgee Ecological Monitoring Programme commenced in 2008. The project is being undertaken by the GHD Water Sciences Group for Icon Water to establish information and data regarding relevant biological and water quality information prior to and then following on from the commissioning and initial operation of the Murrumbidgee to Googong (M2G) water transfer project and Murrumbidgee Pump Station (MPS).

Over the course of this monitoring programme, there have been a number of changes and modifications to the programme, which have been in line with the adaptive management philosophy adopted in the design phase of the MEMP. The most recent and major change to the MEMP followed the recent peer review of the programme by Jacobs Group (Australia). The review resulted in a number of recommendations to adapt the programme so that Icon Water may continue to have a robust monitoring programme, capable of detecting potential ecological impacts, while at the same time accounting for the lowered ecological risk during periods of standby and maintenance modes of operation.

Three modes of operation were defined for the M2G and MPS to help target the monitoring programme. 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/d 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.*
- ***Operational (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 Murrumbidgee Pump Station, this extraction volume rarely occurs due to water quality in the Murrumbidgee River. Hence smaller volumes are likely to be taken and shandied with cleaner Cotter River water from the Bendora Main.*

With this in mind, the revised MEMP will adopt a two-stage approach which incorporates sentinel monitoring during **standby** operation modes and **impact** monitoring assessment during the various operation modes.

The purpose of the sentinel monitoring is to understand if major catchment-scale changes to the aquatic ecology are taking place. Sentinel monitoring will occur during standby periods when the risk to the ecosystem is deemed to be very low. Hence sentinel monitoring will occur in autumn and spring every three years beginning in autumn 2015 with a reduced number of monitoring sites (1 upstream and 1 downstream of Angle crossing (M2G); Burra Creek discharge weir (M2G) and at the Murrumbidgee Pump Station (MPS)). Periphyton sampling 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

The trigger for impact monitoring to go ahead is the decision to operate the M2G or MPS infrastructure. This monitoring scenario requires a before and after approach, and relies on replicated sampling protocols. Under this monitoring protocol several univariate indicators of river health and condition with be analysed before and after the operation period at both upstream and downstream locations. Periphyton photogrammetry will be assessed at both time periods and compared between monitoring locations. The key difference between this, and the sentinel monitoring is the number of sites, replicates and sampling events (impact monitoring requires at least one before and one after sampling event) and the level of detail used in the analysis.

Following the operation period, a consecutive spring and autumn monitoring schedule must also be carried out; and should pumping occur across a spring and/ or autumn period, sampling will be carried out during those times.

Component 1 – Angle Crossing Overview

Icon Water constructed an intake structure and pipeline to abstract water from the Murrumbidgee River at Angle Crossing (southern border of the ACT). The system is designed to pump up to a nominal 100 ML/d and was completed in August 2012. There are operating rules in place that limit when and how much water can be extracted to ensure that environmental harm is minimised. The Angle Crossing component of the MEMP has focused on the assessment of potential impacts associated with flow reductions in the Murrumbidgee River downstream of Angle Crossing as a result of water abstraction. However, during the current reporting period the only pumping which was undertaken by Icon Water was that of maintenance flows. These flows only have a minimal impact upon flow in the Murrumbidgee River.

Component 1 – Angle Crossing autumn 2015

The results from the Angle Crossing water quality show that the upstream and downstream sites were very similar in terms of all the monitoring elements (water quality, macroinvertebrates, and photogrammetry).

There were very few breaches of the ANZECC & ARMCANZ (2000) guidelines throughout the autumn season. The upper limit of the pH recommended range was exceeded at both sites, which was the only exceedance recorded from the in-situ probe results. Outside the high flow events at the Lobb's Hole continuous monitoring station, pH was elevated above the guideline levels for the duration of the recorded period. The elevation of pH through this reach of the Murrumbidgee River is not uncommon during period of low flow. Turbidity was only recorded in exceedance of the guidelines as a result of the high flow events which is to be expected.

The collection and reporting of periphyton data has been removed from the MEMP sentinel monitoring component of the MEMP, however GHD has included this into the photogrammetry assessments to maintain the data record, albeit visual as opposed to quantitative.

Periphyton during autumn 2015 was consistent between the upstream and downstream sites with reach scale assessments both recorded as having coverage of 35-65%, while the riffle habitats were assessed as having coverage of 65-90%. These photographic assessments indicate a reduction in coverage compared to autumn 2014 downstream of Angle Crossing which was assessed at 65-90% coverage at the reach scale and >90% for the riffle habitat coverage. This change is most likely due to the change in flow volumes between the two seasons with autumn 2014 experiencing very low flow levels with increased flows during autumn 2015.

The geomorphology at Angle Crossing has shown over previous years that it is a very dynamic section of river which has shown periods of large deposition and both erosion and scour of pools and bars. The downstream photo points indicate that there has been some recent sand deposition along the channel margins through this reach, particularly on the left bank. This follows the findings in the MEMP Geomorphology report which indicated that the centre of the channel was being scoured out, particularly during periods of higher flows with deposition along channel margins.

In terms of the biological assessment, there has been a high degree of consistency in the assessments of ecological condition at bothe the upstream and downstream sites over the projects history. In the current study, AUSRIVAS has determined the overall site condition upstream downstream of Angle Crossing to be Band B, ("significantly impaired"), which is consistent with the long term assessments of these two sites.

Component 2–Burra Creek Overview

The operational phase of the M2G will involve the transfer of water from Angle Crossing to Burra Creek, where it will be released as a run of river flow into Googong reservoir for storage. Up to 100 ML/d will be pumped to Burra Creek, with the natural flow regime characterised by low base flows and peak flow events that only exceed 100 ML/d for short periods of time. Consequently, this could potentially result in changes to the hydrological regime of this system and subsequent changes to its ecology (both detrimental and beneficial). The Burra Creek component of the MEMP has focused on assessing the potential impacts of changes in hydrology on aquatic biota.

Monitoring for the Angle Crossing and Burra Creek components of the MEMP has been carried out in autumn and spring for five years. This includes a baseline monitoring phase between 2009 and 2012 and, nominally, an operation phase from August 2012 to present. However, since the completion of the M2G in August 2012, the *system has only been operating in standby mode. Only limited trial and maintenance abstractions and releases have occurred. Hence the monitoring to date, including the last two years, largely represents an extended baseline survey. However, it has encompassed a range of natural flow conditions and, consequently, has been useful in terms of collecting data that allows a better understanding of the relationships between biota and flow with better predictive capacity in respect to the likely nature of changes that will occur once the M2G goes into full operation.*

Monitoring to date has covered ACT AUSRIVAS macroinvertebrate sampling, periphyton sampling, water quality monitoring (via in situ testing, laboratory analysis and continuous data loggers) and an assessment of hydrology at locations upstream and downstream of Angle Crossing and the nominated release point in Burra Creek.

Component 2– Burra Creek Autumn 2015

The continuous water quality data at Burra Weir showed signs of the low flows during the start of the period with elevated EC, pH and temperature, and lower levels of DO. Turbidity spikes throughout the autumn period coincided with the high flow event during April and also the M2G maintenance APPLE run during May, while it remained at very low levels throughout the rest of the period. Both pH and EC exceeded the guidelines for the duration of the period, with the exception of periods of high flow, either from natural rainfall events or artificial M2G maintenance runs. These elevated levels are considered 'normal' in Burra Creek and have been frequently recorded through the duration of the MEMP. Flows from the M2G APPLE run increased the compliance of the water quality with the guidelines at the Burra Weir through the pumping of the lower EC and pH Murrumbidgee River water.

Periphyton coverage was high at both sites upstream and downstream of Williamsdale Road (>90%) which is consistent with the results recorded during autumn 2014. However of particular interest is the level of filamentous algae which was observed during autumn 2015 (65-90%) compared to that which was observed during autumn 2014 (<10%). This large increase could be the result of the increased nitrogen entering Burra Creek from Holden's Creek resulting in increased filamentous algae growth. The high periphyton coverage could be limiting further periphyton growth which is leaving nutrients available for uptake by the filamentous algae.

During the current maintenance phase of the M2G pipeline, the use of photogrammetry at the previously identified cross sections along Burra Creek are considered to be a robust method for the monitoring of potential changes in bank erosion and slumping. The photographs collected during autumn 2015 will be used for comparison to future photo points (in two years' time), or with photographs and observations recorded before and after the use of the M2G pipeline for operational purposes, should this occur within the next two years.

As indicated in the MEMP Geomorphology report (GHD, 2015c) the area of greatest concern along Burra Creek is the downstream reach at BUR 2c (upstream of London Bridge). This has been identified as the most likely point of major bank slumping with M2G maintenance and operational flows (should they occur in the future) potentially exacerbating the problem currently being driven by natural high flow events.

During autumn 2015 the macroinvertebrate communities were relatively similar in relation to the total richness and EPT richness. The overall site result of Band B's of both the upstream and downstream sites has been consistent over the previous four autumn sampling seasons. This suggests that the ecological health of these sites has been maintained at Band B during the autumn periods, consistently for several years.

Component 3- Murrumbidgee Pump Station Overview

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. The Murrumbidgee Pump Station has undergone a significant upgrade which increased its pumping capacity to The Mount Stromlo Water Treatment plant from 50ML/d to approximately 150ML/d. The framework for this programme responds primarily to the ACTEW water abstraction licence reporting requirements. Water abstraction at the MPS, requires an assessment of the response of the river through monitoring methods that can quantify subtle impacts.

Component 3- Murrumbidgee Pump Station autumn 2015

The water quality results from the MPS sentinel monitoring sites showed that exceedances of the ANZECCC & ARMCANZ (2000) guidelines were not common. Outside of the exceedance values recorded during the high flow event at the continuous monitoring station, the only parameter to exceed the guidelines was pH. This was recorded in exceedance at both sites, upstream and downstream of the MPS, with pH slightly decreasing at the downstream site, MUR 935. This reduction is likely to be the result of a dilution factor from the water coming from the Cotter River confluence. pH at this level is not unexpected within this region of the Murrumbidgee River and is consistent with exceedances recorded during autumn 2013 and 2014, while also likely related to the period of low flows prior to autumn 2015.

Periphyton photographs using both the quadrat and underwater aspects provide a visual record of the coverage qualified on other AUSRIVAS data sheets. Periphyton cover during autumn 2015 was consistent between the upstream and downstream sites with both reaches being assessed as having a coverage of 65-90%, while the riffle habitats were assessed as having a coverage of >90%. These values are consistent with the results from autumn 2014 at the site upstream of the MPS (the downstream site was not sampled in autumn 2014).

The macroinvertebrate results from the MPS sites during autumn 2015 showed improved AUSRIVAS scores compared to autumn 2013 (MUR 28 & 935) and 2014 (MUR 28 only). Both sites were assessed as Band A ("similar to reference"), which is the first time that the overall site assessments for these sites have been over Band B ("significantly impaired"). This increase in banding is the result of increased OE/50 scores across both sites and habitats, except the edge at MUR 935 compared to the previous autumn results. The number of taxa missing from the riffle habitat replicates was limited to a single taxon.

While the AUSRIVAS indicate an improvement in ecological condition at these sites, it is important to note that these increases are only minor. The replicates at these sites have over the previous two autumns shown high numbers of Band A replicates. Over autumn 2013 and 2014 67% of the replicates recorded at MUR 28 have been assessed as Band A. While at MUR 935 during autumn 2013 75% of the replicates at this site were assessed as Band A. The edge habitat during autumn 2014 was the only habitat during this period not to have any replicates assessed as Band A.

Summary

The purpose of the sentinel monitoring programme is to provide a broad scale assessment of control and impact sites related to the Angle Crossing abstraction point, the discharge weir in Burra Creek and the Murrumbidgee pump station, located just downstream of the Cotter Road bridge. Specifically this programme aims to "provide confidence that the condition of the potential impact sites is broadly [sic] similar to non-impact sites across time".

There were no obvious differences in any of the measured parameters between all of the upstream / downstream site pairs for each of the components of this sampling run. Furthermore, these results were also consistent with those of previous autumn sampling periods (see Appendix B) throughout the MEMP which suggests that in the absence of the operation of M2G or MPS, these sites are generally showing similar temporal and spatial variation. The upshot of this is that we can be confident that at each site and location there are no other site specific influences that may impose additional stresses to the aquatic environment. If that were the case (i.e. there were significant changes to one site but not the other during standby mode) then this would imply that site specific stressors may exists, which may reduce our ability to detect change if there is any, during the operational phases of M2G or MPS projects.

Recommendations

1. *In the original format of the MEMP, the replicate AUSRIVAS scores were considered separately for each site. This was a deliberate step in the analysis process to highlight the (often high) variability with a given site and habitat. One of the questions related to applying this method is how AUSRIVAS bands are reported when there is a large amount of variation in the results. The conservative approach and the method that GHD have applied is to assign the site with the Band (from the sub-sample) farthest from Band A (Barmuta et al., 2003).*

However, now that the focus of the monitoring has changed and is now concerned with how the upstream and downstream sites are tracking on a broad temporal scale, we recommend that for the sake of meeting the specific objectives of this part of the monitoring programme and to avoid cases of no reliable assessment, that the mean O/E50 score and its subsequent Band assignment be reported from here on. Sub-sample data and assessments will continue to be provided, but the habitat scores should be reported as mean values.

2. *It is recommended to use the Rapid Appraisal of Riparian Condition (RARC; Jansen et al., 2007) to compliment the vegetation photo points and riparian vegetation assessments. This assessment methodology is designed to be rapid and can be completed in the already allocated field time for the project at vegetation sites. This addition will improve comparability between sentinel assessments and potential impact assessment, through direct comparison of scores, complementing the current visual methodology. This method is currently being used by ACT Waterwatch and has been in use in the Upper Murrumbidgee River for some time. This method is ideal for determining changes over longer time periods, and is therefore suitable for the sentinel component of the MEMP.*
3. *Photos from the current monitoring period demonstrate that weather conditions, particularly sunlight (angle, shadow, etc.) and rain, are important factors when using standalone photogrammetry monitoring. It is recommended that during sampling, a back-up field day, within one week of the macroinvertebrate monitoring, for potentially inclement weather impacting on photograph quality. This will provide some flexibility in capturing photos of adequate quality to provide the opportunity for condition assessment and comparability with previous and future seasons.*

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Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

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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

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 Programme

ML/d – Megalitres per day

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), the ACT's dam storage volumes declined to unprecedented levels. Icon Water (formally ACTEW Corporation), the major water utility company in the ACT, developed a water security programme that involved building additional and upgrading existing infrastructure to improve the future water supply security for the residents of Canberra and Queanbeyan.

The water security projects include:

1. Murrumbidgee to Googong transfer pipeline (M2G): from Angle Crossing just within the ACT's southern border to Burra Creek in the Googong Dam catchment, at a nominal 100 ML/d;
2. 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);
3. Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing, and;
4. A new 78 GL Cotter Dam called the Enlarged Cotter Dam (ECD) just downstream of the existing 4 GL Cotter Dam.

To assess the influence of the construction and operations of these major projects Icon Water developed a detailed monitoring programme to establish a comprehensive baseline data set which could then be compared to the conditions during and following construction and also during the operation of M2G and MPS.

Since the completion of the MPS upgrade and the M2G infrastructure, both have been used infrequently because Icon Water has opted to abstract from other catchments which offer raw water with lower production costs. Furthermore, given the breaking of the drought in 2010 there has been no operational need to operate M2G or MPS because of improved water storage levels. Modelling by Icon Water has shown that it may be several years before full scale operation of either infrastructure is required which means that the MPS and M2G are both essentially on standby mode; implying that ecological impacts relating to these projects may be minimal.

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

The Murrumbidgee Ecological Monitoring Programme (MEMP) was initially set up by Icon Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River and the influence of increased water volumes in Burra Creek on ecological communities. 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. Sampling has been conducted in spring and autumn each year between spring 2008 and autumn 2015.

Over the course of this monitoring programme, there have been a number of changes and modifications to the programme, which have been in line with the adaptive management philosophy of the MEMP. The history of the MEMP is shown schematically in Figure 1-1.

Between spring 2008 and autumn 2013 there were four component areas being considered as part of the MEMP[1]:

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

[1] Note that the MEMP does not include monitoring related to the Enlarged Cotter Dam.

However, following the autumn 2013 monitoring period Icon Water reviewed the MEMP which resulted in the discontinuation of part 3 (the Murrumbidgee Pump Station component) and Component 4 (the Tantangara to Burrinjuck component).

Following this review the MEMP continued to assess Component 1 and Component 2 from spring 2013 to spring 2014. During 2014 Icon Water commissioned a full independent review of the MEMP project. This review was completed by Jacobs (2014) and produced a number of recommendations which are outlined below.

Commencing in autumn 2015 (the present study), these changes are:

- Sentinel monitoring – completion of autumn and spring seasonal analysis every 3 years;
- The re-inclusion of Component 3: Murrumbidgee Pump Station;
- Reduction of sites assessed for macroinvertebrates for each Component from 6 sites to 2 sites;
- Reduction from 2 riffle and 2 edge habitat samples to 1 riffle and 1 edge habitat sample;
- Removal of water quality grab sampling from Component 2 and Component 3;
- Removal of quantitative periphyton assessment;
- Introduction of photogrammetry monitoring for periphyton, vegetation and geomorphology at relevant locations.

1.2 Project review and requirements

The most recent and major change to the MEMP followed the recent peer review of the programme by Jacobs Group (Australia). The review resulted in a number of recommendations to adapt the programme so that Icon Water may continue to have a robust monitoring programme, capable of detecting potential ecological impacts, while at the same time accounting for the lowered ecological risk during periods of standby and maintenance modes of operation.

Three modes of operation were defined for the M2G and MPS to help target the monitoring programme. 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/d 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.
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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.
- **Operational (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 Murrumbidgee Pump Station, this extraction volume rarely occurs due to water quality in the Murrumbidgee River. Hence smaller volumes are likely to be taken and shandied with cleaner Cotter River water from the Bendora Main.

During periods of standby for MPS and M2G the risks from these projects is minimal to the ecological condition of the Murrumbidgee River and Burra Creek. Alternatively, it is anticipated that any risks to the Murrumbidgee River and Burra Creek are most likely to manifest during periods of full operation.

With this in mind, the revised MEMP will adopt a two-stage approach which incorporates sentinel monitoring during **standby** operation modes and **impact** monitoring assessment during the various operation modes described in section 2.2. These two types of monitoring are described in sections 2.2.1 and 2.2.2 respectively.

1.2.1 Sentinel Monitoring (MPS and M2G)

The purpose of the sentinel monitoring is to understand if major catchment-scale changes to the aquatic ecology are taking place. Sentinel monitoring will occur during standby periods when the risk to the ecosystem is deemed to be very low. Hence sentinel monitoring will occur in autumn and spring every three years beginning in autumn 2015 with a reduced number of monitoring sites (1 upstream and 1 downstream of Angle crossing (M2G); Burra Creek discharge weir (M2G) and at the Murrumbidgee Pump Station (MPS)). Periphyton sampling 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

1.2.2 Impact Monitoring (MPS and M2G)

The trigger for impact monitoring to go ahead is the decision to operate the M2G or MPS infrastructure. This monitoring scenario requires a before and after approach, and relies on replicated sampling protocols. Under this monitoring protocol several univariate indicators of river health and condition with be analysed before and after the operation period at both upstream and downstream locations. Periphyton photogrammetry will be assessed at both time periods and compared between monitoring locations. The key difference between this, and the sentinel monitoring is the number of sites, replicates and sampling events (impact monitoring requires at least one before and one after sampling event) and the level of detail used in the analysis.

Following the operation period, a consecutive spring and autumn monitoring schedule must also be carried out; and should pumping occur across a spring and/ or autumn period, sampling will be carried out during those times.

Details of the monitoring elements for sentinel and impact monitoring are provided in section 1.6.

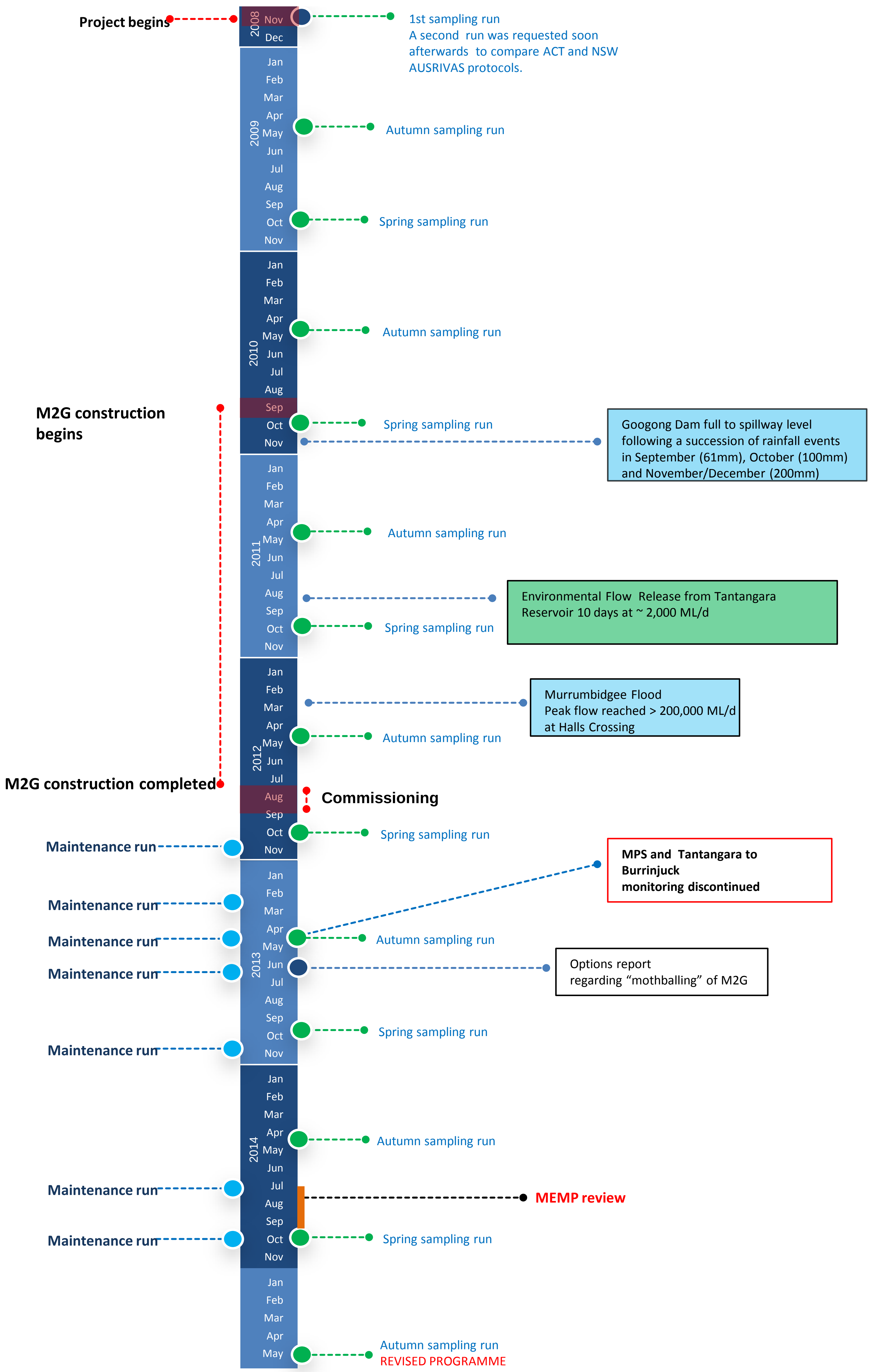


Figure 1-1. Schematic time line of the Murrumbidgee Ecological Monitoring Programme history

1.2.3 Environmental flows and the 80:90 percentile rule

The environmental flow rules for the Murrumbidgee to Googong (M2G) component have been adopted from the framework outlined in the Environmental Flow Guidelines (ACT Government, 2013). 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 Murrumbidgee Pump Station 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.

The 80:90 rule has been applied to hydrological modelling of the Murrumbidgee River at Angle Crossing for the M2G operational plan and was based on data collected from the Lobb's Hole gauging station. Specifically the 80th percentile flow applies from November to May and the 90th percentile from June through to October (Figure 1-2).

As can be seen from Figure 1-1, the lowest flows in the Murrumbidgee River occur in summer and autumn. The 80th percentile flows from November to May are less than the 90th percentile flows except for November. 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.

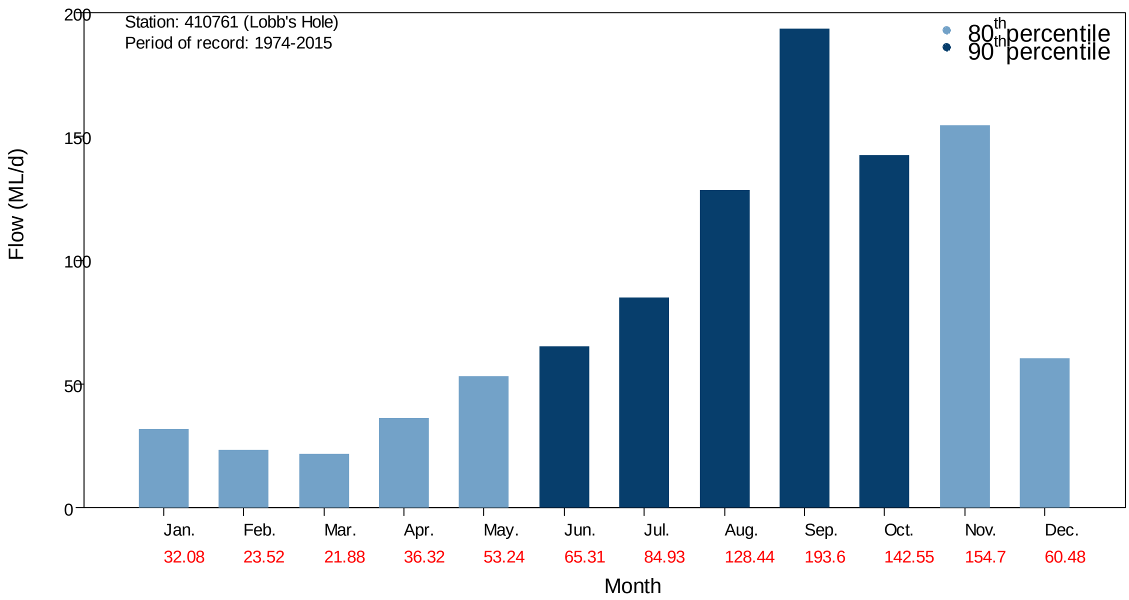


Figure 1-2. Environmental flow values for the operation of the M2G pipeline

Note: Flow data values for data to 31/05/2015. Monthly values in red are megalitres 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.

1.2.4 Parts 1 & 2 – Murrumbidgee to Googong transfer pipeline (M2G)

The pumping system at Angle Crossing transfers water from the Murrumbidgee River through a 12 km underground pipeline into Burra Creek. The water is then to be transported a further 13 km by run of river flows into Googong Reservoir. Water abstraction from the Angle Crossing pump station will be dictated by the Googong Reservoir's capacity and by 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 will be directed by the Operational Environmental Management Plan (ACTEW Corporation, 2010).

Murrumbidgee River

During periods of low flow (whether climate related or artificially induced), impacts upon aquatic environments can be measured using surrogate indices based on changes to macroinvertebrate communities such as changes in species richness, abundances and community structure. Such changes can result either directly through invertebrate drift, or indirectly through reductions in habitat diversity or flow conditions which do not suit certain taxa.

Dewson, *et al.* (2007) reported that certain macroinvertebrate taxa are especially sensitive to reductions in flow and can be useful indicators in flow restoration assessments and assist in longer term management of flows in regulated river systems. It is possible that there will be changes to the aquatic ecosystem within the Murrumbidgee River as a result of M2G. Some of these effects include, but are not limited to:

- changes to water chemistry;
- changes to channel morphology;
- changes to velocity;
- changes to water depth.

All of these changes have potential knock-on effects to the biota within the river's ecosystem. The current monitoring programme forms the basis of an Ecological Monitoring Programme to satisfy the EIS and compliance commitments for the M2G Project.

Burra Creek

In light of the natural low flow conditions in Burra Creek compared to the nominal pumping rate of 100 ML/d, it is expected that the increased flow due to the discharge from the Murrumbidgee River may have several impacts on water quality, channel and bank geomorphology and the ecology of the system. Some beneficial ecological effects might occur in the reaches of Burra Creek between the discharge point (just upstream of Williamsdale Road) to downstream of the confluence of the Queanbeyan River.

These may include, but are not limited to:

- The main channel being more frequently used by fish species due to increased flow permanence and longitudinal connectivity between pools;
- Increased biodiversity in macroinvertebrate communities;
- A reduction in the extent of macrophyte encroachment in the Burra Creek main channel.

On the other hand, there is potential for the transfer of Murrumbidgee River water into Burra Creek to adversely affect the natural biodiversity within Burra Creek due to the different physico-chemical characteristics of water in each system (particularly with regards to EC). Potential impacts are highlighted in Table 1-1.

Table 1-1. Potential impacts to Burra Creek following Murrumbidgee River discharges

Property	Possible impact	Source	Comments based on data collected to date (2009-2015)
	The inter-basin transfers (IBT) of soft Murrumbidgee water into the harder water of Burra Creek may change the natural biodiversity within Burra Creek.	Davies *et. al.* (1992) Martin and Rutlidge (2009)	Based on the data collected following the short term maintenance runs, there have been changes to several physico-chemical water quality parameters. The changes to these parameters are short lived and there has been no evidence of alterations to the indices of macroinvertebrate community composition and quality as a result. It is still unknown if this will be the case for prolonged periods of M2G operation or if there are likely to be cumulative impacts to these periodic changes in water quality. Turbidity increases with the first initial pulse following flow release. These are short term changes only and there is no evidence to date to support the possible impacts in column one.
	Changes in water temperature could be expected from the IBT and increased turbidity. This may affect plant growth, nutrient uptake and dissolved oxygen levels and ultimately compromise the quality of fish habitat.	Martin and Rutlidge (2009)	The observed changes to the water temperature, turbidity and dissolved oxygen are only short term during the pumping schedule. Compromising fish habitat is not a concern in Burra Creek as the fish community is comprised of wholly introduced species.
Ecology	Changes in macroinvertebrate communities and diversity through habitat loss from sedimentation, changes to riparian vegetation and scouring of macrophytes. Changes in macroinvertebrates are also expected with an increase of flow (e.g. increased abundances of flow dependant taxa).	Bunn and Arthington (2002)	The current M2G pumping regime has not continued for durations long enough to, nor at volumes large enough to result in significant macrophyte scouring, sediment movement or alter the community composition over and above what occurs naturally within the system.
	Potential risk of exotic species recruitment from IBT. This could displace native species in the catchment and pose a risk of the spread of disease.	Martin and Rutlidge (2009), Davies *et al.* (1992)	No evidence of any new introduced species since the commencement of M2G operations including fish species (GHD, 2015a). This is potentially due to the use of fish egg filters which were installed during the construction phase of M2G.
	Infilling from fine sediment transport could threaten the quality of the hyporheic zone, which provides important habitat for macroinvertebrates in temporary streams.	Brunke and Gonser (1997)	The transport of fine sediment within the creek by the operation of M2G is minor compared to the sediment transport capabilities of the natural high flow events that occur in Burra Creek.
	Increased flow with improved longitudinal connectivity which will potentially provide fish with more breeding opportunities and range expansion, although this will be dependent on the flow regime.	Martin and Rutlidge (2009)	Water transfer has increased the longitudinal connectivity between the pools in Burra Creek. However, the short duration of the releases would be unlikely to facilitate breeding opportunities or range expansion by native fish species.
Bank Geomorphology	Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and increased erosion rates from bank instability. Increased sedimentation may also reduce benthic habitat complexity, which may result in a loss of benthic macroinvertebrate diversity and a potential loss of sensitive taxa.	GHD, 2013_a	Natural events have a much larger impact potential upon the geomorphology than the pump maintenance releases from M2G. However, if the pumps are run for a prolonged period (greater than 1 week), this may have additional impact due to saturation of the creek embankment from continued elevated water levels.
Channel Geomorphology	Scouring of the river bed may result in a loss of emergent and submerged macrophyte species. This would result in a reduction of river bed stability and a change in macroinvertebrate diversity and dynamics.	Harrod (1964)	There has been no evidence of scouring directly related to commissioning flows over and above the scouring which has been recorded following natural high flow events (GHD, 2013_a). Ongoing vegetation monitoring is coinciding with seasonal biological sampling.
Riparian vegetation	Changes in the natural flow regime could potentially lead to changes in species composition and dominance of select species leading to a reduction in diversity. An increase in bare ground due to more frequent high flow events could also lead to an increase in weed coverage and diversity, or encroachment of terrestrial species. Increases in flow level could lead result in changes to instream macrophyte cover and diversity.	GHD, 2010	Current flows from the M2G pipeline are restricted to maintenance flows which are short in duration and infrequent. The current M2G flow regime does not pose a threat to fringing riparian vegetation or instream macrophytes due to short duration that the flow level is increased (GHD, 2014).

1.2.5 Part 3 – Murrumbidgee Pump Station (MPS)

The Murrumbidgee Pump Station (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 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 Reach below the dam. This project is referred to as the Murrumbidgee to Cotter (M2C) transfer. The MEMP project does not include monitoring related to the M2C transfer, but rather provides a characterisation of the Murrumbidgee River condition upstream and downstream of the MPS.

The upgraded pump station was commissioned in 2010. Pumping is dependent on demand, licence requirements, and water quality. The framework for this programme responds primarily to requirements of Icon Waters abstraction licence.

The increase in abstraction at the MPS) may place additional stress on the downstream river ecosystem. Originally part of the MEMP MPS was removed following a review by Icon Water after the autumn 2013 reporting period. However, following the Jacobs (2014) review Part 3 has been re-established with sentinel monitoring of the Murrumbidgee River at the key upstream and downstream sites.

1.1 Project Objectives

The Murrumbidgee Ecological Monitoring Programme (MEMP) was set up by Icon Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River at Angle Crossing and the Murrumbidgee Pump Station (Components 1 & 3) and the subsequent changes that might occur in Burra Creek (Component 2).

Increasing water abstractions from the Murrumbidgee River could have several impacts on water quality, riparian vegetation, riverine geomorphology and the aquatic ecology of the system. Some beneficial ecological effects could be expected in the reaches downstream of the discharge point in Burra Creek under the proposed flow release regime, including increased habitat availability for native fish species. The increased flow in those locations is also likely to favour flow-dependent macroinvertebrates and improve surface water quality.

The aim of the sentinel monitoring presented in this report is to compare the ecological conditions of control sites to those of the impacted sites overtime to determine if there is any evidence of change in condition due to discharges into Burra Creek and water abstractions from the Murrumbidgee River.

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 programme, on which this programme is based.

This monitoring programme is designed to be adaptive. This has been demonstrated through the adjustments to the programme following the autumn 2013 reporting period and also the project review completed by Jacobs (2014). The information derived from this programme will also support Icon Waters' adaptive management approach to water abstraction and environmental flow provision in the ACT.

1.2 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 known 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 620 mm at Canberra airport (B.O.M, 2015).

Prior to spring 2010, drought was the most significant impact on catchment quality within the upper Murrumbidgee catchments in recent times. 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 monthly average base flows (Figure 1-3). More recently, during the period between November 2012 and May 2013, there was a decline in base flows in the Murrumbidgee River following a particularly dry summer and autumn. As of 31st May 2015, base flows in the Murrumbidgee River are following an increasing trend following a particularly dry summer in 2014 (Figure 1-3).

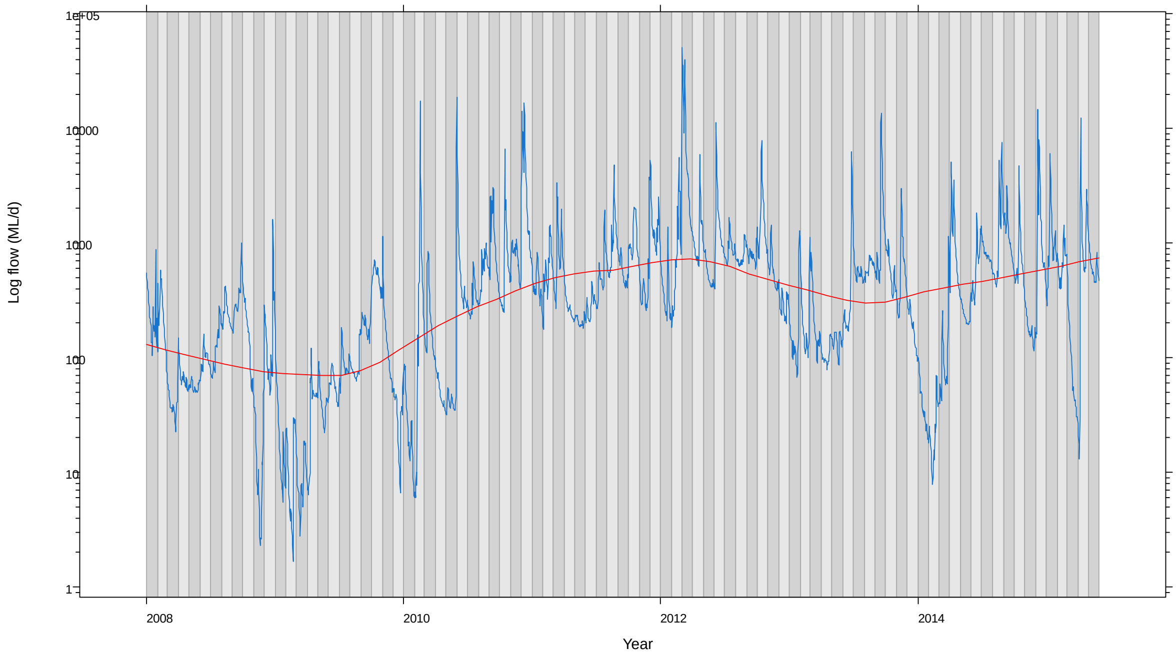


Figure 1-3. Hydrograph of the Murrumbidgee River at Lobb's Hole (410761) from 2008 to May 2015

Note: The red line is a locally weighted smoother (LOESS) trend line with a smoothing coefficient of 0.3.

1.3 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 submergent macrophyte beds with limestone bedrock and frequent pool-riffle sequences throughout its length. During low flow periods the main channel is commonly choked with *Typha orientalis* (also known as cumbungi or bull rush). Burra Creek is within a wider eroded channel in the lower section 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. The mean daily flow in Burra Creek (from January 1st 2009 to the 31st May 2015) was 12.6 ML/d. Since flow records began in 1985 a mean monthly flow of 100 ML/d has been exceeded 8 times, while daily flows in excess of 100 ML/d have only occurred 1.3% of the time.

Flow conditions have varied considerably since the inception of the MEMP in late 2008 (Figure 1-4). 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 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 another period of large rainfall events. These rainfall events resulted in another upward trend in average flows until early spring 2012 (Figure 1-4). Summer in 2014 was the driest since 2010 although autumn rainfall balanced out the smoothing curve resulting in positive trend since September 2013. The overall trend since the beginning of 2014 has been neutral (Figure 1-4). Summer flows in 2015 were considerably higher in Burra Creek compared to summer 2014 where average flows for each period were 5.95 ML/d and 1.22 ML/d respectively. Summer flows are an ecologically important consideration because summer is potentially a particularly stressful period for macroinvertebrates, especially in intermittent streams and these flows have the potential to strongly influence the dynamics and structure of macroinvertebrate communities.

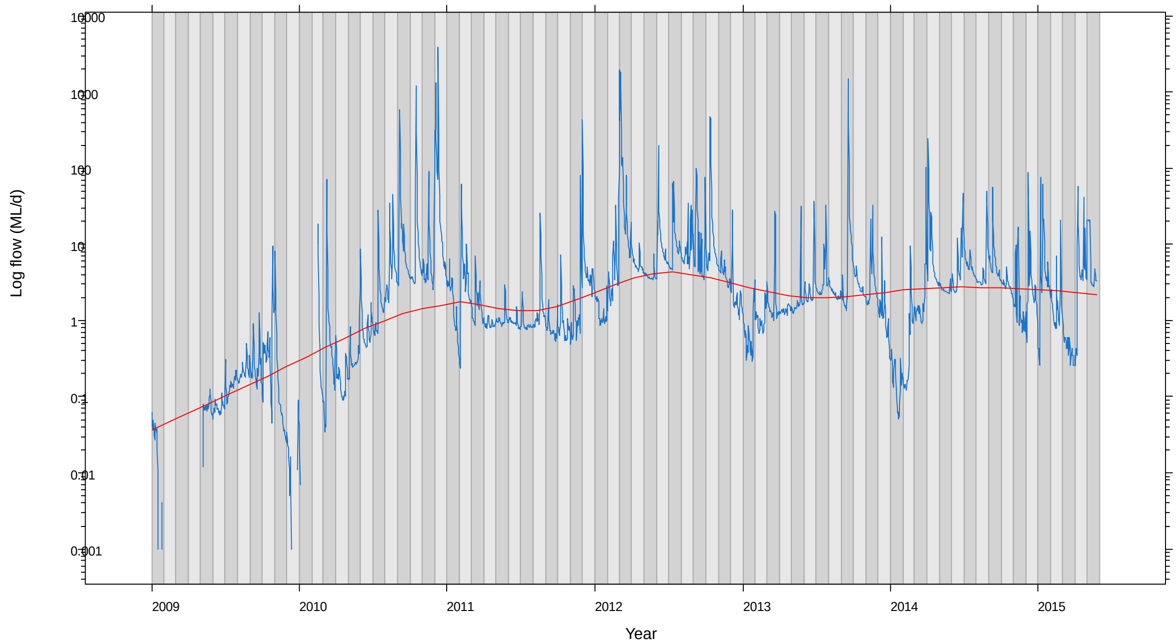


Figure 1-4. Hydrograph of Burra Creek at the Burra Road weir (410774) from 2008 to May 2015

Note: The red line is locally weighted smoother (LOESS) trend line with a smoothing function coefficient of 0.3.

1.4 Scope of work

Part 1 – 3: Angle Crossing, Burra Creek & Murrumbidgee Pump Station

The current ecological health of the sites monitored as part of the MEMP was estimated using AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the autumn 2015 sentinel monitoring. Specifically, 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[3], vegetation and geomorphology at the relevant sites;
- *In-situ* water quality measurements; and
- Water quality grab samples analysed for nutrients in the Australian Laboratory Services (ALS) Canberra NATA accredited laboratory from Burra Creek sites only.

The monitoring elements for each component of the revised monitoring programme are outlined in Table 1-2.

Table 1-2. General suite of monitoring elements and monitoring scenario to which they will be undertaken

Monitoring element	Provider	M2G sentinel	M2G impact	MPS sentinel	MPS impact
Water Quality (online)	Icon Water	✓	✓	✓	✓
Water Quality (grab samples)	Icon Water	✓	✓	✓	✓
Macroinvertebrates	Contractor	✓	✓	✓	✓
Periphyton	Contractor	Not required	✓	Not required	✓
Geomorphology	Contractor	✓	✓	Not required	Not required
Riparian vegetation	Contractor	✓	✓	Not required	Not required
Fish	ACT Government	✓	✓	✓	✓

[2] The reason for the genus resolution stems from the extensive and high quality data set which precedes the adjusted programme. By including genus level identification, the long term integrity of the data record can be maintained.
[3] Not required for sentinel monitoring but it was felt that given the extra effort was negligible in the field, that it would be a useful inclusion to assist in the interpretation of macroinvertebrate data and to continue the data record.

2. Methodology

2.1 Study Sites

One site upstream and one site downstream of the respective infrastructure formed the basis of this sentinel monitoring component of the MEMP. These sites are a subset of existing sites which have previously been sampled as part of the MEMP (2009-2014). These sites were initially chosen based on several criteria, which included:

- Safe access and approval from land owners;
- Sites have 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 programme, 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.

The number of sites to be sampled during sentinel monitoring was specified in the MEMP project review (Jacobs, 2014). The sentinel monitoring component therefore consists of six sites (details of these sites are given in Table 2-1) and are shown in Figure 2-1. Macroinvertebrate and water quality sampling, and photogrammetry for periphyton, vegetation and geomorphology were conducted at the relevant sites on the Murrumbidgee River and Burra Creek. Aquatic macroinvertebrates were sampled from two habitats (riffle and pool edges) and organisms identified to genus level (where practical) to characterise each site in terms of river health and community composition.

Table 2-1. Sampling locations and details

Component of the MEMP		Site Code	Location	Alt. (m)	Landuse	Latitude	Longitude
PART 1	**Angle Crossing**	MUR 18	U/S Angle Crossing	608	Grazing	**-35.587542**	**149.109902**
		MUR 19	D/S Angle Crossing	608	Grazing / Recreation	**-35.583027**	**149.109486**
PART 2	**Burra Creek**	BUR 1c	Upstream Williamsdale Road	762	Grazing / residential	**-35.556511**	**149.221238**
		BUR 2a	Downstream Williamsdale Road	760	Grazing	**-35.554345**	**149.224477**
Part 3	**Murrumbidgee Pump Station**	MUR 28	Upstream Cotter River Confluence	468	Grazing	**-35.324382**	**148.950381**
		MUR 935	Casuarina Sands	471	Grazing	**-35.319483**	**184.951667**

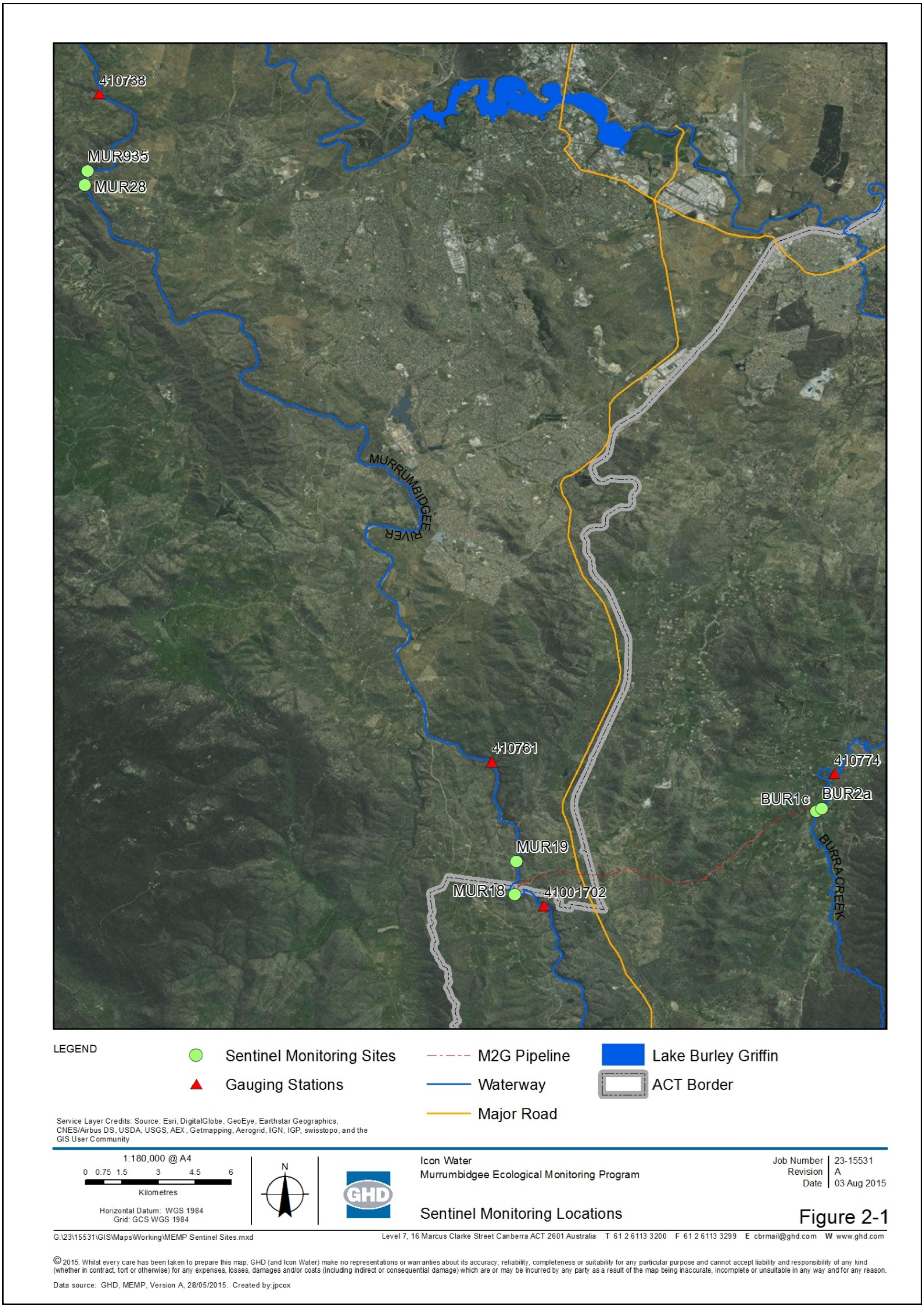


Figure 2-1. Map of site locations on the Murrumbidgee River and Burra Creek for the current sentinel monitoring

2.2 Hydrology and Rainfall

River flows and rainfall for the sampling period were recorded at ALS operated gauging stations located: upstream of Angle Crossing (41000270); at Lobb's Hole (downstream of Angle Crossing: 410761); Mt. MacDonald (downstream of the MPS; 410738) and Burra Creek (upstream of BUR 2b: 410774). A list of parameters measured at each station is given in Table 2-2. 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.

Table 2-2. 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
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 / Murrumbidgee Pump Station
410738	Murrumbidgee River @ Mt. MacDonald	WL, Q	-35.2916	148.9552	Murrumbidgee Pump Station
410774	Burra Creek D/S road bridge	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5425	149.2279	Burra Creek

** 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.*

2.3 Water Quality

Water temperature, turbidity, dissolved oxygen (DO), electrical conductivity (EC) and pH was measured *in situ* using a laboratory calibrated YSI 556 multi-parameter water quality meter as a part of the ACT AUSRIVAS field sheets.

Grab samples were collected at all sites in accordance with AUSRIVAS protocols (Nichols, *et al.* 2000), with Burra Creek samples submitted to ALS for analysis. The Murrumbidgee River samples have been frozen for potential future analysis if requested by Icon Water. Burra Creek grab samples were analysed for alkalinity, TDS, TKN, total NO_x, TP, TN, total iron and total manganese. Total Alkalinity was measured *in-situ* using CHEMetrics Titrets® (REF: K-9810) at Murrumbidgee River sites in conjunction with the macroinvertebrate sampling as this parameter is a key predictor variable in the ACT riffle AUSRIVAS models.

2.3.1 Data analysis

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000). Summary statistics were determined for the parameters collected at the gauging stations and time series plots were created to assist with the interpretation.

2.4 Macroinvertebrate monitoring

Rapid bioassessment (RBA) methods (i.e. AUSRIVAS) will occupy the main component of the sentinel monitoring programme. The Australian Rivers Assessment System (AUSRIVAS) is a rapid, standard method for assessing the ecological health of freshwaters through biological monitoring and habitat assessment (Nichols *et al*., 2000). This assessment will provide an overview of the system that will indicate on a broad scale whether there are notable changes based on the ratio of the number of observed to expected taxa which are recorded at each site. The observed / expected ratio is an indication of the current ecological condition at a given site. These data will be used for comparison with data collected during operational periods (i.e. during impact monitoring) in the Murrumbidgee River and Burra Creek, so relative seasonal and annual changes over time can be monitored against any potential changes directly resulting from the Icon Water projects.

At each site, macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site (Nichols *et al*., 2000) and potentially allow the programme 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.

Riffle and edge habitats were sampled for macroinvertebrates using the ACT AUSRIVAS protocols outlined in Nichols *et al*. (2000). The sampling nets and all other associated equipment were washed thoroughly between habitats, sites and sampling events to remove any macroinvertebrates retained on them. A single sample was collected from each of the two habitats (edge and riffle - where available) at all sites in autumn. The bulk 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. The ACT AUSRIVAS field sheets were also completed at each site.

Processing of the aquatic macroinvertebrate bulk samples followed the ACT AUSRIVAS protocols (Nichols *et al*., 2000). In the laboratory, each preserved macroinvertebrate sample was placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was then agitated to evenly distribute the sample, and the contents of randomly selected cells were removed and examined under a dissecting microscope until a minimum of 200 animals were counted. All animals within the selected cells were identified.

In order to preserve the long term integrity of the data record within the experimental design, laboratory processing of each sample was repeated 3 times to align with the data collected between 2009-2014 which will allow these data and the existing data to be amalgamated with limited disruption to the project methodology.

For similar reasons, 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. The Jacobs (2014) review recommended the use of the lower resolution family level identification. However, to enable comparison with previous sample seasons where genus level data was utilised, Icon Water has continued the use of this method, based on recommendations from GHD.

2.4.1 Data analysis

The broader, less intensive nature of the sentinel monitoring component (Jacobs, 2014) means that all formal hypothesis testing, which was a significant feature of the previous manifestation of the MEMP is either not required or has limited power due to the low sample sizes. In light of this, the statistical component of this report is presented in the form of descriptive methods including univariate indices and metrics, which are outlined below.

Univariate Analysis

The univariate techniques performed on the macroinvertebrate data include:

- Taxa Richness and EPT taxa index (richness);
- SIGNAL-2 Biotic Index;
- ACT AUSRIVAS O/E scores and Bandings.

These metrics are often used in a lines-of-evidence approach to river assessments and have solid foundations in biomonitoring. Each index is used to assess slightly different aspects of river health. SIGNAL -2 for example usually relates to changes in water quality while AUSRIVAS is mainly an indicator of habitat changes. Total richness is an indicator of changes in composition and needs to be assessed carefully because it does not indicate where in the community changes such as increases or losses of sensitive taxa occur. EPT is used to do just this, which is why it is used together with Taxa Richness since both provide complimentary information.

Taxa Richness

The number of taxa (taxa richness) was counted for each site and richness of pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera - EPT) were examined at family and genus levels. Taxa richness was calculated as a means of assessing macroinvertebrate diversity. In assessing the taxonomic richness of a site, it is important to keep in mind that high taxa richness scores may, though not always, indicate better ecological condition at a given location. In certain instances high taxa richness may indicate a response to the provision of new habitat or food resources that might not naturally occur as a result of anthropogenic activities.

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 higher values indicating higher community sensitivity. These grades have been improved 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

In addition to assessing the composition and calculating biometrics based on the macroinvertebrate data, river health assessments based on the ACT AUSRIVAS autumn riffle and edge models were conducted. AUSRIVAS is a prediction system that uses macroinvertebrate communities to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics which cannot be influenced by human activities, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived (O/E) is used to indicate the extent of any impact. The ratio derived from this analysis is compiled into Bandwidths (i.e. X, A-D; Table 2-3) which are used to gauge the overall health of that particular site (Coysh *et al*., 2000). Data are presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating Bands (Table 2-3).

The site assessments are based on the results from both the riffle and edge samples. Using a precautionary approach, the overall site condition was based on the farthest Band from reference in a particular habitat at a particular site. For example, a site that had an A assessment in the edge and a B Band in the riffle would be given an overall site assessment of B (Coysh *et al*., 2000). In cases where the Bands deviate significantly between habitat (e.g. D – A) then an overall site-level assessment was avoided due to the unreliability of the results.

The use of the O/E 50 scores is standard in AUSRIVAS. However it should be noted that this restricts the inclusion of rare taxa and influences the sensitivity of the model. Taxa that are not predicted to occur more than 50% of the time are not included in the O/E scores produced by the model. This could potentially limit the inclusion of rare and sensitive taxa and might also reduce the ability of the model to detect any changes in macroinvertebrate community composition over time (Cao, *et al*., 2001).

Table 2-3. AUSRIVAS Band widths and interpretations for the ACT autumn riffle and edge habitats

Band	RIFFLE	EDGE	Explanation
	O/E Band width	O/E Band width	
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.

2.4.2 Quality control

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

- Organisms that were heavily damaged were not selected during sorting. To overcome losses associated with damage to intact organisms during sample handling attempts were made to obtain significantly more than 200 organisms;
- 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 and these QA/QC results are found in Appendix A;
- Very small, immature, damaged animals or pupae that could not be positively identified were not included in the dataset.

All procedures were performed by AUSRIVAS accredited staff.

2.5 Photogrammetry (Periphyton, Geomorphology and Vegetation)

Photogrammetry is introduced in this component of the MEMP as a means to monitor potential changes in response to the full pumping operation of M2G and MPS over and above those occurring naturally. This method will be used to monitor periphyton, vegetation and geomorphology at the relevant sites as listed in Table 2-4.

Photogrammetry is a cheap and robust alternative to quantitative techniques (O'Connor and Bond, 2007). Using this method, photo points are 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. Photo points have been established at all of the existing MEMP sites.

The resulting photographs provide a robust and valuable resource to help understand the temporal dynamics of the system; and provide a good visual reference of habitat in relation to the qualitative macroinvertebrates results as a measure of river health.

Table 2-4. Locations of photogrammetry for each assessment type and number of photo points

Site	Periphyton	Vegetation	Geomorphology
Burra Creek			
BUR 1c	✓		1 Photo Point
BUR 2a	✓		4 Photo Points
BUR 1a			3 Photo Points
BUR 2		4 Photo Points	4 Photo Points
BUR 2c		4 Photo Points	4 Photo Points
D/S Pool 29		3 Photo Points	3 Photo Points
D/S Pool 51		No Access	No Access
Murrumbidgee River			
MUR 18	✓		
MUR 19	✓		5 Photo Points
MUR 28	✓		
MUR 935	✓		

2.5.1 Periphyton

Representative photographs were taken at each site of the substrate using a 1m x 1m quadrat for scale at relevant sites (Table 2-4). Four photos were taken at each site. These photographs were considered to be representative of the habitat and site. Quantitative assessments of the proportion of cover were recorded using the ACT AUSRIVAS field sheet methodology (Nichols, *et al.*, 2000).

2.5.2 Vegetation

Photographs were taken at 3 or 4 (site dependent) existing photo points to record the current extent of riparian and instream vegetation at relevant sites (Table 2-4). 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. Sites will be revisited in 2 years' time, when both photographs will be taken and field notes recorded.

2.5.3 Geomorphology

Photographs were taken at each of the geomorphology sites (Table 2-4) with 1 to 5 photo points used at each site. Geomorphological features of interest have already been established (GHD, 2015c) and 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.

2.6 Licences and permits

All sampling was carried out with current scientific research permits under section 37 of the Fisheries Management Act 1994 (permit number P01/0081(C)).

All GHD aquatic ecology field staff hold current ACT and NSW AUSRIVAS accreditation.

3. Angle Crossing

3.1 Summary of sampling and river conditions

Sampling of Angle Crossing sites was conducted on the 19th May 2015. Weather on the day was overcast with showers and a maximum temperature reaching just over 14°C as recorded at Canberra Airport (BoM, 2015). The flow in the Murrumbidgee River during sampling was stable with the mean daily flow on the day being 460 ML/d at the Lobb's Hole gauging station (410761). One sample was collected from both the riffle and edge habitats and site photographs are presented in Plate 3-1. Submerged macrophyte cover was high with large stands of *Myriophyllum* spp. at both MUR 18 and MUR 19. There were some patches of filamentous green algae present at MUR 19, while the substrate of the riffle habitats at both sites showed high levels of sand. Full site summaries are presented in Appendix B. Habitat data is available in Appendix C.


MUR 18: Looking upstream (left) and downstream (right)


MUR 19: Looking upstream (left) and downstream (right)

Plate 3-1. Photographs of the Angle Crossing sites during autumn 2015 sampling

3.2 Hydrology and Rainfall

Over the previous 5 years, rainfall has been higher during March than the following months of April and May (Figure 3-1). However, during autumn 2015, rainfall during April was recorded at approximately 130 mm (Table 3-2), considerably higher than rainfall during both March and May. This is similar to 2009 where rainfall was much higher during April than the other autumn months. Full rainfall and flow summaries for upstream and downstream of Angle Crossing for autumn 2015 are presented in Table 3-2.

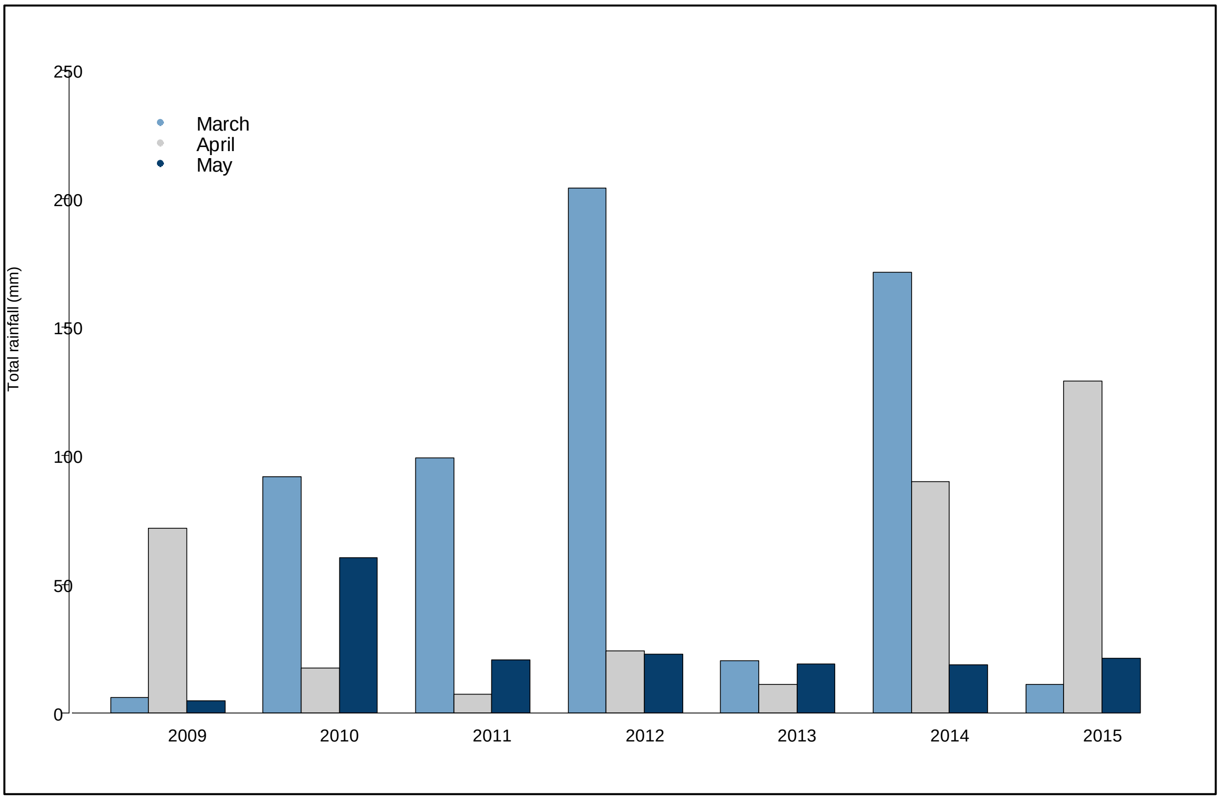


Figure 3-1. Annual comparison of autumn rainfall (mm) recorded at Lobb's Hole (570985)

Table 3-1. Autumn rainfall and flow summaries upstream and downstream of Angle Crossing

	Upstream Angle Crossing (41001702)		Lobb's Hole (410761)	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
March	7.6	230	11.13	261
April	135.8	1,600	128.95	1,669
May	20.8	510	21.37	622
Autumn (mean)	164.2 (54.7)	800	161.45 (53.82)	850

This high rainfall during April lead to a high flow event during mid-April which peaked at over 16,000 ML/d on the 9th April 2015 at the Lobb's Hole gauging station (410761; Figure 3-2). This was the largest high flow event to occur in autumn since the high flow event during March 2012. Following the recession of the high flow event during mid-April, there was a second small event which peaked at over 3,500 ML/d on the 26th April 2015. Following this second event of the season, the flow in the Murrumbidgee River stabilised at approximately 500 ML/d for about two weeks, during which sampling was conducted (Figure 3-2). The abstraction for the M2G APPLE runs is not visible in Figure 3-2 due to the scale of the plot.

Prior to the high flow event in mid-April flows at Lobb's Hole were the second lowest to have been recorded in the previous 2 years, with mean daily flow reaching 13 ML/d during the first week of April (Figure 3-3). Flows during March were lower than those recorded during April 2014, however, flows in both April and May ware considerably higher than those recorded the previous year (GHD, 2014a).

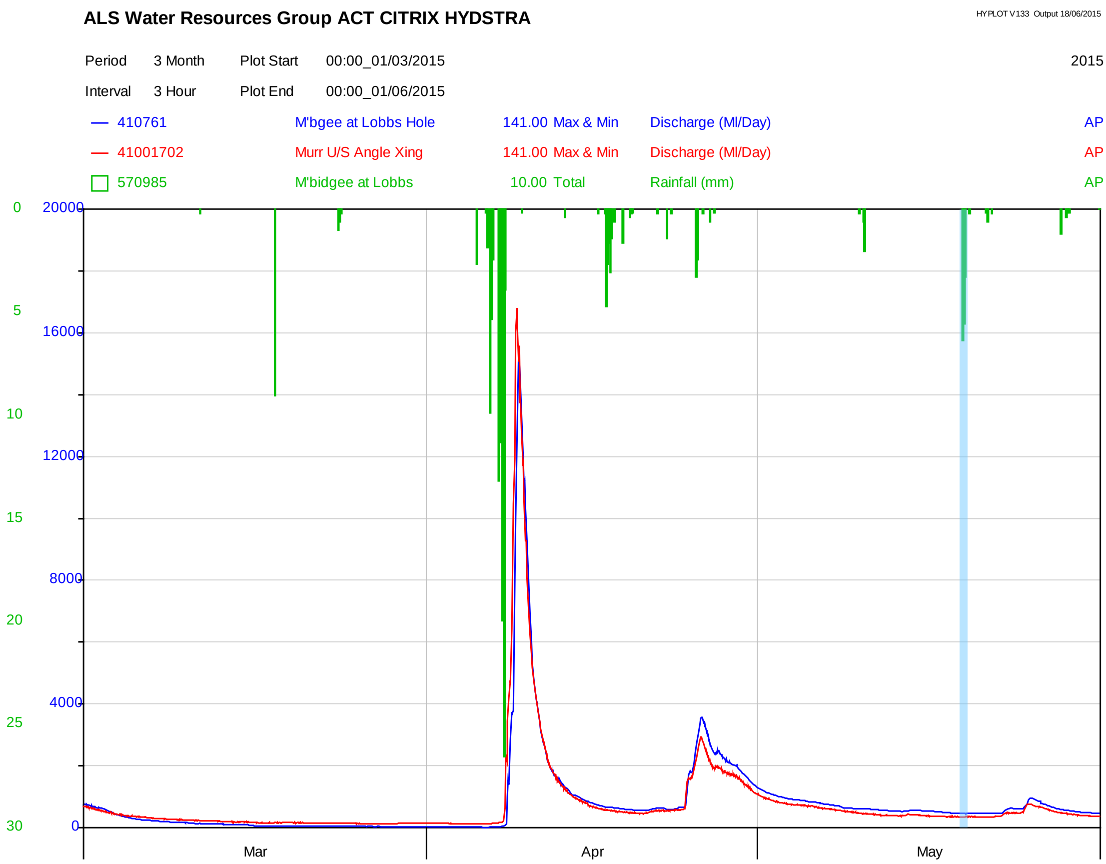


Figure 3-2. Autumn 2015 hydrograph of the Murrumbidgee River upstream (41001702) and downstream (410761) of Angle Crossing

Note: Sampling time highlighted by blue shading.

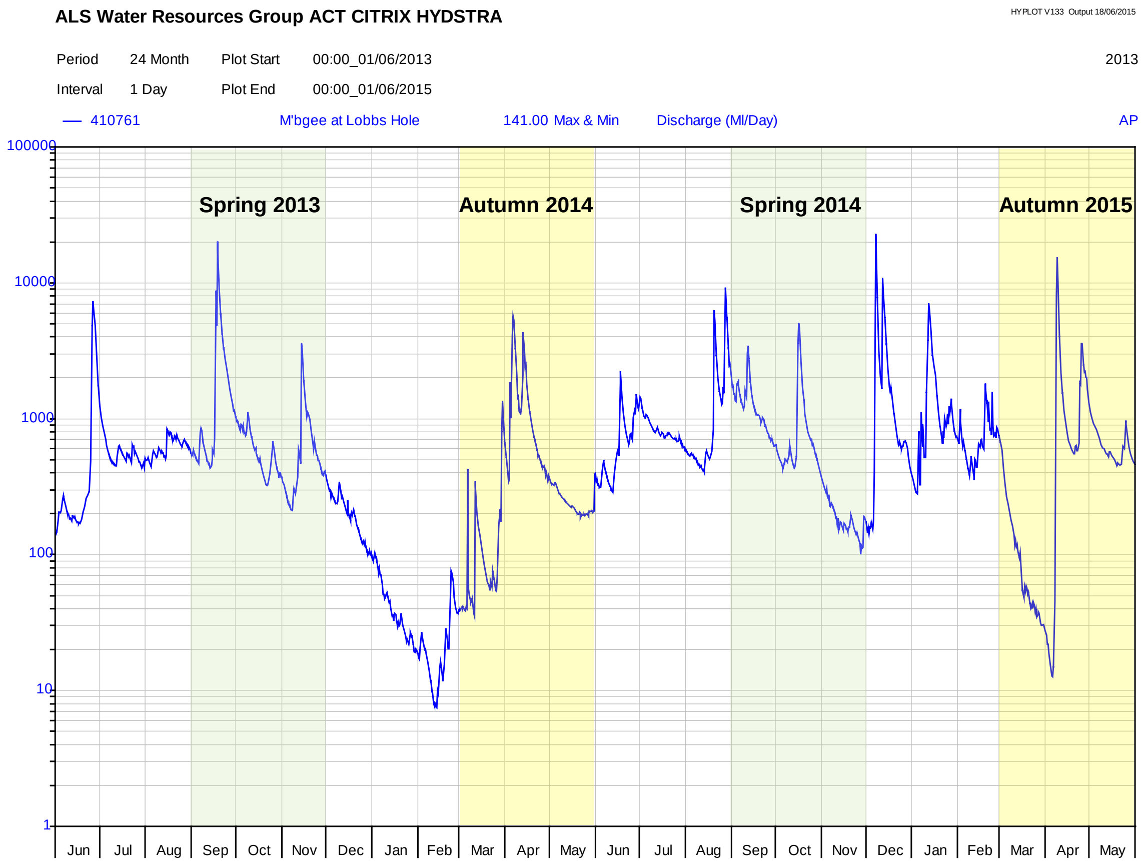


Figure 3-3. Hydrograph from Lobb's Hole highlighting the past four sampling periods between September 2013 and May 2015

3.3 Water Quality

3.3.1 Grab samples and *in-situ* parameters

In-situ parameters which were recorded at the time of sampling are presented in Table 3-2. Parameters which were within the ANZECC & ARMCANZ (2000) guideline ranges at both upstream and downstream sites were electrical conductivity (EC), turbidity and dissolved oxygen (DO) percent saturation. However, pH was elevated above the upper limit at both sites with the upstream site (MUR 18) recording a higher value than the downstream site (MUR 19) by 0.1 pH units (Table 3-2). Both of these sites were recorded within the pH recommended range during autumn 2014. Additional water quality grab samples were collected by ALS during the autumn period with the results of these presented in Appendix D.

Table 3-2. *In-situ* water quality results from Angle Crossing during autumn 2015

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)
Upstream	MUR 18	19/5/2015	9:00	9.2	170.9	8.0	8.14	100.2	10.85	42
Downstream	MUR 19	19/5/2015	10:45	9.4	174.2	7.0	8.04	101.4	10.71	44

Note: ANZECC and ARMCANZ (2000) guidelines are in yellow parentheses, yellow cells indicate values outside of the guidelines.

3.3.2 Continuous water quality monitoring

The continuous water quality records from both Lobb's Hole (410761) and upstream Angle Crossing (410738) are presented in Figure 3-4 and Figure 3-5 respectively. There were no data recorded between 29th December 2014 and 7th April 2015 at Lobb's Hole (410761) due to a lightning strike damaging the probe. The sensor was not able to be replaced earlier due to inaccessibility to the sensor from high flows. The data recorded at upstream Angle Crossing, with the exception of temperature, appears erroneous and has not been archived at this point in time (Figure 3-5). This data will not be interpreted as part of this report because it is not representative of the water quality over this period. This site is currently in the process of being relocated downstream of its current position and the issues illustrated here add to the reasoning (which includes the issues with siltation around the water quality probe) behind the sites relocation.

Following the sensor repairs all parameters responded to the April high flow event with large changes to all parameters excluding dissolved oxygen (DO). These parameters behaved as would be expected during the period of high flows and returned to normal ranges after the flow had receded (Figure 3-4).

Electrical conductivity remained within the ANZECC & ARMCANZ (2000) recommended range for the entire period. The pH values were predominantly elevated above the upper limit of the guideline between approximately 8.0 and 8.3, with the exception of the periods of high flow which reduced the pH to within the recommended range. Turbidity readings remained within the guideline levels, excluding the two spikes recorded during the periods of increased flow. There was a predictable pattern in DO that underwent diurnal variation due to natural changes to photosynthesis rates. The lowest DO recordings usually occurred during the night-time and it was during these times, that concentrations occasionally dropped below the lower guideline limit (Figure 3-4).

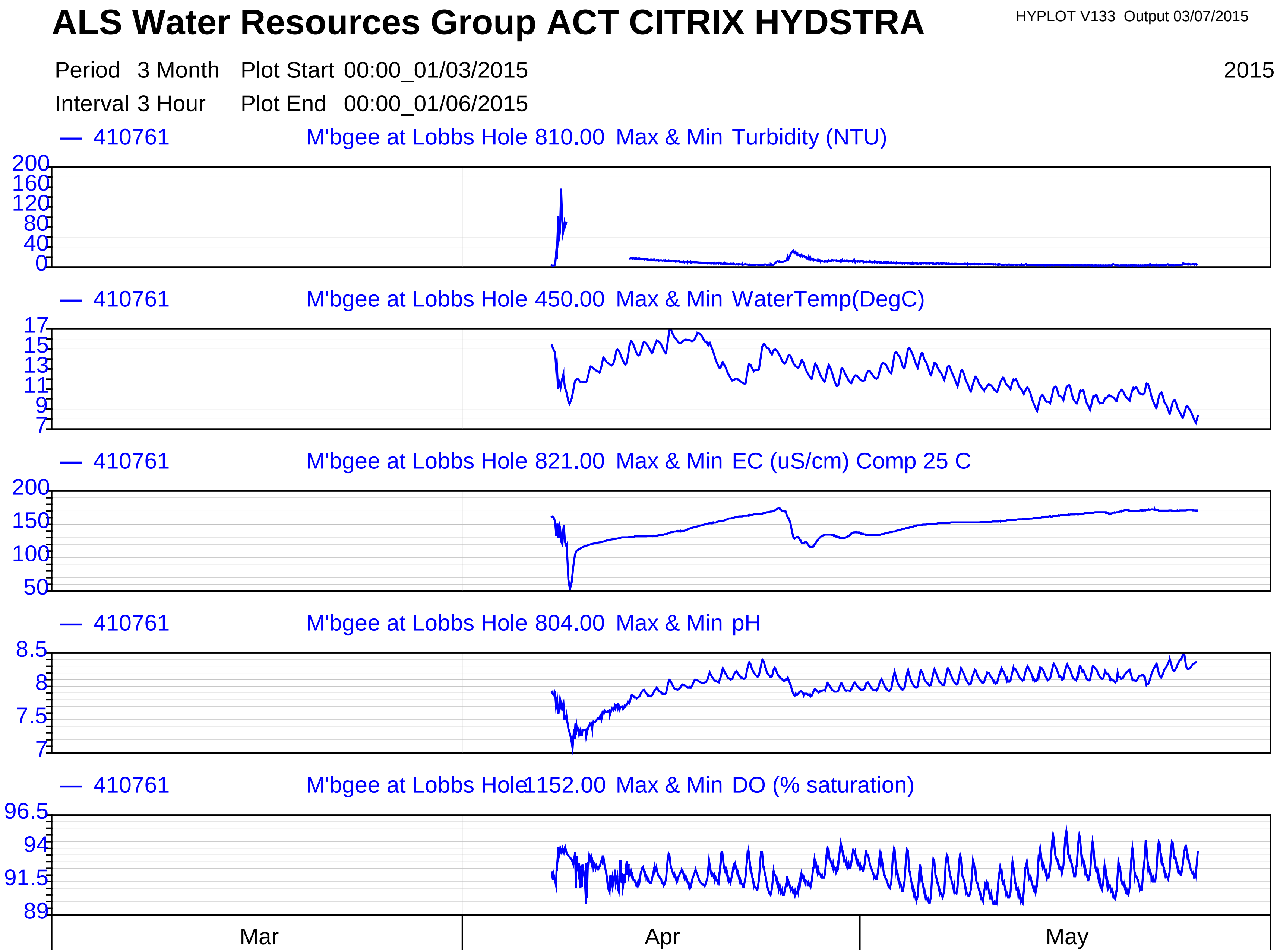


Figure 3-4. Continuous water quality records from Lobb's Hole (410761) for autumn 2015

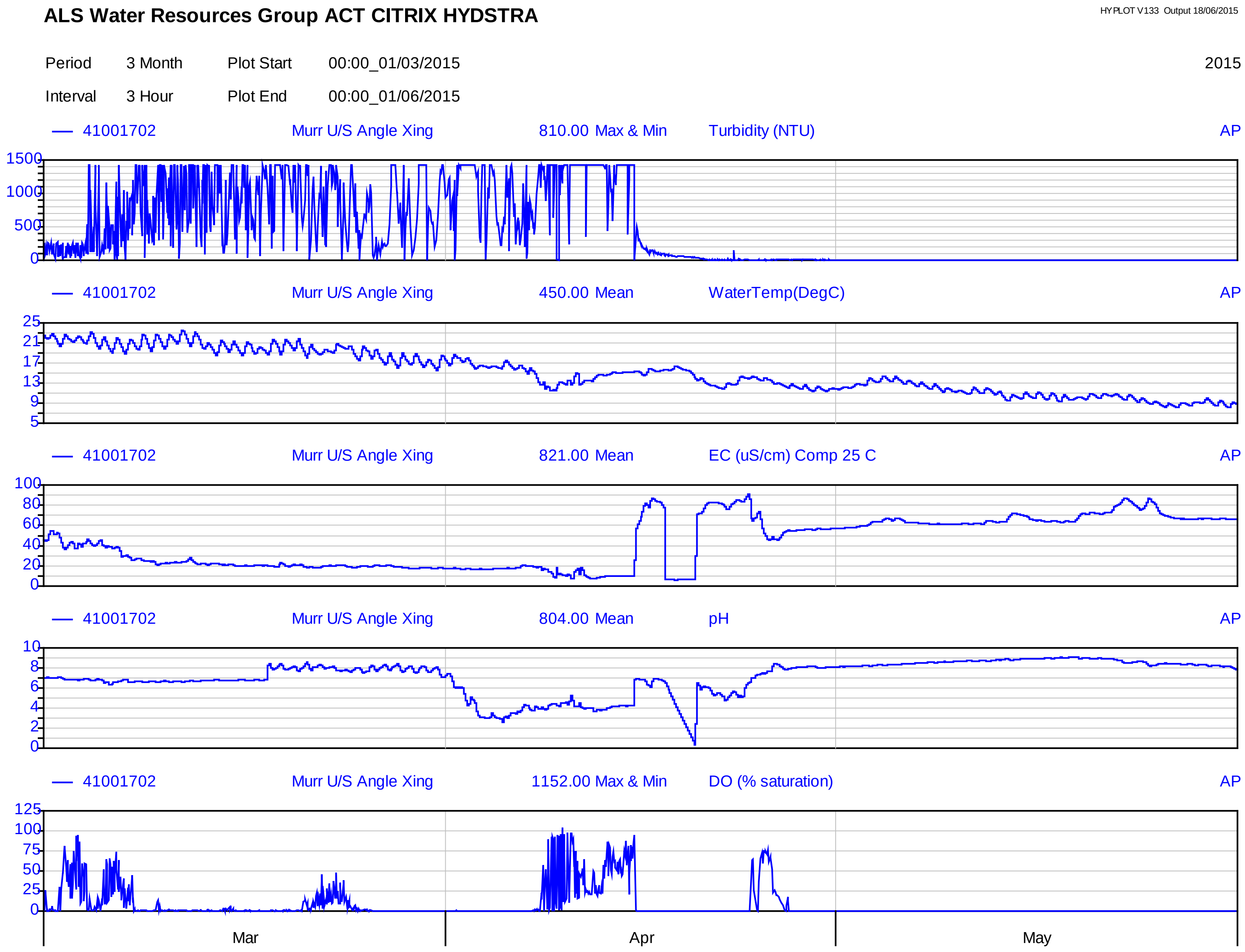


Figure 3-5. Continuous water quality records from upstream Angle Crossing (41001702) for autumn 2015

3.4 Photogrammetry

3.4.1 Periphyton

The periphyton coverage at MUR 18 was approximately 35-56% for the reach and 65-90% for the riffle habitat using the AUSRIVAS assessment (Plate 3-2). There were large stands of the submerged macrophyte *Myriophyllum sp.* growing throughout the reach. The dominant substrate was cobble and sand in the riffle habitat. Plate 3-3 shows the periphyton coverage on the cobbles and epiphytic growth on *Myriophyllum* spp.

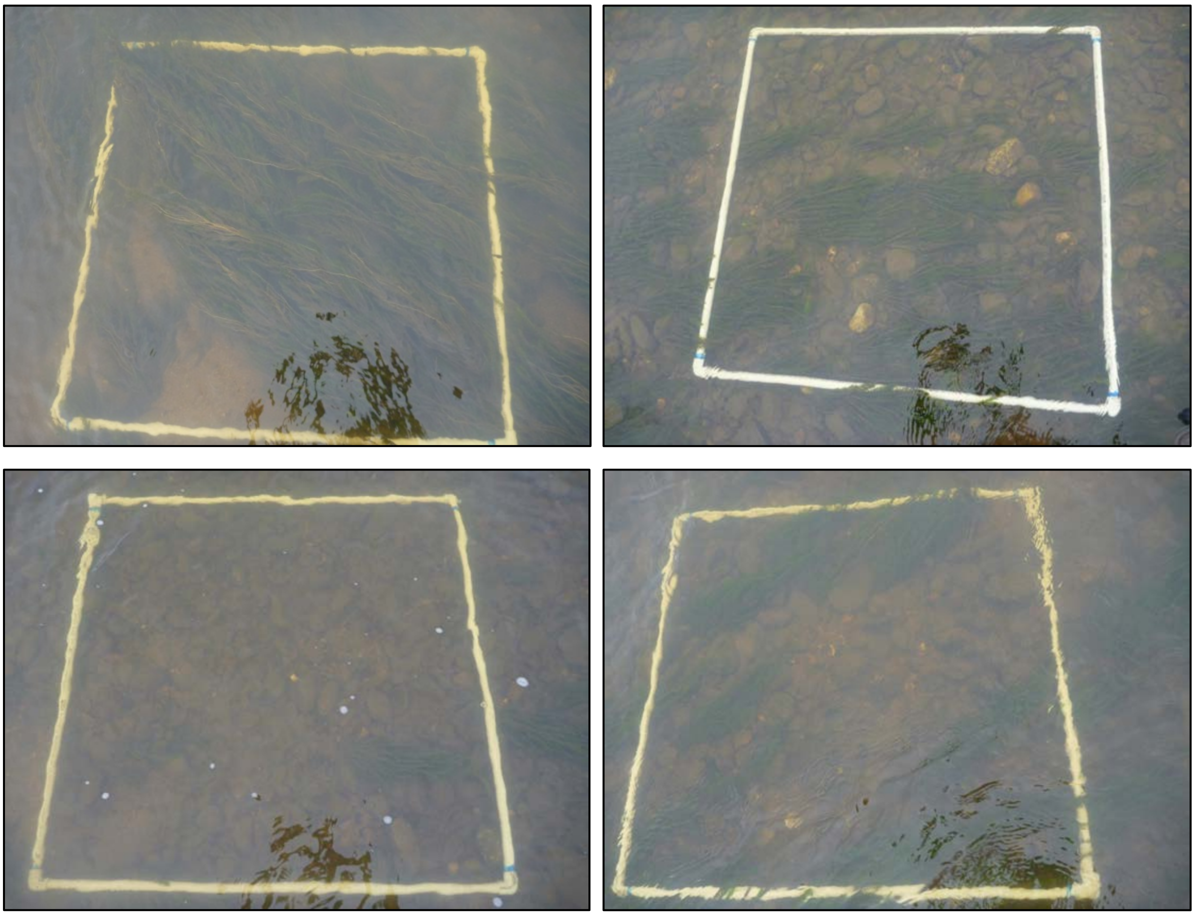


Plate 3-2. Quadrats showing the periphyton coverage at the tail of the riffle habitat at MUR 18

Note: Quadrat area is 1 m^2.

Plate 3-3. Underwater photos at MUR 18 showing periphyton coverage in the riffle habitat

MUR 19

The periphyton coverage was approximately 35-65% for the reach and 65-90% for the riffle habitat using the AUSRIVAS assessment (Plate 3-4). The submerged macrophyte *Myriophyllum* spp. was dominant throughout the riffle habitat, while the dominant substrate was cobble. The extent of the periphyton coverage is shown in the underwater photos in Plate 3-5.

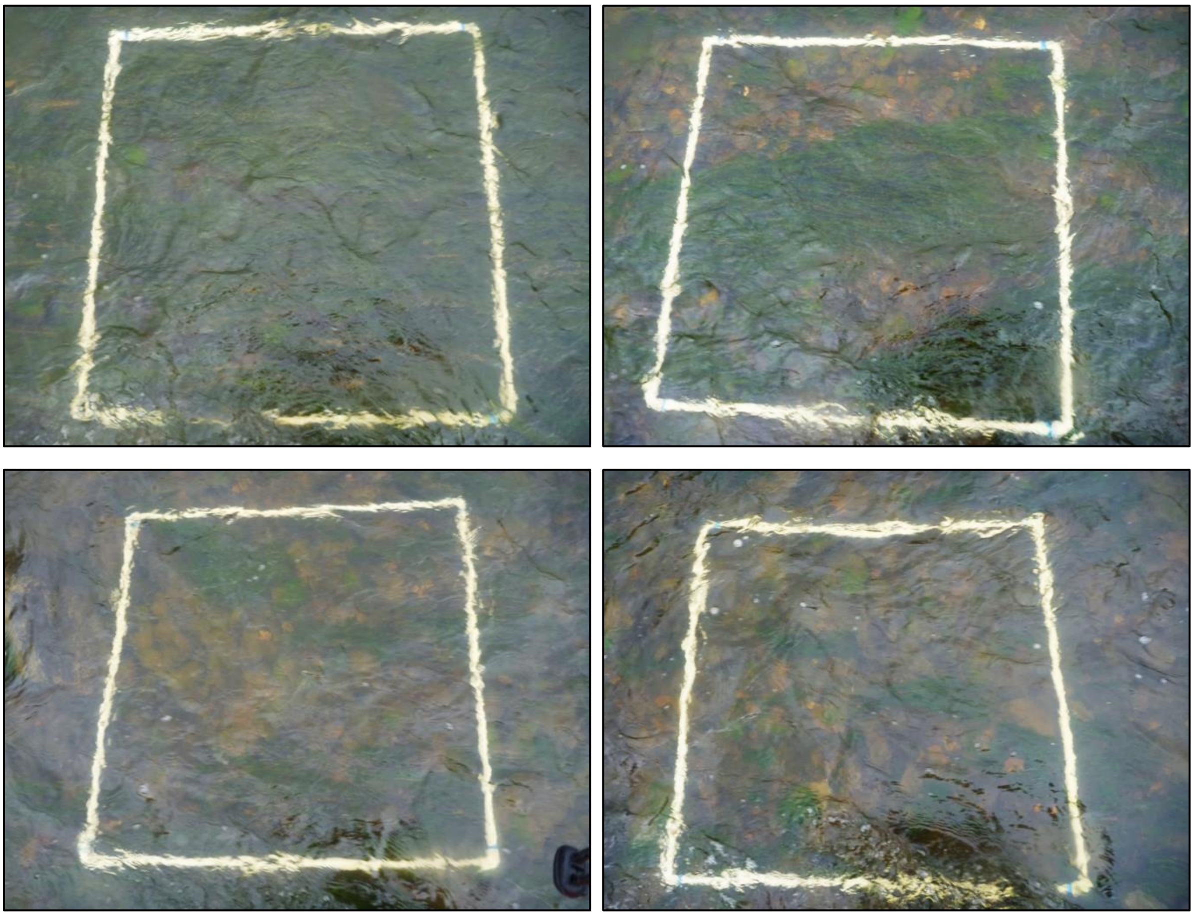


Plate 3-4. Quadrats showing the periphyton and macrophyte coverage at the tail of the riffle MUR 19

Note: Quadrat area is 1 m^2.

Plate 3-5. Underwater photos at MUR 19 showing periphyton coverage

3.4.2 Geomorphology

Angle Crossing

The most significant geomorphological feature at the M2G intake structure is the large dynamic pool directly adjacent to the structure itself. This pool fluctuates in depth and is highly influenced by changes in flow with deposition and sediment removal with scouring occurring during high flow events and deposition occurring at various stages of the hydrograph which continuously changes the structure of the pool and presence of bars (GHD, 2015c). Photo points 1 and 2 cover this area (Plate 3-6 and Plate 3-7 respectively). Potential deposition of sand deposits in the area immediately downstream of Angle Crossing is monitored through photo point 2 and 3 (Plate 3-7 and Plate 3-8 respectively).

Change in the channel downstream of Angle Crossing has been previously identified, with removal of bars and deepening of the central channel (GHD, 2015). This reach downstream of Angle Crossing could potentially see increased sediment deposits and increased bar formation as a result of the abstraction decreasing flows. This section of river is monitored through photo point 4 and 5 (Plate 3-9 and Plate 3-10 respectively).

a)

b)

c)

Plate 3-6. Geomorphology photo point 1 at Angle Crossing showing upstream (a), downstream (b) and across the channel (c)


a)


b)


c)

Plate 3-7. Geomorphology photo point 2 at Angle Crossing showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 3-8. Geomorphology photo point 3 at Angle Crossing showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 3-9. Geomorphology photo point 4 at Angle Crossing showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 3-10. Geomorphology photo point 5 at Angle Crossing showing upstream (a), downstream (b) and across the channel (c)

3.5 Macroinvertebrates

The number of taxa which were collected from the upstream and downstream Angle Crossing sites was lower than the numbers collected in autumn 2014 (historical macroinvertebrate indices are presented in Appendix E), which was again lower than autumn 2013. This is the case for both family and genus level data, showing richness has been consistently decreasing over the previous two years (Appendix E). Both upstream and downstream sites showed the same number of taxa present in the riffle habitat, while MUR 18 had 3 more families and 5 more genera collected in the edge habitat compared to the downstream site, MUR 19 (Table 3-3).

Comparatively, the number of EPT taxa which were recorded during autumn 2015 at Angle Crossing sites was either the same as recorded in autumn 2014 or higher (Table 3-4). 16 EPT genera were recorded in the edge habitat at MUR 18, which is higher than the number of genera recorded at any Angle Crossing site during autumn 2014 (GHD, 2014a). Probably important to state that there were more EPT US compared to DS (albeit only slightly).

Table 3-3. Number of taxa at family and genus level from riffle and edge habitats

Total Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
MUR 18	13	16	19	27
MUR 19	13	16	16	22

Table 3-4. Number of EPT taxa at family and genus level from riffle and edge habitats

EPT Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
MUR 18	7	10	8	16
MUR 19	6	9	8	14

3.5.1 AUSRIVAS & SIGNAL-2

SIGNAL-2 scores in the riffle habitat were comparable between the upstream and downstream sites with MUR 18 recording an average SIGNAL-2 of 4.76, compared to 4.80 at MUR 19 (Table 3-5). For the edge habitat there was a more notable difference between the average SIGNAL-2 scores, with 4.60 recorded at MUR 18 and 4.13 recorded at MUR 19 (Table 3-5). This difference is due to the absence of Leptophlebiidae (SIGNAL-2 = 8) from all MUR 19 replicates and Leptoceridae from 2 of the MUR 19 replicates, while both taxa were present in all MUR 18 replicates (taxa predicted/collected can be found in Appendix F).

The AUSRIVAS results showed consistency across the edge habitats with all replicates from both sites recording a result of Band B, indicating that the sites both upstream and downstream of the intake structure and Angle Crossing are “significantly impaired” (Table 3-5). While the riffle habitat from MUR 19 was assessed overall as Band B, recording two Band B replicates and a single Band A replicate (Table 3-5). The riffle habitat at MUR 18, showed high variation amongst the three replicates with one replicate assessed as Band A, B & C respectively. As a result in accordance with the AUSRIVAS (Coysh et al., 2000) protocols this habitat was assessed overall as having “no reliable assessment” (Table 3-5).The difference between replicate 3 from MUR 18 being a Band B versus a Band C is the absence of Oligochaeta (SIGNAL-2 = 2), which was present in every other replicate from the autumn 2015 and this should be taken into consideration when interpreting these results.

The overall site assessments were classified as Band B, which is consistent with the results from this site for the previous three autumn periods (Table 3-6). The predicted/collected results from the AUSRIVAS model are presented in Appendix F, while a full taxonomic inventory can be found in Appendix G.

Table 3-5. AUSRIVAS and SIGNAL-2 scores for autumn 2015

Site	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
MUR 18	**1**	4.86	4.60	0.78	0.78	B	B	**NRA**	**B**	**B**
	2	4.63	4.60	0.89	0.78	A	B			
	3	4.80	NS	0.56	NS	C	NS			
MUR 19	**1**	4.88	4.38	0.89	0.62	A	B	**B**	**B**	**B**
	2	4.67	4.00	0.67	0.70	B	B			
	3	4.86	4.00	0.78	0.62	B	B			

Note: NS = No sample; NRA = No reliable assessment; all Angle Crossing riffle samples are “nearly outside the experience of the model” (see Coysh et al. (2000) for details)

Table 3-6. Overall site assessments for autumn and spring since 2012

	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Spring 2014	Autumn 2015	Change since autumn 2014
MUR 18	**B**	**B**	**B**	**B**	**B**	**B**	**B**	↔
MUR 19	**B**	**B**	**B**	**B**	**B**	**A**	**B**	↔

3.6 Discussion

3.6.1 Water quality

The results from the Angle Crossing water quality show that the upstream and downstream sites were very similar. There were very few breaches of the ANZECC & ARMCANZ (2000) guidelines throughout the autumn season. The upper limit of the pH recommended range was exceeded at both sites, which was the only exceedance recorded from the *in-situ* probe results. Outside the high flow events at the Lobb's Hole (410761) continuous monitoring station, pH was elevated above the guideline levels for the duration of the recorded period. The elevation of pH through this reach of the Murrumbidgee River is not uncommon during period of low flow. Turbidity was only recorded in exceedance of the guidelines as a result of the high flow events which is to be expected.

3.6.2 Photogrammetry

Periphyton

Periphyton has been included in the monitoring programme for Angle Crossing sites as a means of assessing the influence of flow upon the algal communities downstream of the abstraction point. 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 through abstraction. While not required for the sentinel monitoring component, the inclusion of these images will increase the baseline information for the impact monitoring which will occur if the pumping conditions are satisfied.

The photos of the substrate presented in section 3.4.1 using both the quadrat and underwater aspects, provides a good overview of the periphyton coverage at both upstream and downstream sites. The coverage of periphyton during autumn 2015 was consistent between the upstream and downstream sites with reach scale assessments both recorded as having coverage of 35-65%, while the riffle habitats were assessed as having a coverage of 65-90%.

These photographic assessments indicate an decrease in coverage compared to autumn 2014 at MUR 19 which was assessed at 65-90% coverage at the reach scale and >90% for the riffle habitat coverage. This change is most likely due to the change in flow levels between the two seasons with autumn 2014 experiencing lower flows compared to autumn 2015. The impacts of flow on periphyton have been well documented with Biggs & Stokseth (1996) showing that periphyton communities which were exposed to lower flow velocities produced higher biomass.

Geomorphology

The geomorphology at Angle Crossing has shown over previous years that it is a very dynamic section of river which has shown periods of large deposition and both erosion and scour of pools and bars (GHD, 2014b; GHD, 2015c). The downstream photo points (4 & 5) indicate that there has been some recent sand deposition along the channel margins through this reach, particularly on the left bank. This follows the findings in the MEMP Geomorphology report (GHD, 2015c) which indicated that the centre of the channel was being scoured out, particularly during periods of higher flows with deposition along channel margins.

These processes are currently being driven by natural flow variation with the use of the M2G pipeline not occurring to date for operational purposes. There is potential, should operational pumping commence, for increased deposition throughout this downstream reach resulting from decreased velocities associated with the Angle Crossing abstraction. These photo points will track the movement of sediment through this reach to compare to future changes should M2G pumping become operational above the trigger level requiring impact assessment.

3.6.3 Macroinvertebrate communities and river health assessment

There has been a high degree of consistency in the assessments of ecological condition at MUR18 and MUR19 for the project history. AUSRIVAS has determined the overall site condition to be Band B, “significantly impaired” on all except one occasion in spring 2014. This shows that prior to the M2G commissioning these sites were consistently similar and are both likely being affected by legacy issues with water quality and land use practices in the catchment.

The difference in total richness from the edge habitats between the upstream and downstream sites is mostly due to the presence of Molluscs. Some of these Molluscs include the freshwater limpets *Ferrisia* sp. (Family: Planorbidae), the introduced snail *Physa acuta* (Family: Physidae) and the bivalves *Corbicula* sp. (Family: Corbiculidae). It was noted during the autumn 2015 sampling that the edge habitat appeared to have been scoured by high flows, particularly along the bank, with a majority of this available edge habitat occurring on the inside of a bend. This has increased the exposure of woody root material and larger cobbles throughout this edge habitat, while the depth of the habitat was also noticeably deeper. The depth of this habitat was approximately 0.4 m during the spring 2014 sampling, compared to the same location during autumn 2015 which was 1.2 m. These changes may be responsible for the colonisation of these species, with only *Corbicula* sp. present during autumn 2014 (GHD, 2015), while *Ferrissia* sp. are known to show preferences for habitats which have rocky substrates and wood debris (Gooderham & Tsyrlin, 2005).

The difference in the edge habitats between SIGNAL-2 scores is being driven by the absence of Leptophlebiidae (SIGNAL-2 = 8) and Leptoceridae (SIGNAL-2 = 6) at MUR19. Leptoceridae were present in replicate 1 but missing from the following two replicates, indicating either it was present in relatively low abundances or had a clumped distribution. The absence of Leptophlebiidae is surprising given its presence at the upstream site with both the *Atalophlebia* and *Nousia* genera present. The habitat at MUR 19 was more silted than the habitat at MUR 18, while the root coverage at the upstream site provided substantial habitat, which was very limited at MUR 19. This could be a key reason for its absence at MUR 19 with Gooderham and Tsyrlin (2005) summarising that *Atalophlebia* is usually found in slower flowing waters amongst wood debris and aquatic plants. Some species of *Nousia* have shown an association with shading of the habitat, while also preferring habitat with cobbles and wood debris present (Finlay, 2000).

It is also important to note that while shading was limited at MUR 18, due to the smaller nature of the native shrubs, it was almost completely absent at MUR 19, with the large overhanging willows bare of foliage during sampling.

The high variation seen in the AUSRIVAS banding in the MUR 18 riffle habitat has produced a habitat assessment of ‘no reliable assessment.’ This is somewhat misleading given that the Band C result was due to the absence of a single taxon (Oligiochaeta: SIGNAL-2=2) which was otherwise present in all of the other samples. This follows earlier observations that there is considerable spatial variation with these sites. Future impacts if severe enough may reduce this intra-site variation. So, if ongoing monitoring finds less variation within a site this may in itself indicate impairment (Anderson, 2006).

These results could make it more difficult for comparisons to future impact assessments should operational use of the M2G pipeline be required. While this method is accepted as the most precautionary approach (Coysh, 2000), it may not be ideal for this type of background monitoring in a river such as this where there is a high degree of intra-site variation (as has been demonstrated in this study). Moving forward, it is suggested that for sentinel monitoring, mean values are used for the method of assessment and the use of replicates in this sense is reserved for inferential statistics in future impact assessments.

4. Burra Creek

4.1 Summary of sampling conditions

Sampling of the Burra Creek sites was completed on the 18th May 2015. Weather on the day was fine, with a top temperature of 18°C recorded at the Canberra Airport (BoM, 2015). The mean daily flow in Burra Creek on the 18th of May was 2.9 ML/d recorded at the Burra Weir (410774). Photographs of BUR 1c & 2a are shown in Plate 4-1. One riffle and one edge sample were collected from both sites (Table 4-1).

There was extensive emergent macrophyte die back at both sites (Plate 4-1), particularly *Schoenoplectus validus* at BUR 1c and *Phragmites australis* at BUR 2a. The riffle habitat at both sites was highly silted, with greater than 50% of the substrate size class at these sites being classed as silt. Full site summaries can be found in Appendix B. Habitat data are available in Appendix C.


BUR 1c: Looking upstream (left) and looking downstream (right)


BUR 2a: Looking upstream (left) and looking downstream (right)

Plate 4-1. Photographs of the Burra Creek sites during autumn 2015 sampling

4.2 Hydrology and rainfall

Surface flow in Burra Creek was low (predominantly < 1 ML/d) at the beginning of March and continued into early April until a large rainfall event occurred, resulting in a high flow event of greater than 1,000 ML/d, which peaked on the 8th April 2015 (Figure 4-1). Following this short high flow event, there were two APPLE runs of the M2G pipeline with a short period of flow during April, and a more consistent period of pumping occurring in May. These periods of pipeline operation are highlighted in Figure 4-1. Flow remained stable at approximately 3 ML/d following the May APPLE run, during which autumn 2015 sampling was conducted.

Rainfall for the period was considerably higher during April, compared to both March and May, receiving 107.4 mm (Table 4-1 and Figure 4-3). The last time that April total rainfall exceeded both March and May was during autumn 2012 (Figure 4-3). Flow for the previous two years is presented in Figure 4-2, indicating that the low flows leading into the sampling period were not as low as flows preceding the autumn 2014 sampling period (during January and February).

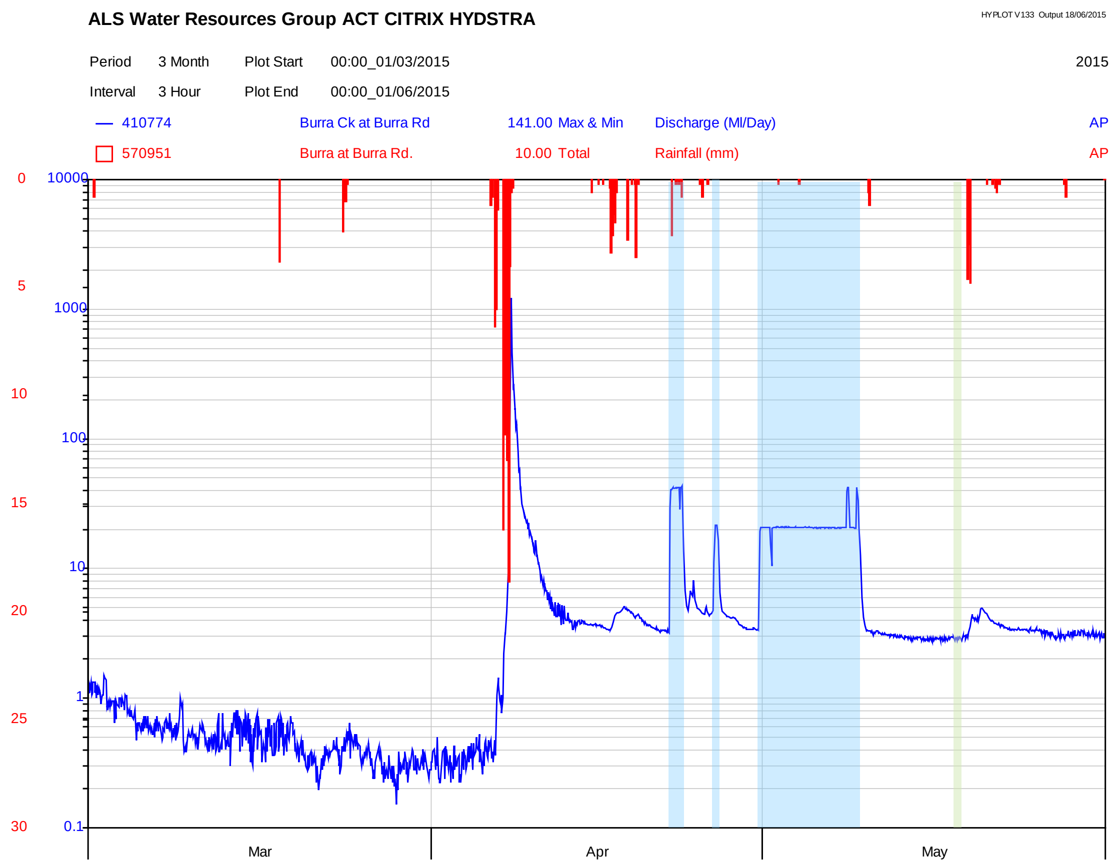


Figure 4-1. Hydrograph and rainfall from Burra Creek (410774) during autumn 2015

Note: The green shading indicates time of sampling, blue highlight indicates APPLE run.

Table 4-1. Rainfall and flow summaries for Burra Creek for autumn 2015

	Burra Creek (410774)	
	Total Rainfall (mm)	Mean Flow (ML/d)
March	9.2	0.53
April	107.4	17
May	17.2	8.5
Autumn (mean)	133.8 (44.6)	8.6

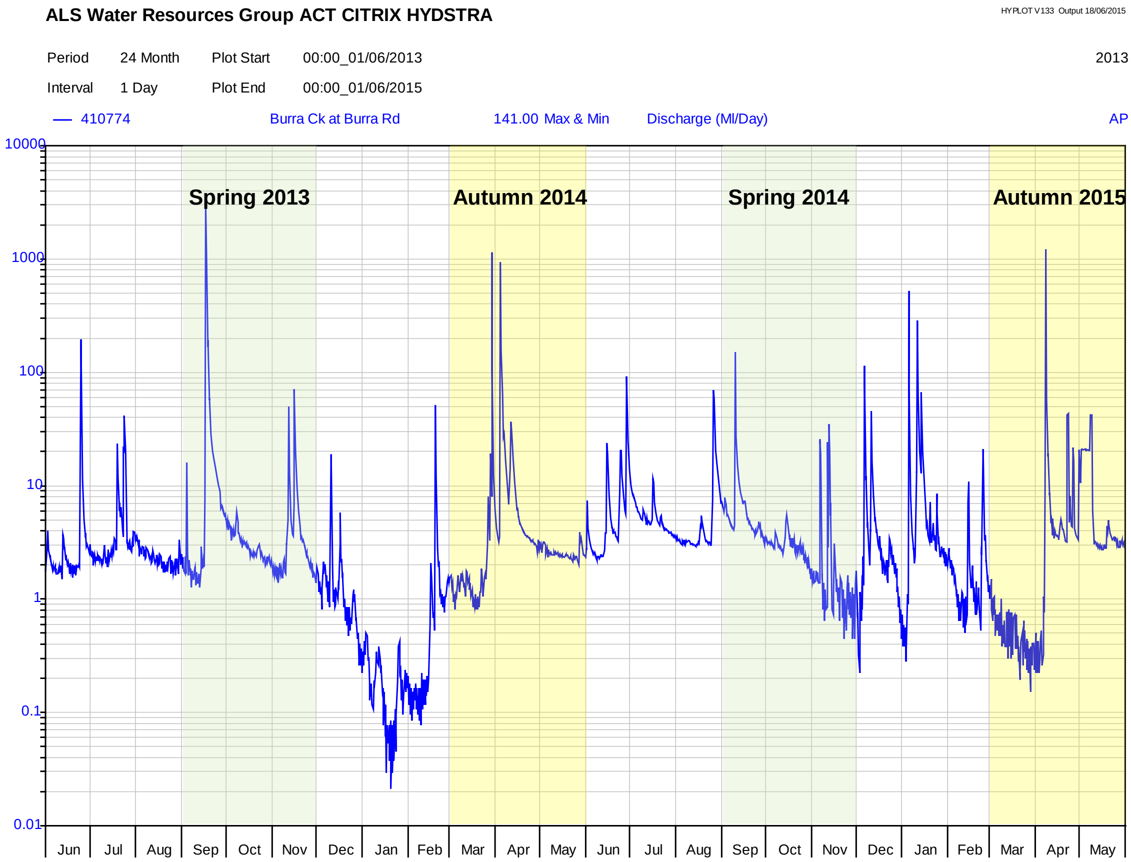


Figure 4-2. Burra Creek hydrograph highlighting the past four sampling periods between September 2013 and May 2015

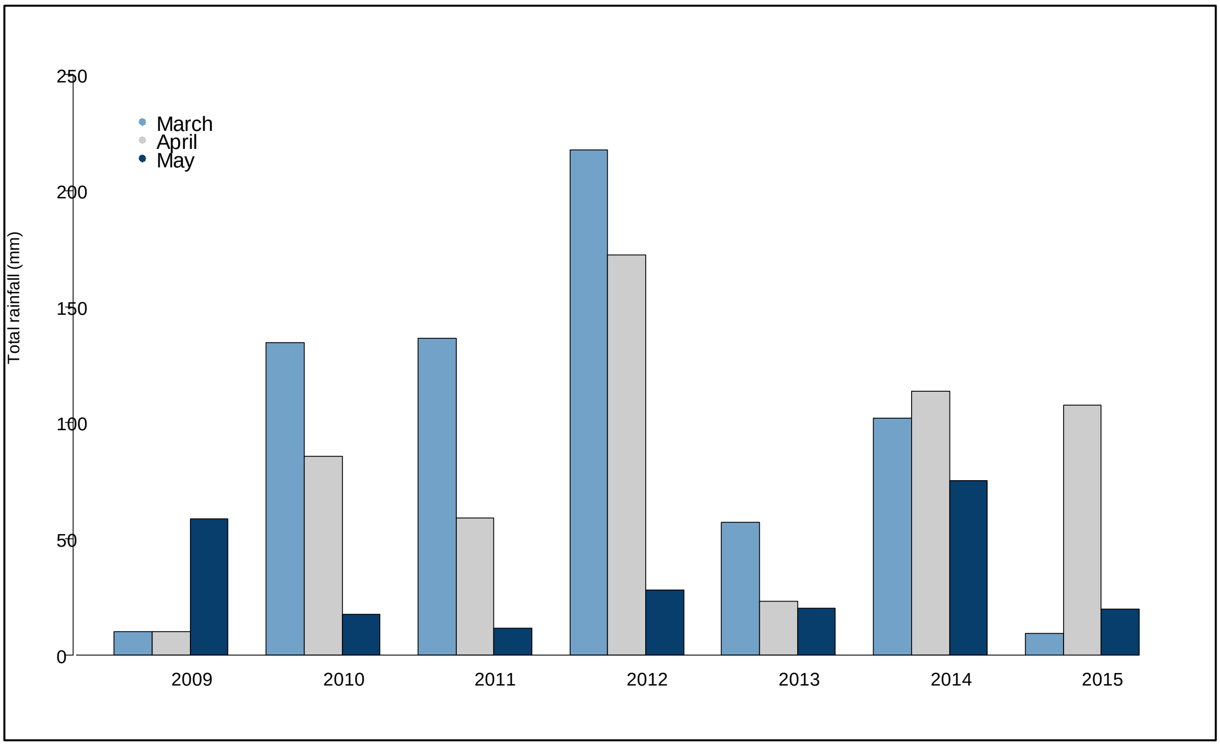


Figure 4-3. Annual comparisons of autumn rainfall (mm) recorded at Burra Creek (570951)

4.3 Water Quality

4.3.1 Grab Samples and *in-situ* parameters

The water quality parameters which were recorded *in-situ* at the Burra Creek sites showed some variability in the conformance to the ANZECC & ARMCANZ (2000) guidelines as presented in Table 4-2**.**. The EC at both sites was elevated above the upper limit of the guidelines, which was also the case for pH at BUR 2a, while BUR 1c remained within the recommended range (Table 4-2). Comparatively, BUR 1c was below the lower limit for the DO guideline, while BUR 2a remained within the recommended range. The results of the grab sample analysed at ALS Canberra show exceedances of the trigger values for both NO_x and total nitrogen (TN). While comparatively, there were no exceedances of the nutrient trigger values at BUR 1c. With the exception of the pH at BUR 2a and the DO at BUR 1c, these are the same exceedances which were recorded at these sites in autumn 2014.

4.3.2 Continuous water quality monitoring

Continuous water quality data recorded at Burra Weir (410774) is presented in Figure 4-4. This data shows the reaction of both electrical conductivity (EC) and pH to the low baseflow levels at the start of the period with steady increases during March, while dissolved oxygen (DO) was low during March also. During April all parameters responded to the high flow event with a short sharp spike in turbidity levels, disruption of the DO diurnal trend and sharp drops in EC, pH and temperature. This was followed by some recovery prior to the M2G APPLE runs.

Turbidity showed no response to the initial APPLE flows during April, however there was some noise associated with the second half of the May release. For DO, other than some minor alterations to the diurnal trend, there was no response to any of the APPLE runs. EC and pH levels changed with the dilution of the creek with Murrumbidgee River water causing decreases in both parameters during all periods of pumping. These parameters gradually returned to background levels following the pumping as the lower EC and pH water was flushed through the system.

The DO values were below the ANZECC & ARMCANZ (2000) guidelines for the entire period. EC and pH were elevated above the ANZECC & ARMCANZ (2000) respective recommended ranges during all periods when flow wasn’t elevated, whether naturally or artificially.

Table 4-2. *In-situ* water quality results from Burra Creek during autumn 2015 sampling

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TDS mg/L	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) (0.015)	TKN (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)	Total Iron (mg/L)	Total Manganese (mg/L) (1.9)
Upstream	BUR 1c	18/5/2015	9:26	6.5	428	5.1	258	7.75	86.4	9.89	160	0.005	0.15	0.007	0.15	0.51	0.041
Downstream	BUR 2a	18/5/2015	10:55	8.0	495	7.9	279	8.27	93.0	10.11	198	0.230	0.12	0.010	0.35	0.60	0.052

Note: ANZECC and ARMCANZ (2000) guidelines are in yellow parentheses; yellow cells indicate values outside of the guidelines;; trigger value for Total Manganese is the 95% species level protection for slightly-moderately disturbed systems.

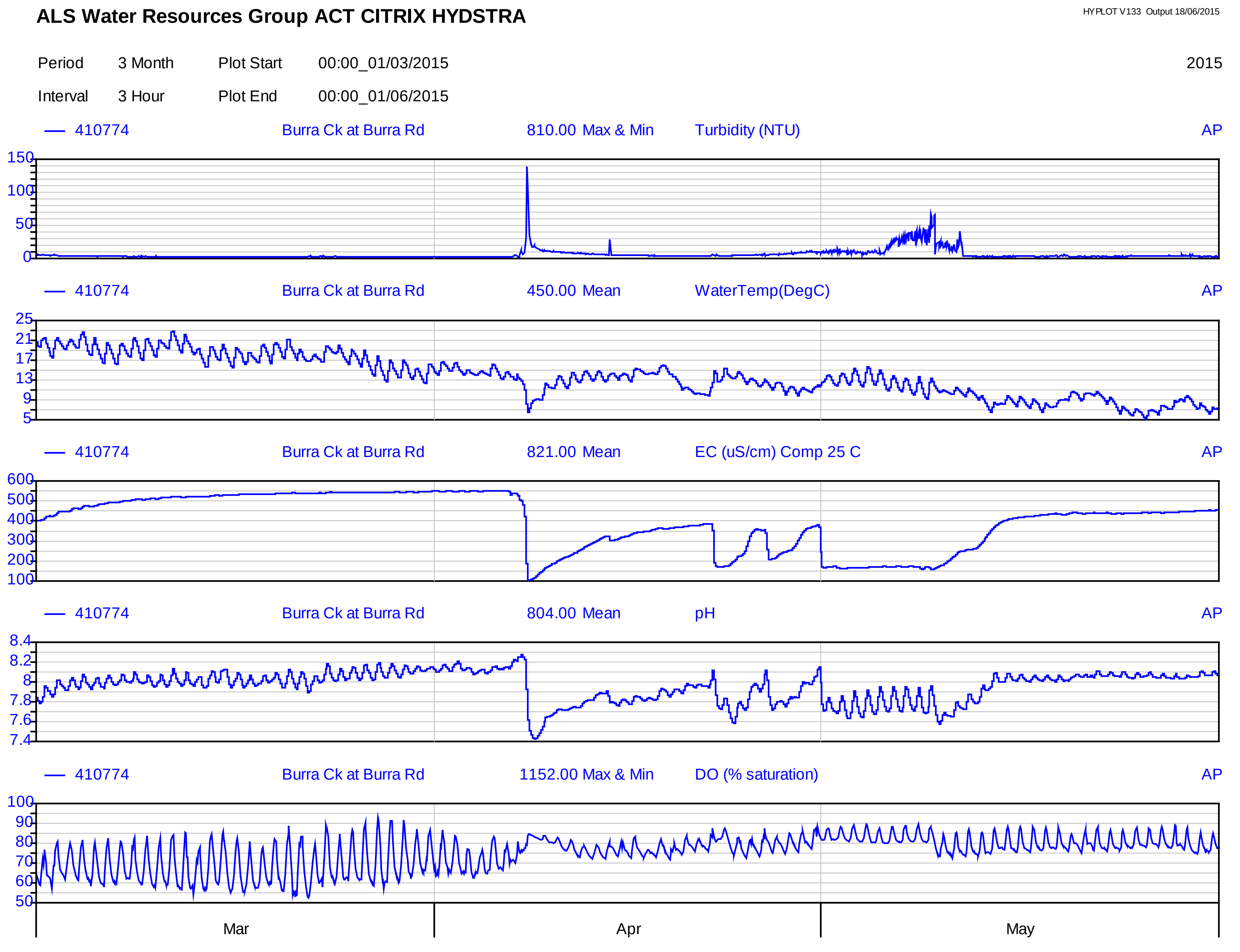


Figure 4-4. Continuous water quality records from Burra Creek (410774) during autumn 2015

4.4 Photogrammetry

4.4.1 Periphyton

BUR 1c

Plate 4-2. Periphyton coverage at BUR 1c

The periphyton coverage at BUR 1c was estimated at >90% for both the reach scale and riffle habitat using the AUSRIVAS assessment (Plate 4-2). There were some small sections of *Myriophyllum sp.* and *Eleocharis sp.* growth along the edge of the riffle habitat, while *Schoenoplectus validus* was dominant throughout the reach. The dominant substrate in the riffle habitat was cobbles and silt.

BUR 2a

Plate 4-3. Periphyton coverage at BUR 2a

Periphyton coverage at BUR 2a was >90% at both the reach scale and riffle habitat specifically using the AUSRIVAS assessment (Plate 4-3). There were *Schoenoplectus validus* stands along the riffle margins, with minimal *Myriophyllum* sp. present. Filamentous algae growth throughout the reach was high covering the substrate and attaching to macrophytes. The dominant substrate was cobbles.

4.4.2 Vegetation

BUR 2

Few trees are present at BUR 2a. There is a large *Populus* sp*.* immediately downstream of the Williamsdale Road causeway on the edge of the channel and a couple of small *Salix* sp. (approximately 3 m) upstream of the causeway. The remaining terrestrial vegetation is dominated by pasture grasses and weeds. Instream vegetation is dominated by *Phragmites australis* (Common Reed), with large stands both upstream and downstream of the causeway. There are also some small patches of *Typha orientalis* (Broad leaf Cumbungi). Four vegetation photo points were identified at BUR 2 which are presented in Plate 4-4 through to Plate 4-7.

Downstream of Pool 29

This site, similar to BUR 2 has few trees, restricting shading of the site to the steep banks. Some small *Salix* sp. are present on the left bank within the macro channel, while a single *Acacia dealbata* or Silver Wattle was present on the right bank. There is a large portion of the point bar along the water's edge which is covered by *Rubus fruiticosus* (Blackberry), along with numerous thistle species and *Conyza* sp. (Fleabane). Large portions of the ground cover within the macro channel are covered in native grasses, predominantly *Poa* spp. There are stands of *Shoenoplectus validus* (Great Bulrush) along the water's edge, while there are infrequent small stands of *Typha orientalis* (Broad leaf Cumbungi). The three vegetation photo points for this site are shown in Plate 4-8, Plate 4-9 and Plate 4-10.

BUR 2c

The upper banks of BUR 2c hold numerous large *Eucalyptus* spp*.* with a ground cover which has large numbers of native *Poa* spp. Within the macro channel at the upstream half of the site, the sparsely vegetated point bar consists of mostly weeds species and pasture grasses, predominantly *Conyza* sp. (Fleabane). The downstream half of the site is mostly vegetated with *Poa* spp. and pasture grasses line the banks, with infrequent small sections of *Rubus fruiticosus* (Blackberry). The instream vegetation is present without being dominant with stands of *Phragmites australis* (Common Reed) and *Typha orientalis* (Broad-leaf Cumbungi), while *Schoenoplectus validus* (Great Bulrush) is also present in smaller patches. Four vegetation photo points have been identified for BUR 2c which are shown in Plate 4-11 through to Plate 4-14.

BUR 2

a)

b)

c)

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

a)

b)

c)

Plate 4-5. Vegetation extent photo point 2 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-6. Vegetation extent photo point 3 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

a)


b)


c)


Plate 4-7. Vegetation extent photo point 4 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

Downstream Pool 29

a)

b)

c)

Plate 4-8. Vegetation extent photo point 1 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-9. Vegetation extent photo point 2 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)


a)


b)


c)

Plate 4-10. Vegetation extent photo point 3 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)

BUR 2c

a)

b)

c)

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

a)

b)

c)

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

a)

b)

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

a)

b)

c)

Plate 4-14. Vegetation extent photo point 4 at BUR 2c showing upstream (a), downstream (b) and across the channel (c)

4.4.3 Geomorphology

BUR 1a

BUR 1a has a large macro channel, with a smaller inset low flow channel which follows mostly along the right hand side of the macro channel. Previous monitoring has shown sections of bank at BUR 1a show areas of erosion and slumping over a relatively short period, and minor movement of the preferential flow path during low flow periods (GHD, 2015c). There are also some small laterally attached bars in the downstream section of the site, which consist mainly of coarse material and pebbles. Three geomorphology photo points have been identified for monitoring at BUR 1c. The photos from these points can be found in Plate 4-15, Plate 4-16 and Plate 4-17 showing photo point 1, 2 and 3 respectively.

BUR 1c

The reach at BUR 1c is unique amongst Burra Creek sites in that almost none of the bank area is un-vegetated. This reach of the creek has a very low sinuosity and few trees. Vegetation in this reach is dominated by grasses along both banks. There is a small sand bar located just downstream of the macroinvertebrate sample location. Due to this sites homogeneity only a single geomorphology photo point has been identified for this site, the photos from this point are presented in Plate 4-18.

BUR 2

The area around the M2G discharge structure has been well protected from any changes in the pool and bank shape through the non-natural rock banks created to protect from the higher flow from the discharge. This upstream area is monitored by two geomorphology photo points which are presented in Plate 4-19 and Plate 4-20. Downstream of Williamsdale Road is highly vegetated, with a small drop off which could potentially erode towards the causeway. This downstream area is monitored by two geomorphology photo points which are presented in Plate 4-21 and Plate 4-22.

BUR 2a

BUR 2a is located on a bend which has a steep un-vegetated bank on the right hand side. However, unlike sites like BUR 1a & 2c this bank has shown no signs of movement during previous monitoring (GHD, 2015c), likely due to its composition mostly being a hard packed clay material. The left bank slopes gradually to the top of bank which is mostly vegetated. There is a large pool at the downstream end of the site which has a large portion of bedrock, with a bedrock outcrop from the right bank also. The geomorphology photo points were identified for monitoring at BUR 2a, these are presented in Plate 4-23 and Plate 4-24.

Downstream of Pool 29

This site has a very large macro channel with steep banks approximately 3.5 – 4 m high. The left bank, upstream of the riffle habitat was assessed as having a high erosion potential (GHD, 2015c) as it is in the direct flow path during high flow events and is completely un-vegetated. On the inside of this bend is a large partially vegetated point bar which is made up of coarse sands, pebbles and cobbles. Three geomorphology photo points were identified to monitor this site and are presented in Plate 4-25, Plate 4-26 and Plate 4-27.

BUR 2c

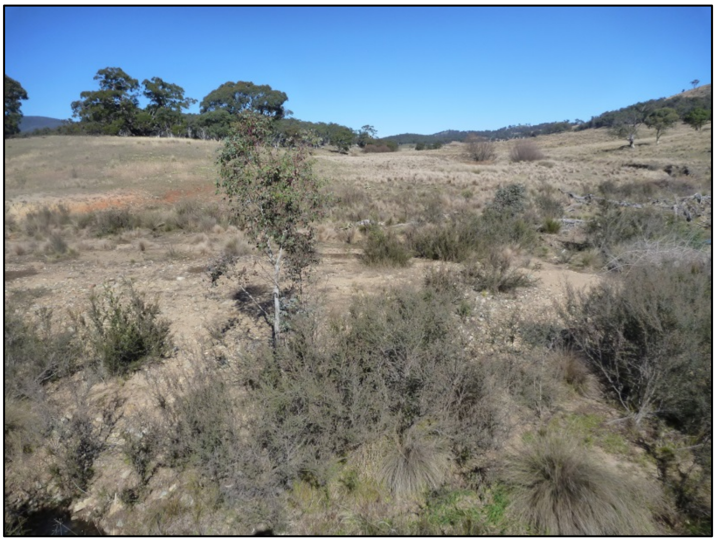
BUR 2c is another site which has a large macro channel, with an inset low flow path which follows the left bank at the bottom of a steep bank (approximately 3m). The inset channel becomes more central within the macro channel after a sharp bend in the river which holds a large pool. The site is located within a depositional zone of the catchment with a couple of point bars present within this reach consisting of mostly coarse sands, pebbles and cobbles. BUR 2c has previously been identified as the site with the highest potential for substantial erosion of any site on Burra Creek downstream of the

M2G discharge structure (GHD, 2015c). This is due to the un-vegetated steep banks which occur at this site. Banks slumps have occurred during the previous monitoring periods with the potential for operational M2G flows to exacerbate the erosion occurring from natural flows at this site (GHD, 2015c).

BUR 1a

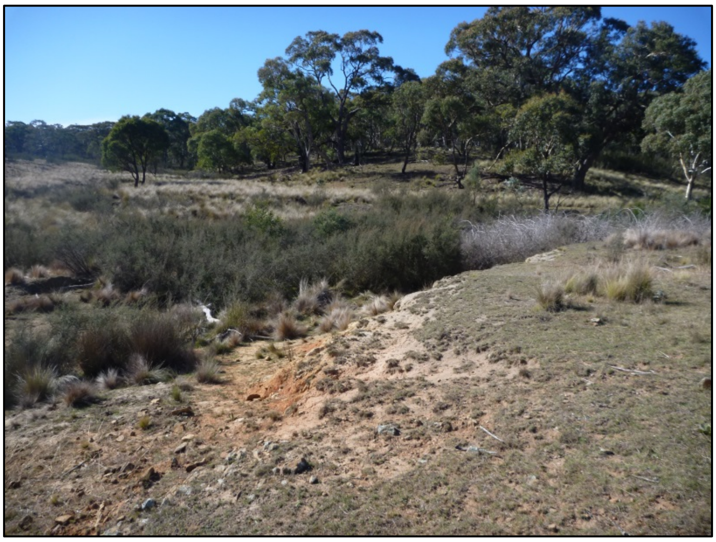
a)

b)



c)

Plate 4-15. Geomorphology photo point 1 at BUR 1a showing upstream (a), downstream (b) and across the channel (c)


a)


b)


c)

Plate 4-16. Geomorphology photo point 2 at BUR 1a showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-17. Geomorphology photo point 3 at BUR 1a showing upstream (a), downstream (b) and across the channel (c)

BUR 1c

a)

b)

Plate 4-18. Geomorphology photo point 1 at BUR 1c showing upstream (a) and downstream (b)

BUR 2

a)

b)

c)

Plate 4-19. Geomorphology photo point 1 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-20. Geomorphology photo point 2 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-21. Geomorphology photo point 3 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-22. Geomorphology photo point 4 at BUR 2 showing upstream (a), downstream (b) and across the channel (c)

BUR 2a

a)

b)

c)

Plate 4-23. Geomorphology photo point 1 at BUR 2a showing upstream (a), downstream (b) and across the channel (c)

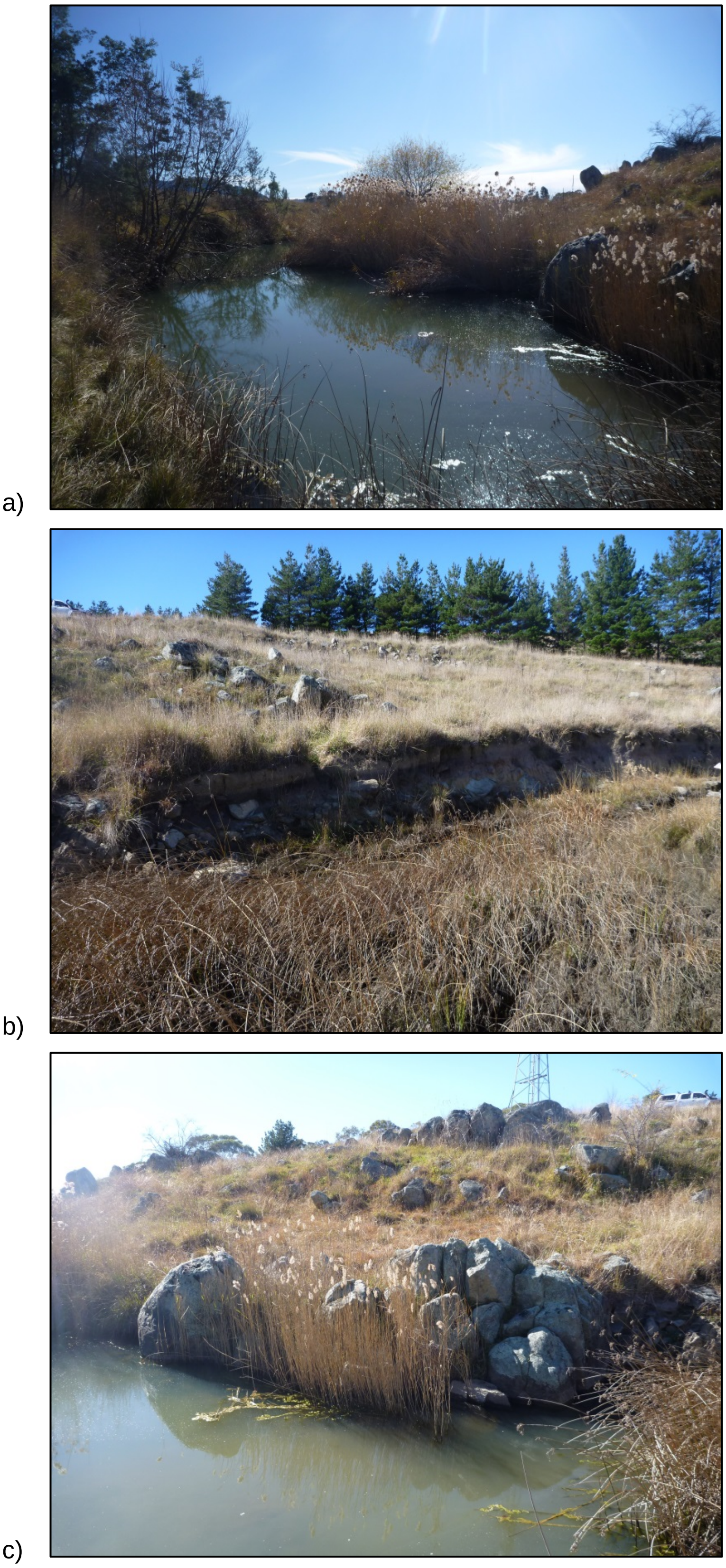


Plate 4-24. Geomorphology photo point 1 at BUR 2a showing upstream (a), downstream (b) and across the channel (c)

Downstream pool 29

a)

b)

c)

Plate 4-25. Geomorphology photo point 1 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-26. Geomorphology photo point 2 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)

a)


b)


c)


Plate 4-27. Geomorphology photo point 3 downstream of pool 29 showing upstream (a), downstream (b) and across the channel (c)

BUR 2c

a)

b)

c)

Plate 4-28. Geomorphology photo point 1 at BUR 2c showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-29. Geomorphology photo point 2 at BUR 2c showing upstream (a), downstream (b) and across the channel (c)

a)
b)
c)

Plate 4-30. Geomorphology photo point 3 at BUR 2c showing upstream (a), downstream (b) and across the channel (c)

a)

b)

c)

Plate 4-31. Geomorphology photo point 4 at BUR 2c showing upstream (a), downstream (b) and across the channel (c)

4.5 Macroinvertebrates

The number of taxa at each site was relatively similar across both habitats (Table 4-3). The difference between the upstream and downstream sites was only one EPT family with the number of EPT genera the same for both the edge and riffle habitats (Table 4-4).

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

Total Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
BUR 1c	21	24	22	23
BUR 2a	19	22	23	25

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

EPT Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
BUR 1c	8	9	8	9
BUR 2a	7	9	7	9

4.5.1 AUSRIVAS & SIGNAL-2

Mean SIGNAL-2 scores from the riffle habitat were similar between the upstream and downstream site with only 0.05 separating the two with BUR 1c and BUR 2a scoring 4.75 and 4.80 respectively. This suggests that macroinvertebrates which were collected in the riffle habitat at these two sites are of a similar sensitivity. The results of the SIGNAL-2 scores from the edge habitat were not as similar with the upstream site consisting of more sensitive taxa scoring a mean of 4.57 compared to the downstream mean of 3.99.

The mean O/E score at BUR 1c for the riffle habitat was 0.88 which falls within Band A, however, as a single replicate was assessed as Band B, AUSRIVAS methodology uses the precautionary approach of using the lower Band as the overall assessment (Coysh et al., 2000) resulting in an overall riffle habitat assessment for BUR 1c as Band B. This one replicate was awarded Band B due to the absence of Hydrobiosidae (SIGNAL-2 = 8), which was present at both other replicates from that sample (Appendix F).

Comparatively, the mean O/E score at for the BUR 2a riffle habitat was 0.75 which falls within Band B, which corresponds to the replicates which were all assessed as Band B (Table 4-5).The O/E scores for the edge habitat were similar with the upstream and downstream means of 0.86 and 0.89 respectively falling within Band A (Table 4-5). While the BUR 1c edge habitat was given a Band A, the edge at BUR 2a was awarded an overall assessment of Band B. This is due to the use of the precautionary AUSRIVAS methodology (Coysh et al., 2000), as was the case with the riffle at BUR 2a with a single replicate assessed as Band B (Table 4-5). This one replicate was awarded Band B due to the absence of Leptophlebiidae (SIGNAL-2 = 8), which was present at both other replicates from that sample (Appendix F).

The overall site assessments were classified as Band B for both BUR 1c and BUR 2a, which is consistent with the results from these sites for the previous three autumn periods (Table 4-6). The predicted/collected results from the AUSRIVAS model are presented in Appendix F, while a full taxonomic inventory can be found in Appendix G.

Table 4-5. AUSRIVAS and SIGNAL-2 scores for autumn 2015

Site	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
BUR 1c	**1**	4.64	4.73	0.80	0.90	B	A	**B**	**A**	**B**
	2	4.85	4.40	0.95	0.82	A	A			
	3	4.75	NS	0.88	NS	A	NS			
BUR 2a	**1**	4.90	4.20	0.73	0.89	B	A	**B**	**B**	**B**
	2	4.50	3.78	0.73	0.80	B	B			
	3	5.00	4.00	0.80	0.98	B	A			

Note: NS = No sample.

Table 4-6. Overall site assessments for autumn and spring since 2012

	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Spring 2014	Autumn 2015	Change since autumn 2014
BUR 1c	**B**	**B**	**B**	**B**	**B**	**A**	**B**	↔
BUR 2a	**B**	**A**	**B**	**A**	**B**	**A**	**B**	↔

4.6 Discussion

4.6.1 Water quality

The water quality grab sample results from the autumn 2015 sampling run showed some similarities with regards to the parameters used in this assessment. However there were also a number of differences, leading to exceedances of the ANZECC & ARMCANZ (2000) guidelines for some parameters particularly at the downstream site, BUR 2a. Both upstream and downstream sites exceeded the guidelines for EC, which has been consistent throughout the MEMP programme, particularly during periods of low flow.

Previous recommendations have been made suggesting that an appropriate local guideline range be developed and implemented for Burra Creek, specifically for EC (GHD, 2013b). The breach of the lower limit of the recommended range for DO at BUR 1c, is related to the low flows at the time of sampling, with levels only slightly below the lower limit of 90%. Exceedance of the pH ANZECC & ARMCANZ (2000) upper limit, along with the nutrient breaches of NO_x and TN at the downstream site, BUR 2a, are likely related to the inflow of Holden's Creek (immediately upstream of the M2G discharge structure and downstream of BUR 1c).

The continuous water quality data at Burra Weir (410774) showed signs of the low flows during the start of the period with elevated EC, pH and temperature, and lower levels of DO. Turbidity spikes throughout the autumn period coincided with the high flow event during April and also the M2G APPLE run during May, while it remained very low throughout the rest of the period. Both pH and EC were both in exceedance of the ANZECC & ARMCANZ (2000) guidelines for the duration of the period, with the exception of during periods of high flow, either from natural rainfall event or artificial M2G maintenance runs. These elevated levels are considered 'normal' in Burra Creek and have been frequently recorded through the duration of the MEMP. Flows from the M2G APPLE run increased the compliance of the water quality with the ANZECC & ARMCANZ (2000) guidelines at the Burra Weir (410774) through the pumping of the lower EC and pH Murrumbidgee River water.

4.6.2 Photogrammetry

Periphyton

Periphyton has been included in the monitoring programme 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.

Periphyton coverage was high at both sites (>90%) which is consistent with the results which were recorded during autumn 2015. However of particular interest is the level of filamentous algae which was observed during autumn 2015 (65-90%) compared to what was observed during autumn 2014 (<10%). This large increase could be the result of the increased nitrogen entering Burra Creek from Holden's Creek (see section 4.6.1 above) and is resulting in increased filamentous algae growth. The high periphyton coverage could be limiting further periphyton growth which is leaving nutrients available for uptake by the filamentous algae.

Vegetation

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 (in two years' time), or with photos and observations recorded before and after the use of the M2G pipeline for operational purposes, should this occur within the next two years.

While these photo points provide a good overview of the site, additional data would be very beneficial, particularly in the event of operational pumping requiring before and after observations. This would need to be a rapid assessment which can be completed in the already allocated field time, preventing an increase in the project cost, such as the Rapid Appraisal of Riparian Condition (RARC; Jansen *et al*., 2007). The RARC consists of five components: habitat, cover, natives, debris and features; and is currently used by ACT Waterwatch for riparian vegetation assessments (Upper Murrumbidgee Waterwatch, 2015). This assessment is more applicable than the AUSRIVAS methods currently used in the MEMP, which is designed to complement the model parameters and not as a standalone vegetation assessment methodology.

Geomorphology

During the current maintenance phase of the M2G pipeline, the use of photogrammetry at the previously identified cross sections along Burra Creek are considered to be a robust method for the monitoring of potential changes in bank erosion and slumping. The photo points collected during autumn 2015 will be used for comparison to future photo points (in two years' time), or with photographs and observations recorded before and after the use of the M2G pipeline for operational purposes, should this occur within the next two years.

As indicated in the MEMP Geomorphology report (GHD, 2015c) the area of greatest concern along Burra Creek is the downstream reach at BUR 2c. This has been identified as the most likely point of major bank slumping with M2G maintenance and operational flows (should they occur in the future) potentially exacerbating the problem currently being driven by natural high flow events.

4.6.3 Macroinvertebrates and AUSRIVAS

During autumn 2015 the macroinvertebrate communities were relatively similar, with very similar results across both sites in relation to the total richness and EPT richness numbers. The overall site result of Band B's of both BUR 1c and BUR 2a has been consistent over the previous four autumn sampling seasons. This suggests that the ecological health of these sites has been maintained at the current level during the autumn periods for some time.

The lower SIGNAL-2 scores at the downstream site is largely due to the absence of Leptophlebiidae (SIGNAL-2 = 8). Similar to previous seasons, the AUSRIVAS results showed a high number of replicates assessed as Band A, "similar to reference", however there were the odd Band B results which reduced the overall assessments to this level of "significantly impaired." The only replicate assessed as Band B at BUR 1c was the first replicate in the riffle habitat. This was due to the absence of a single taxa; the presence of either Ancylidae (SIGNAL-2 = 4) or Hydrobiosidae (SIGNAL-2 = 8) would have produced a Band A assessment, with both of these taxa present at both other BUR 1c riffle replicates.

The result from the riffle habitat at BUR 2a of Band B was consistent across all replicates indicating that the riffle habitat at this site is "significantly impaired." The edge habitat was also assessed as a Band B, however, two of the three replicates were assessed as Band A. The single Band B replicate was missing a single taxa (Leptophlebiidae) compared to the other two replicates. This single replicate reduced the overall habitat assessment to Band B, even though Leptophlebiidae was recorded in two of the three replicates. This is the accepted precautionary approach (Barmuta *et al*., 2003; Coysh, 2000), however may not be ideal for the aims of this sentinel monitoring.

5. Murrumbidgee Pump Station

5.1 Summary of sampling and river conditions

Sites for the Murrumbidgee Pump Station were samples on the 19th May 2015. Weather on the day was overcast with rain, maximum temperature on the day reached just over 14°C at the Canberra Airport (BoM, 2015). Mean daily flow on the day was recorded at 460 ML/d at the Lobb's Hole gauging station (410761) and 510 ML/d at the Mt. MacDonald gauging station (410738). A single riffle sample and a single edge sample were collected from both MUR 28 and MUR 935 (Table 5-1). Site photographs are presented in Plate 5-1.

Organic matter and debris was present in high volumes in the edge habitat at MUR 935, this was compared to MUR 28, which had a relative minimal amount of organic matter, consistent with previous sample runs. MUR 935 was sampled for the first time since autumn 2013, however, the general site morphology and riffle habitat are relatively unchanged since that time. Full site summaries are can be found in Appendix B. Habitat data is available in Appendix C.


MUR 28: Looking upstream (left) and looking downstream (right)


MUR 935: Looking upstream (left) and looking downstream (right)

Plate 5-1. Photographs of the Murrumbidgee Pump Station sites during autumn 2015 sampling

Note: Photos of MUR 28 are from post sampling, during a high flow event from late June. Photos collected on the day of sampling were not usable due to the rain during sampling.

5.2 Hydrology and rainfall

Flow in the Murrumbidgee River was consistent leading into autumn showing a steady baseflow at both the Lobb's Hole (410761) and Mt. MacDonald (410738) gauging stations (Figure 5-1). This flow pattern occurred until April when 100 mm of rainfall fell over a three day period creating a high flow event which peaked at over 16,000 ML/d at Mt. MacDonald (410738; Figure 5-1). This was a short event with flow receding quickly and a small second peak in the hydrograph resulting from further rainfall. Flow receded to baseflow levels in early May and remained at this level until after the sampling period on the 19th of May 2015. Flow in the Cotter River was approximately 40 ML/d for most of the autumn period with some short periods of increased flow, with one of these increases occurring at the time of sampling (Figure 5-2). Flow and rainfall summaries for autumn 2015 are presented in Table 5-2 which clearly show the increased flow and rainfall during April compared to both March and May, with more rainfall over the three day period during April (6th – 8th) than the rest of the season combined. Plate 5-2 and Plate 5-3 show the comparison in river conditions to when sites were sampled for the MPS during autumn 2013 (the last time sites were sampled for the MPS) with flows in the Murrumbidgee River more than three times higher during autumn 2015 than during autumn 2013.

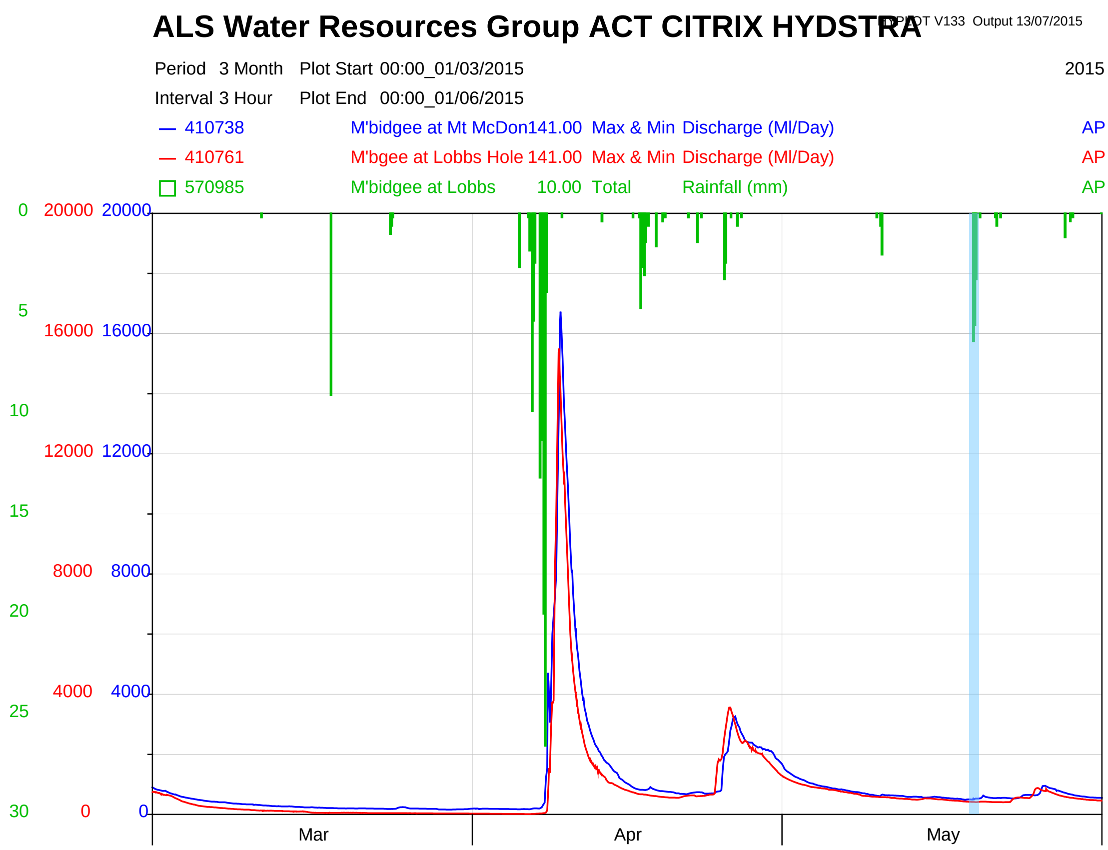


Figure 5-1. Autumn hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738), including total rainfall for the Lobb's Hole gauge (570985) from autumn 2015

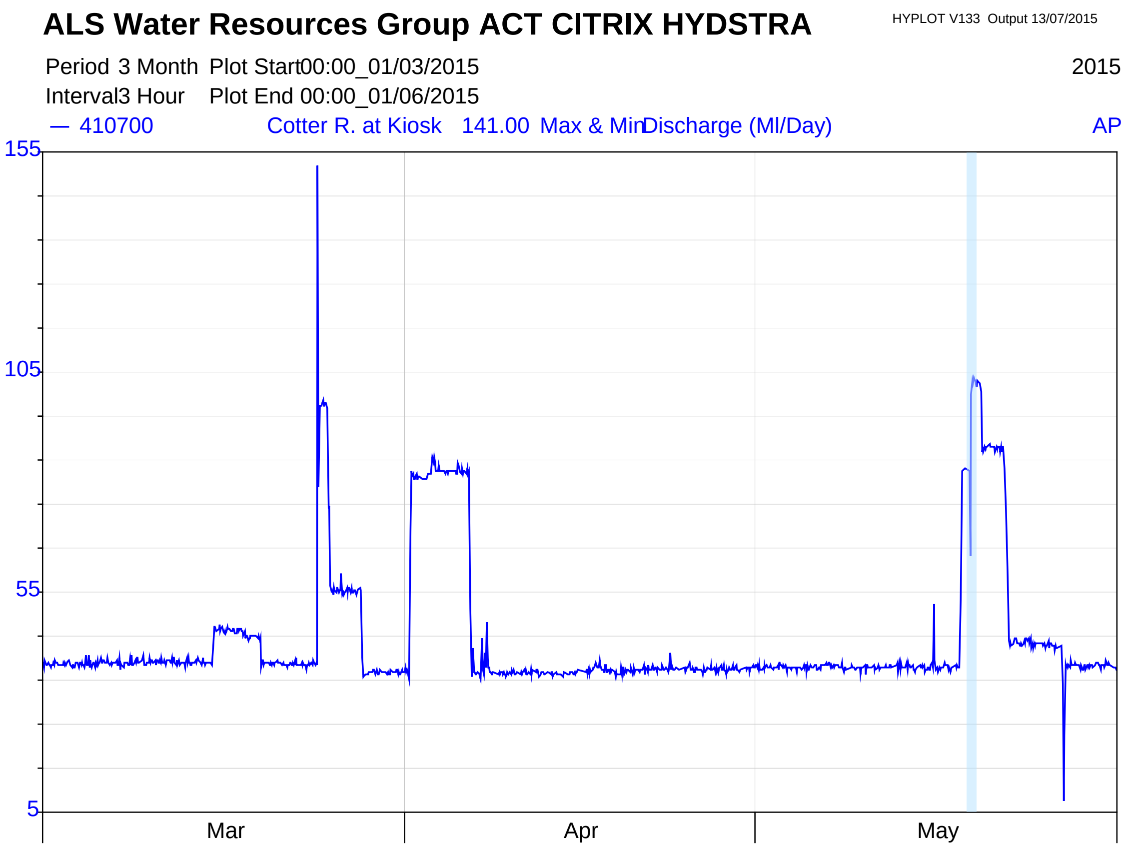


Figure 5-2. Hydrograph for the Cotter River downstream of the Cotter Dam (410700) for autumn 2015

Table 5-1. Autumn rainfall and flow summaries upstream and downstream of the MPS

	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
March	11.13	150	310
April	128.95	1,600	2,000
May	21.37	650	710
Autumn (mean)	161.45 (53.8)	810	1,000

2013 – 140 ML/d (8/5/2013)

2015 - 510 ML/d (19/5/2015)

Plate 5-2. The Murrumbidgee River upstream of the Cotter Road bridge and the MPS in autumn 2013 (top) and 2015 (bottom)

Note: Flow is mean daily flow recorded at Mt. MacDonald (410738)

2013 – 140 ML/d (8/5/2013)

2015 - 510 ML/d (19/5/2015)

Plate 5-3. The Murrumbidgee River downstream of the Cotter Road bridge, MPS on the right bank, in autumn 2013 (top) and 2015 (bottom)

Note: Flow is mean daily flow recorded at Mt. MacDonald (410738)

5.3 Water Quality

5.3.1 Grab samples and *in-situ* parameters

In-situ water quality data collected from MPS sites are presented in Table 5-2. The only parameters which exceed the ANZECC & ARMCANZ (2000) guidelines was the elevation of pH above the upper limit at both upstream and downstream sites. The results for EC, turbidity and DO are all within the recommended ranges at all sites. Additional water quality grab samples were collected by ALS during the autumn period with the results of these presented in Appendix D.

Table 5-2. *In-situ* water quality results from MPS sites during autumn 2015

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)
Upstream	MUR 28	19/5/2015	14:50	10.6	162.9	5.04	8.14	103.4	10.70	45
Downstream	MUR 935	19/5/2015	13:40	10.2	158.7	6.00	8.06	104.4	10.96	48

Note: ANZECC and ARMCANZ (2000) guidelines are in yellow parentheses, yellow cells indicate values outside of the guidelines.

5.3.2 Continuous water quality monitoring

Continuous water quality data recorded at the Lobb's Hole gauging station is shown in Figure 5-3. No data was recorded between 29th December 2014 and 7th April 2015 due to a lightning strike damaging the probe. The sensor was not able to be replaced earlier than this date due to inaccessibility to the sensor from high flows. Immediately following the sensor repairs (the next day) all parameters reacted to a high flow event with large reductions in temperature, EC and pH, while turbidity spiked. Following the event, the continuous water quality parameters returned to their baseflow levels, with natural diurnal trends present in the temperature, pH and dissolved oxygen data.

Electrical conductivity remained within the ANZECC & ARMCANZ (2000) recommended range for the entire period. The pH values were predominantly elevated above the upper limit of the guideline between approximately 8.0 and 8.3, with the exception of the periods of high flow which reduced the pH to within the recommended range. Turbidity readings remained within the guideline levels, excluding the two spikes recorded during the periods of increased flow. While the DO levels remained within the guidelines almost exclusively, with the lowest point of the diurnal trend dropping slightly below the 90% lower limit occasionally.

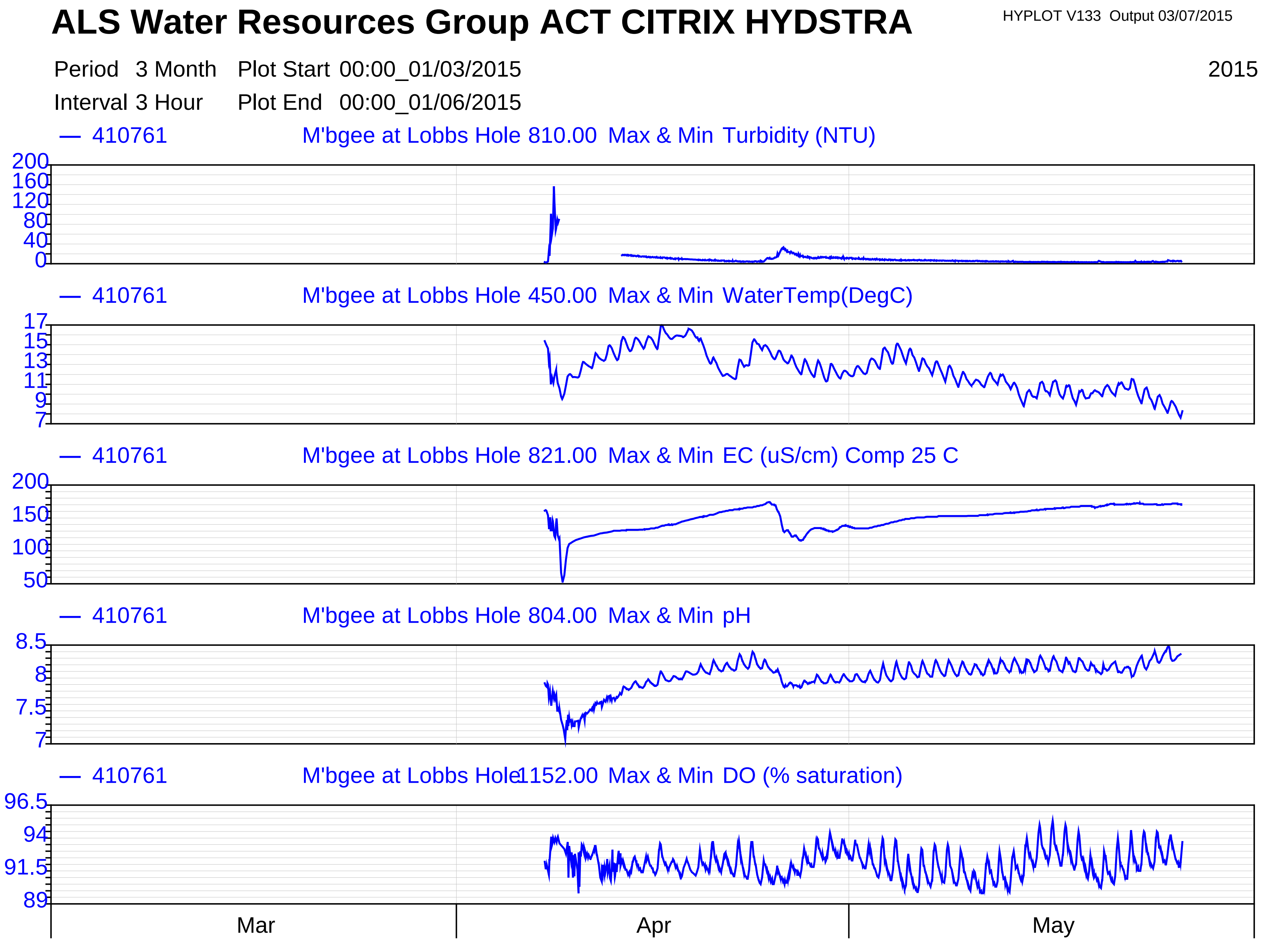


Figure 5-3. Continuous water quality records from Lobb's Hole (410761) for autumn 2015

5.4 Photogrammetry

5.4.1 Periphyton

MUR 28

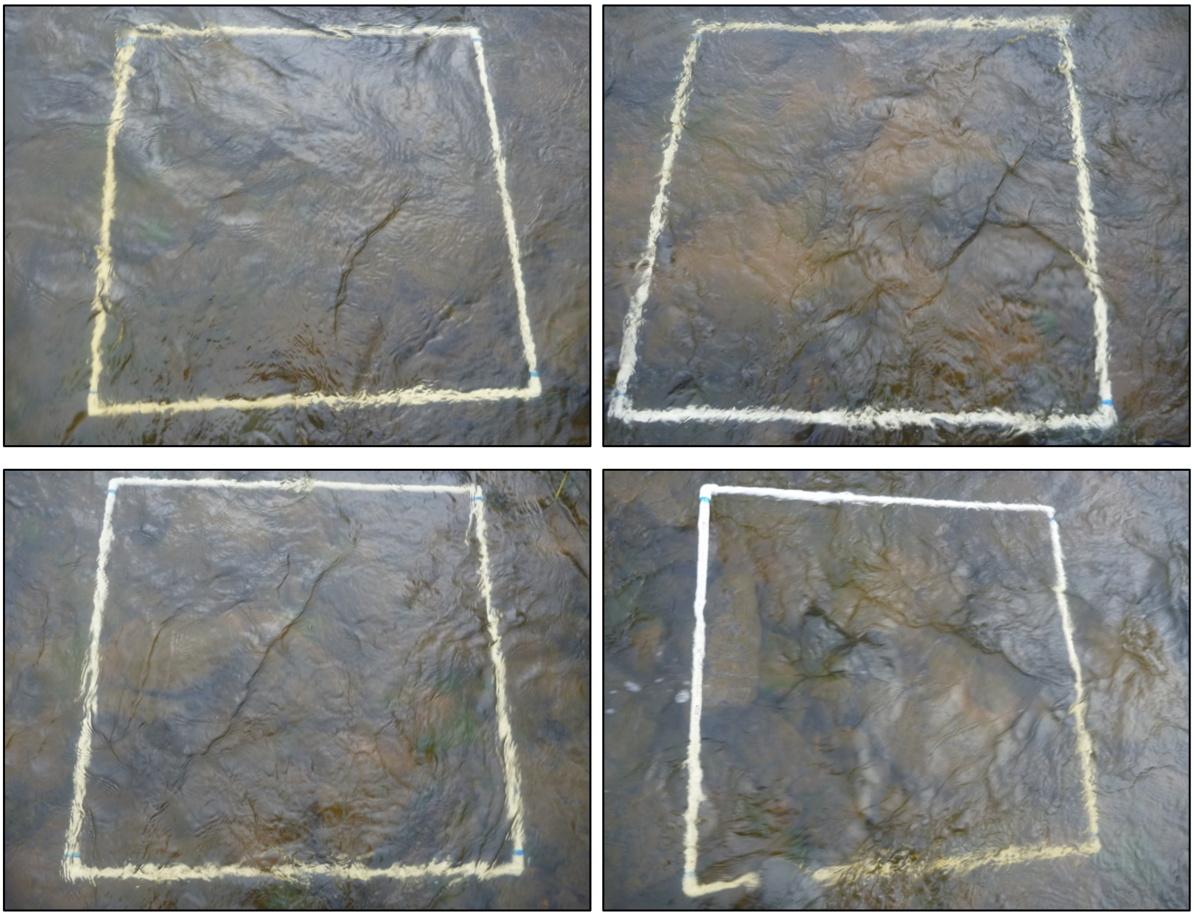
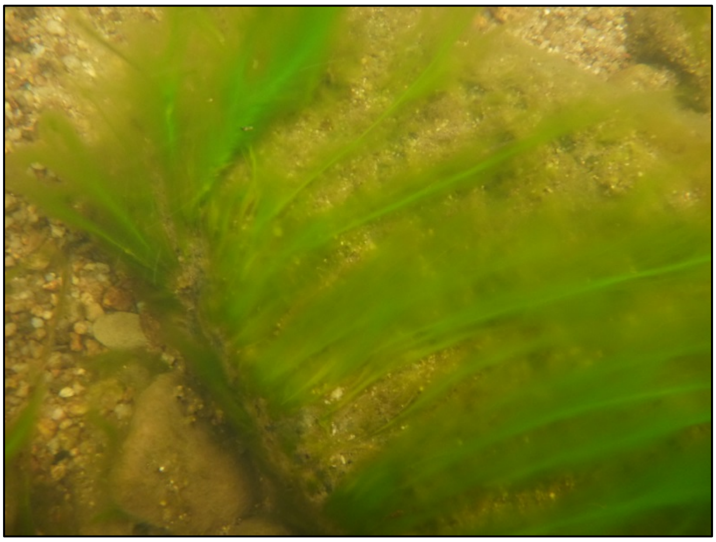


Plate 5-4. Quadrats showing periphyton coverage at MUR 28

Periphyton coverage of the substrate was 65-90% for the reach and >90% for riffle zone, assessed using the AUSRIVAS assessments for site MUR 28 (Plate 5-4). Some submerged *Myriophyllum* sp. and *Potamogeton* sp. was found growing in patches around embedded cobbles. The dominant substrate at the site was cobble and sand. The high periphyton coverage in the riffle habitat is shown in the underwater photographs in Plate 5-5, which also shows the filamentous green algae which was also present in small patches.

a)



b)

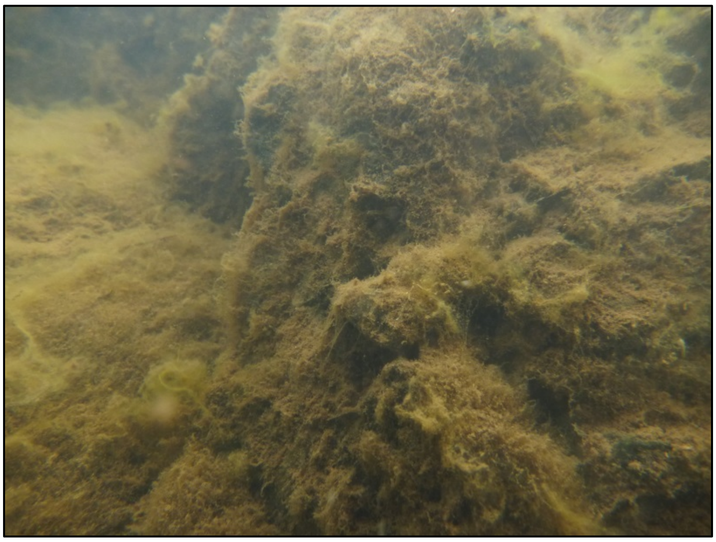


Plate 5-5. Underwater photos at MUR 28 showing periphyton coverage

MUR 935

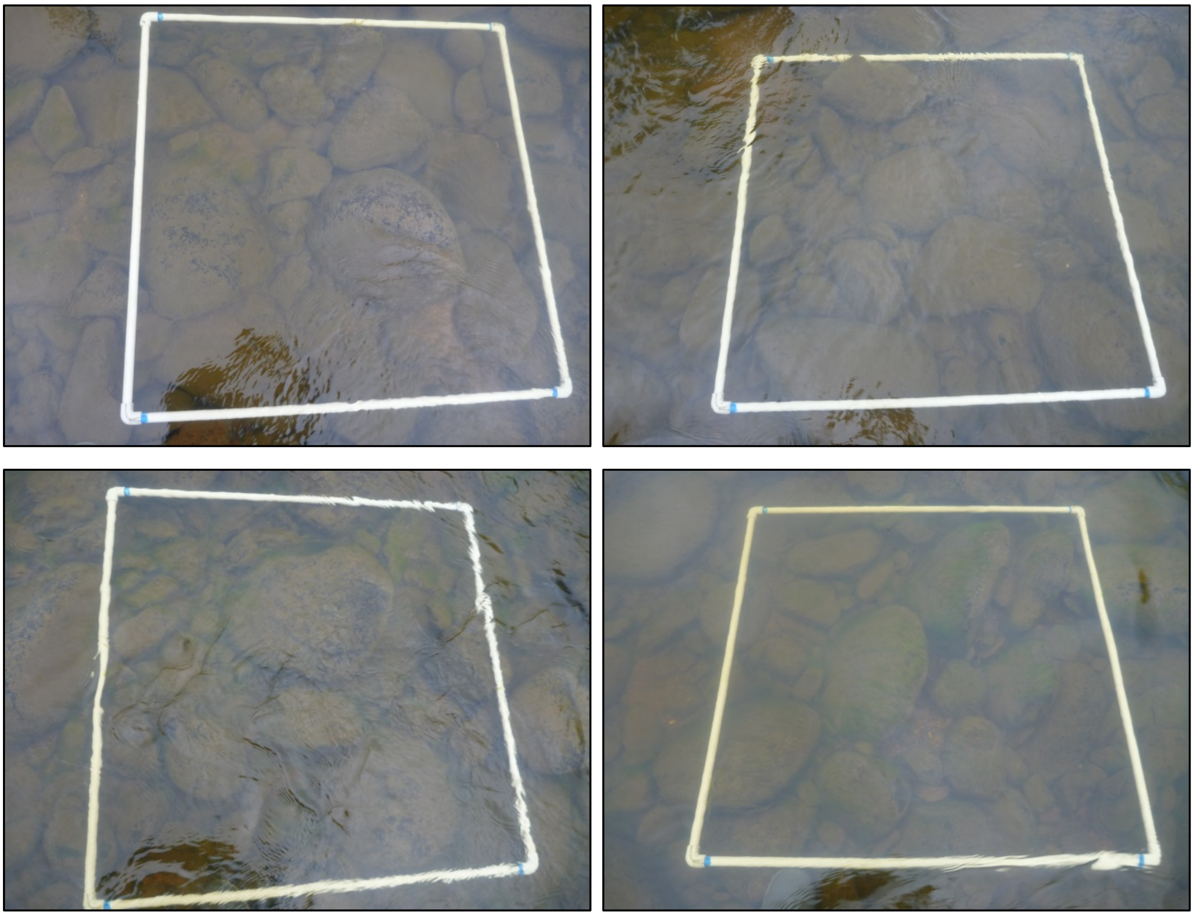
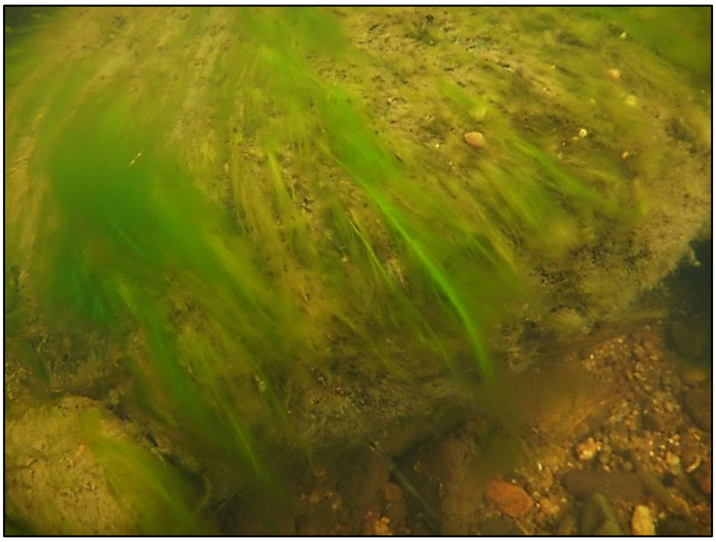


Plate 5-6. Quarats showing periphyton coverage at MUR 935

Periphyton coverage at MUR 935 was 65-90% for the reach and >90% for the riffle habitat using the AUSRIVAS assessment (Plate 5-6).There is evidence of filamentous green algae growth on stable submerged substrate, as demonstrated in Plate 5-7, while scattered patches of *Myriophyllum sp.* were present throughout the reach. The substrate is dominated by cobbles and boulders.

a)



b)

Plate 5-7. Underwater photos at MUR 935 showing periphyton coverage

5.5 Macroinvertebrates

Total richness at the MPS sites was consistently higher at the upstream site, MUR 28, across both habitats when compared to the downstream site, MUR 935 (Table 5-3). A larger number of unique taxa were collected in the edge habitat with 23 families and 29 genera recorded at MUR 28, while 21 families and 25 genera were collected at MUR 935. In the riffle habitat 21 families were recorded at MUR 28 compared to 16 at MUR 935, while MUR 28 recorded 24 genera with 19 recorded at MUR 935 (Table 5-3). Unique taxa results from autumn 2015 were very similar (within one taxa) at MUR 28 to those recorded in autumn 2013, while MUR 935 recorded fewer taxa across all categories compared to the previous sample run (GHD, 2013b).

The number of EPT taxa recorded was much more similar than the unique taxa numbers. The same number of families (7) and genera (10) were recorded in the riffle habitat from MUR 28 and MUR 935 (Table 5-4). The edge habitat was similar with 7 families recorded at MUR 28 and 8 families recorded at MUR 935. It was the reverse for the genera with 13 recorded at MUR 28 and 12 recorded at MUR 935 (Table 5-4). The EPT taxa results from autumn 2015 are similar to those recorded during the previous sample run, autumn 2013 (GHD, 2013b).

Table 5-3. Number of taxa at family and genus level from riffle and edge habitats

Total Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
MUR 28	21	24	23	29
MUR 935	16	19	21	25

Table 5-4. Number of EPT taxa at family and genus level from riffle and edge habitats

EPT Richness	Riffle		Edge	
Site	Family	Genus	Family	Genus
MUR 28	7	10	7	13
MUR 935	7	10	8	12

5.5.1 AUSRIVAS & SIGNAL-2

The SIGNAL-2 scores from the riffle habitat were slightly higher at MUR 935 (downstream) compared to MUR 28 (upstream), they were still relatively similar at 4.75 and 4.60 respectively. This slight difference is potentially due to the absence of Gripopterygidae (SIGNAL-2 = 8) from two of the MUR 28 replicates, while it was present in all replicates from MUR 935 (Appendix F). The SIGNAL-2 results from the edge habitat were almost identical with scores of 4.58 and 4.59 at MUR 28 and MUR 935 respectively.

Results from the AUSRIVAS model indicated that all replicates from both habitats were assessed as Band A, producing an overall site assessment from both sites of Band A, which is deemed to be “similar to reference” (Table 5-5). The observed/expected scores from the riffle habitat were similar with 1.00 and 1.04 for MUR 28 and MUR 935 respectively. Results were also similar between sites in the edge habitat with 0.91 and 0.88 recorded at MUR 28 and MUR 935 (Table 5-5).

Historically, as part of the MEMP programme neither MUR 28 nor MUR 935 have received a Band A rating during either autumn or spring sampling as an overall site assessment (Table 5-6). The overall site assessment results have been consistently Band B for all seasons since the MEMP's inception, with the exception of an NRA assessment during autumn 2012 at MUR 935 (Table 5-6).

Table 5-5. AUSRIVAS and SIGNAL-2 scores for autumn 2015

Site	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
MUR 28	1	4.67	4.82	1.00	0.86	A	A	A	A	A
	2	4.56	4.42	1.00	0.94	A	A			
	3	4.56	4.50	1.00	0.94	A	A			
MUR 935	1	4.90	4.73	1.11	0.86	A	A	A	A	A
	2	4.67	4.50	1.00	0.93	A	A			
	3	4.67	4.55	1.00	0.86	A	A			

Note: NS = No sample; all Angle Crossing riffle samples are "nearly outside the experience of the model" (see Coysh et al. (2000) for details)

Table 5-6. Overall site assessments for autumn and spring samples collected since 2011

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013		Autumn 2015	Change since autumn 2013
MUR 28	B	B	B	B	B		A	↑
MUR 935	B	B	NRA	B	B		A	↑

5.6 Discussion

5.6.1 Water quality

The water quality results from the MPS sentinel monitoring sites showed that exceedances of the ANZECCC & ARMCANZ (2000) guidelines were not common. Outside of the exceedance values recorded during the high flow event at the continuous monitoring station, the only parameter to exceed the guidelines was pH. This was recorded in exceedance at both sites, upstream and downstream of the MPS, with pH slightly decreasing at the downstream site, MUR 935. This reduction is likely to be the result of a dilution factor from the water coming from the Cotter River confluence. pH at this level is not unexpected within this region of the Murrumbidgee River and is consistent with exceedances recorded during autumn 2013 and 2014, while also likely related to the period of low flows prior to autumn 2015.

5.6.2 Photogrammetry

Periphyton

Periphyton has been included in the monitoring programme for MPS to monitor the effect which flow is having upon the algal communities downstream of the abstraction point. The aim of this monitoring is to see, during operational pumping whether algal communities downstream of the MPS are increasing compared to upstream sites due to the reduction in flow through abstraction.

The photos of the substrate presented in section 5.4.1 using both the quadrat and underwater aspects, provide a good overview of the periphyton coverage at both upstream and downstream sites. The coverage of periphyton during autumn 2015 was consistent between the upstream and downstream sites with both reaches being assessed as having a coverage of 65-90%, while the riffle habitats were assessed as having a coverage of >90%. This assessment is consistent with the results from autumn 2014 at MUR 28 (GHD, 2014a; MUR 935 was not sampled in autumn 2014). These assessments will be used to compare to future levels for comparison and changes should operation of the MPS occur above the trigger level for impact assessment.

5.6.3 Macroinvertebrates and AUSRIVAS

The macroinvertebrate results from the MPS sites during autumn 2015 showed improved AUSRIVAS scores compared to autumn 2013 (MUR 28 & 935) and 2014 (MUR 28 only). Both sites were assessed as Band A (“similar to reference”), which is the first time that the overall site assessments for these sites have been over Band B (“significantly impaired”). This increase in banding is the result of increased OE/50 scores across both sites and habitats, except the edge at MUR 935 compared to the previous autumn results. The number of taxa missing from the riffle habitat replicates was limited to a single taxon (Appendix F).

While the AUSRIVAS indicate an improvement in ecological condition at these sites, it is important to note that these increases are only minor. The replicates at these sites have over the previous two autumns shown high numbers of Band A replicates. Over autumn 2013 and 2014 67% of the replicates recorded at MUR 28 have been assessed as Band A. While at MUR 935 during autumn 2013 75% of the replicates at this site were assessed as Band A. The edge habitat during autumn 2014 was the only habitat during this period not to have any replicates assessed as Band A.

6. Conclusions

The purpose of the sentinel monitoring programme is to provide a broad scale assessment of control and impact sites related to the Angle Crossing abstraction point, the discharge weir in Burra Creek and the Murrumbidgee pump station, located just downstream of the Cotter Road bridge. Specifically this programme aims to “provide confidence that the condition of the potential impact sites is broadly [sic] similar to non-impact sites across time”.

There were no obvious differences in any of the measured parameters between all of the upstream / downstream site pairs for each of the components of this sampling run. Furthermore, these results were also consistent with those of previous autumn sampling periods (see Appendix B) throughout the MEMP which suggests that in the absence of the operation of M2G or MPS, these sites are generally showing similar temporal and spatial variation. The upshot of this is that we can be confident that at each site and location there are no other site specific influences that may impose additional stresses to the aquatic environment. If that were the case (i.e. there were significant changes to one site but not the other during standby mode) then this would imply that site specific stressors may exists, which may reduce our ability to detect change if there is any, during the operational phases of M2G or MPS projects.

7. Recommendations

1. In the original format of the MEMP, the replicate AUSRIVAS scores were considered separately for each site. This was a deliberate step in the analysis process to highlight the (often high) variability with a given site and habitat. One of the questions related to applying this method is how AUSRIVAS bands are reported when there is a large amount of variation in the results. The conservative approach and the method that GHD have applied is to assign the Band farthest from Band A (Barmuta et al., 2003).

   However, now that the focus of the monitoring has changed and is now concerned with how the upstream and downstream sites are tracking on a broad temporal scale, we recommend that for the sake of meeting the specific objectives of this part of the monitoring programme and to avoid cases of no reliable assessment, that the mean O/E50 score and its subsequent Band assignment be reported from here on. Sub-sample data and assessments will continue to be provided, but the habitat scores should be reported as mean values.

2. It is recommended to use the Rapid Appraisal of Riparian Condition (RARC; Jansen *et al*., 2007) to compliment the vegetation photo points and riparian vegetation assessments. This assessment methodology is designed to be rapid and can be completed in the already allocated field time for the project at vegetation sites. This addition will improve comparability between sentinel assessments and potential impact assessment, through direct comparison of scores, complementing the current visual methodology. This method is currently being used by ACT Waterwatch and has been in use in the Upper Murrumbidgee River for some time. This method and is ideal for determining changes over longer time periods, and is therefore suitable for the sentinel component of the MEMP.

3. Photos from the current monitoring period demonstrate that weather conditions, particularly sunlight (angle, shadow, etc.) and rain, are important factors when using standalone photogrammetry monitoring. It is recommended that during sampling, a back-up field day, within one week of the macroinvertebrate monitoring, for potentially inclement weather impacting on photograph quality. This will provide some flexibility in capturing photos of adequate quality to provide the opportunity for condition assessment and comparability with previous and future seasons.

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Appendices

Appendix A - QA/QC Results

Appendix A1. QA/QC results for from autumn 2015

		Habitat	Riffle		Edge	
		Sample	1		1	
		Replicate	3	QA	1	QA
CLASS / Order	**Family / Sub-Family**	**Genus**				
ACARINA					2	2
Decapoda	Atyidae	*Paratya*			1	1
Diptera	Orthocladiinae		2	2	5	3
	Simuliidae	*Austrosimulium*	209	206	1	1
		sp.	23	23		
Ephemeroptera	Baetidae	*Baetidae Genus 1*	1	1	7	6
		Baetidae Genus 2	3	3	1	1
		sp.	2	3	3	3
	Caenidae	*Irapacaenis*			9	9
		Tasmanocoenis	5	5	5	4
		sp.				2
	Leptophlebiidae	*Jappa*	2	2		
		sp.	1	1		
Hemiptera	Micronectidae	*micronecta*			10	9
OLIGOCHAETA					118	118
Plecoptera	Gripopterygidae	*Dinotoperla*			2	2
		sp.			1	1
Trichoptera	Hydrobiosidae	*Ulmerochorema*	1	1		
	Hydropsychidae	*Cheumatopsyche*	3	3		
	Hydroptilidae	*Hellyethira*			1	1
		Orthotrichia			28	28
		Oxyethira			4	4
		sp.			7	8
	Leptoceridae	*Notalina*			1	1
		Triaenodes			1	1
		Triplectides			1	1
		Error	1.60%		3.88%	
		Pass Rate	< 5%		< 5%	
		Pass / Fail	**Pass**		**Pass**	

Appendix B - Site Summaries

Part 1: Angle Crossing

MUR18

Upstream Angle Crossing
19/5/2015 9:00 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	Alkalinity (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.2	171	8.0	42	8.14	100.2	10.85

Daily Flow: 350 ML/day

Recorded at the closest station (41001702), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2014:

Autumn 2014:

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	B	B	NRA
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Some scouring of the riffle habitat by a high flow event
- Some riffle habitat now converted to a run
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Coloburiscidae

Edge Habitat

- Edge habitat has been scoured out by a high flow event
- Dominant trailing bank vegetation was overhanging native shrubs and roots

Dominant Taxa

- None

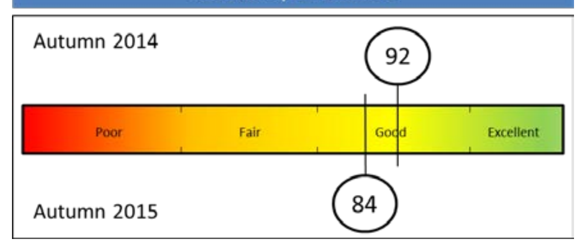
Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Sand deposits were present, likely from the most recent high flow event
- *Myriophyllum* sp. was highly abundant

Site Quality Assessment*



*Site assessment scores are derived from ACT AUSRIVAS field habitat sheets

MUR19

Downstream Angle Crossing
19/5/2015 10:45 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	Alkalinity (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.4	174	7.0	44	8.04	101.4	10.71

Daily Flow: 460 ML/day

Recorded at the closest station (410761), located on the Murrumbidgee River at Lobb's Hole.

Compared to current flow:

Spring 2014: 

Autumn 2014: 

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	B	NRA	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- *Myriophyllum* sp. and filamentous algae were common within the riffle habitat
- Dominant substrate was sand and cobble

Dominant Taxa

- Bivalvia
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

Edge Habitat

- Very few submerged macrophytes were present within the edge habitat
- Dominant trailing bank vegetation was overhanging willows (which had lost their leaves)

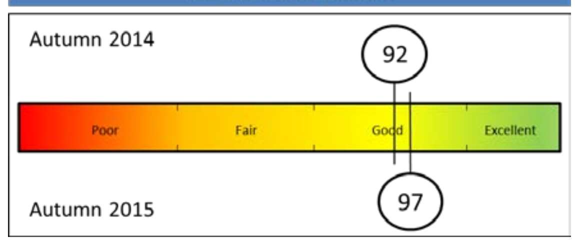
Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment



Additional Comments

- None

Part 2: Burra Creek

BUR1c

Upstream Williamsdale Road
18/5/2015 9:26 am

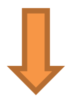
Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TDS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
6.5	428	5.1	258	7.75	86.4	9.89

Alkalinity (mg/L)	NO_x (mg/L)	TKN (mg/L)	TP (mg/L)	TN (mg/L)	Total Iron (mg/L)	Total Manganese (mg/L)
160	0.005	0.15	0.007	0.015	0.51	0.041

Daily Flow: 2.9 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2013:  Autumn 2014: 

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	B	A	B
Edge Habitat	B	A	A
Overall Site Assessment	B	A	B

Riffle Habitat

- Poor quality, highly silted habitat
- Dominant substrate was silt

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae

Additional Comments

- Very little flow

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Schoenoplectus validus*)

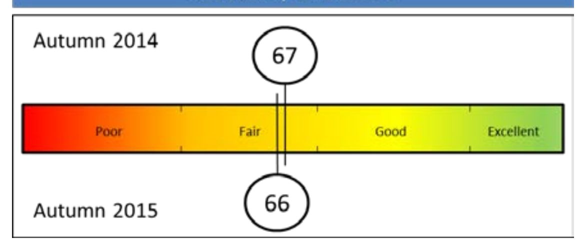
Dominant Taxa

- Aeshnidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



BUR2a

Downstream Williamsdale Road
18/5/2015 10:55 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TDS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
8.0	495	7.9	279	8.27	93.0	10.11

Alkalinity (mg/L)	NO_x (mg/L)	TKN (mg/L)	TP (mg/L)	TN (mg/L)	Total Iron (mg/L)	Total Manganese (mg/L)
198	0.230	0.12	0.010	0.35	0.60	0.052

Daily Flow: 2.9 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2013:  Autumn 2014: 

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	B	A	B
Edge Habitat	A	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Highly silted habitat
- Dominant substrate is cobble and silt

Dominant Taxa

- Chironomidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Dixidae
- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis* and *Schoenoplectus sp.*)

Dominant Taxa

- Corixidae
- Notonectidae

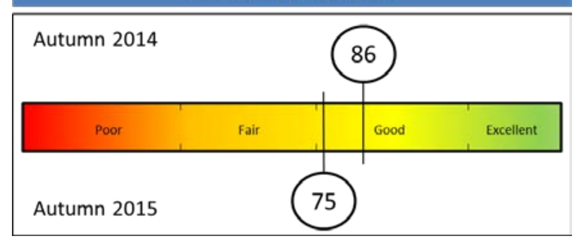
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Surface foam was present

Site Quality Assessment

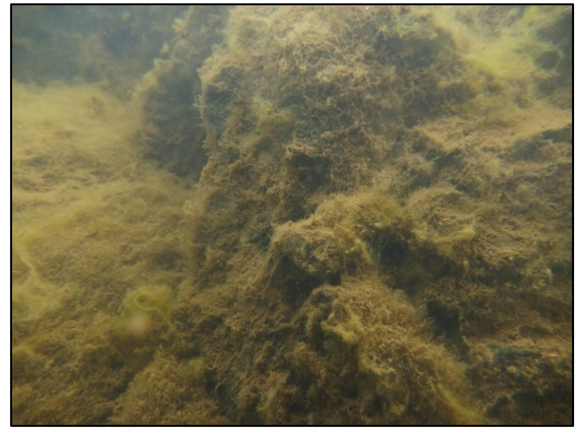


Part 3: Murrumbidgee Pump Station

MUR28

Upstream Cotter River Confluence
19/5/2015 2:50 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	Alkalinity (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.6	163	5.04	45	8.14	103.4	10.70



Daily Flow:

460 ML/day
Recorded at station 410761, located on the Murrumbidgee River at Lobb's Hole.

510 ML/day
Recorded at station 410738, located on the Murrumbidgee River at Mt. MacDonald.

90 ML/day
Recorded at station 410700, located on the Cotter River at Cotter Kiosk (below the Enlarged Cotter Dam).

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

Riffle Habitat

- Dominant substrate was boulder and sand

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was overhanging *Casuarina sp.* and blackberry

Dominant Taxa

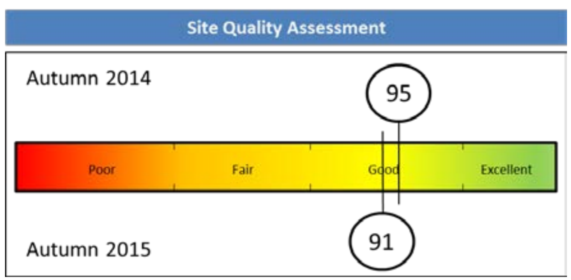
- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	B	B	A
Edge Habitat	C	A	A
Overall Site Assessment	C	B	A



Additional Comments

- Periphyton coverage was high (see photo)

MUR935

Casuarina Sands
19/5/2015 1:40 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	Alkalinity (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.2	159	6.0	48	8.06	104.4	10.96

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

Edge Habitat

- High levels of detritus present in this habitat
- Dominant trailing bank vegetation was overhanging native shrubs and *Casuarina* sp.

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Daily Flow:

460 ML/day
Recorded at station 410761, located on the Murrumbidgee River at Lobb's Hole.

510 ML/day
Recorded at station 410738, located on the Murrumbidgee River at Mt. MacDonald.

90 ML/day
Recorded at station 410700, located on the Cotter River at Cotter Kiosk (below the Enlarged Cotter Dam).

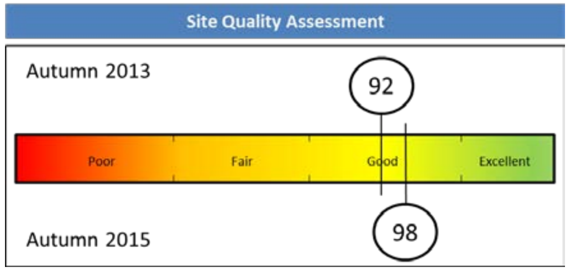
The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

	Autumn 2014	Spring 2014	Autumn 2015
Riffle Habitat	NS	NS	A
Edge Habitat	NS	NS	A
Overall Site Assessment	NS	NS	A

Additional Comments

- Periphyton and filamentous algae coverage was high throughout the site



Appendix C - AUSRIVAS habitat information

Appendix C1. AUSRIVAS habitat information collected on site during autumn 2015

Site Code	BUR1c	BUR2a	MUR18	MUR19	MUR28	MUR935
Date	18/05/2015	18/05/2015	19/05/2015	19/05/2015	19/05/2015	19/05/2015
Time	9:26	10:55	9:00	10:45	14:50	13:40
Season	Autumn	Autumn	Autumn	Autumn	Autumn	Autumn
River	Burra Creek	Burra Creek	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River	Murrumbidgee River
Location	upstream Williamsdale Road	downstream Williamsdale Road	upstream Angle Crossing	downstream Angle Crossing	upstream Cotter River Confluence	Casuarina Sands
Weather	fine	fine	overcast, rain	overcast, cold	overcast, rain, cold	rain
Cloud cover (%)	5	5	100	95	95	100
Rain during the previous week?	yes	yes	yes	yes	yes	yes
Bank Height (m)	1.5	1.5	0.5	2	0.5	2
Bank Full Width (m)	25	26	100	100	100	80
Mode Stream Width (m)	1.5	2	20	30	30	45
Length of Reach	250	260	1000	1000	1000	800
Habitat in Reach						
% Riffle	5	10	10	15	10	5
% Pool	80	75	50	45	20	35
% Run	15	15	40	40	70	60
% Edge	5	15	30	30	10	25
% Macrophyte	95	25	20	20	10	10
Mean Riffle Depth (cm)	21	25	30	26.33	28	32.67
Mean Riffle Velocity (m/s)	0.0347	0.2480	0.3093	0.7463	0.6803	0.3960
Mean Edge Depth (m/s)	30	40	123	80	36.33	61.67
Mean Edge Velocity (m/s)	0.019	0.019	0.067	0.006	0.045	0.032
Riparian Vegetation						
Mean Riparian Width (m)	2	2	3.5	5	5	5
% Trees >10m	5	2	30	20	50	10
% Trees <10m	0	8	20	30	30	40
% Shrubs	0	0	60	60	20	35

Site Code	BUR1c	BUR2a	MUR18	MUR19	MUR28	MUR935
% Grasses/Ferns/Sedges	100	90	5	10	5	15
% Shading	< 5	6 - 25	< 5	< 5	< 5	< 5
% Native	5	10	80	60	60	70
% Exotic	95	90	20	40	40	30
Observations						
Water Odours	normal	normal	normal	normal	normal	normal
Water Oils	sheen	sheen	none	none	none	none
Turbidity	clear	clear	clear	clear	clear	clear
Plume	lots	lots	some	some	some	some
Sediment Oils	absent	absent	absent	absent	absent	absent
Sediment Odours	normal	normal	normal	normal	normal	normal
Flow Level	low	low	moderate	moderate	moderate-high	moderate
Sediment Deposits	silt	silt	sand	sand	sand	sand
Local Erosion	some	some	some	some	moderate	some
Point Source Pollution	no	M2G	no	crossing	no	road, bendora scour valve, camp ground, MPS
Non-Point Source Pollution	agriculture	agriculture	agriculture	agriculture	MPS, recreational area	Cotter Confluence
Dams/Barriers	no	no	no	no	no	no
River Braiding	no	no	no	no	no	no
Site Classification	broad valley	broad valley	steep valley	steep valley	steep valley	steep valley
Left Bank Land Use	grazing	grazing, residential	grazing	exotic grassland (no grazing), native grassland (no grazing), recreational	forestry, recreational	native forest, commercial
Right Bank Land Use	grazing, residential	grazing	exotic grassland, recreational	exotic grassland (no grazing), native grassland (no grazing), recreational, commercial	commercial, recreational	native grassland (no grazing), exotic grassland (no grazing), recreational
% Bar Cover	0	0	0	0	6	0
Reach Substratum Description						
% Bedrock	0	5	5	0	20	15

Site Code	BUR1c	BUR2a	MUR18	MUR19	MUR28	MUR935
% Boulder	5	15	10	10	15	25
% Cobble	5	10	20	20	15	30
% Pebble	5	5	20	10	10	10
% Gravel	5	5	20	10	5	15
% Sand	5	0	20	45	30	20
% Silt	65	55	0	5	5	5
% Clay	10	5	5	0	0	0
% Detritus	60	10	30	30	25	10
% Muck/Mud	40	30	15	20	15	10
% Periphyton	> 90	> 90	35 - 65	35 - 65	65 - 90	65 - 90
% Moss	< 10	< 10	< 10	< 10	< 10	< 10
% Filamentous Algae	10 - 35	65 - 90	10 - 35	35 - 65	35 - 65	< 10
% Macrophytes	> 90	65 - 90	35 - 65	35 - 65	35 - 65	< 10
Riffle Substratum Description						
% Bedrock	0	5	5	0	10	20
% Boulder	0	10	15	15	15	20
% Cobble	5	10	30	25	20	30
% Pebble	15	5	10	15	10	10
% Gravel	5	5	15	15	10	5
% Sand	5	0	20	20	20	10
% Silt	55	60	5	10	10	5
% Clay	15	5	0	0	5	0
% Detritus	60	10	40	30	15	15
% Muck/Mud	80	25	20	5	10	10
% Periphyton	> 90	> 90	65 - 90	65 - 90	> 90	> 90
% Moss	< 10	< 10	< 10	< 10	< 10	< 10
% Filamentous Algae	< 10	65 - 90	10 - 35	65 - 90	35 - 65	65 - 90
% Macrophytes	65 - 90	35 - 65	10 - 35	65 - 90	35 - 65	10 - 35
Edge Substratum Description						
% Bedrock	0	30	0	0	40	15
% Boulder	5	20	0	0	10	10
% Cobble	30	15	10	0	0	15
% Pebble	20	10	15	15	0	15
% Gravel	20	10	15	15	0	15
% Sand	0	0	40	45	15	10

Site Code	BUR1c	BUR2a	MUR18	MUR19	MUR28	MUR935
% Silt	20	15	15	20	30	20
% Clay	5	0	5	5	5	0
% Detritus	35	25	60	40	20	15
% Muck/Mud	20	15	5	10	10	10
% Periphyton	> 90	65 - 90	65 - 90	65 - 90	65 - 90	65 - 90
% Moss	< 10	< 10	< 10	< 10	< 10	< 10
% Filamentous Algae	10 - 35	65 - 90	10 - 35	35 - 65	10 - 35	35 - 65
% Macrophytes	35 - 65	35 - 65	35 - 65	65 - 90	10 - 35	35 - 65
Macrophytes						
Submergent / Floating	yes	yes	yes	yes	yes	yes
Emergent	yes	yes	yes	yes	yes	yes
Habitat score	66	75	84	97	91	98

Appendix D - Additional water quality results

Appendix D1. Additional water quality grab sample results collected during autumn 2015 by ALS on behalf of Icon Water

		Site	MUR 213			MUR 890		
		Location	Angle Crossing Murrumbidgee River			Pump Station Murrumbidgee River (East Side)		
		Date	24/03/2015	14/04/2015	19/05/2015	24/03/2015	14/04/2015	19/05/2015
		Time	9:40	8:30	8:50	8:40	15:40	10:40
Test	Analyte	Units						
A2_COLERT	E.Coli	MPN/100mL	22	80	10	110	110	15
	Total	MPN/100mL	1100	>4800	230	2200	>4800	770
A9__CLOST	Pres_Count	CFU/100mL				58	186	12
	Conf_Count	CFU/100mL				<2	37	3
A9__SPHAGE	Somatic_phage	pfu/100mL				<1	120	1
ALKAL_TOT	Bicarb	mg/L	70.6		67.6		44.1	
	Carb	mg/L	<0.1		<0.1		<0.1	
	Hydrox	mg/L	<0.1		<0.1		<0.1	
	Total	mg/L	71		68		44	
AW_SO4	Sulphate	mg/L SO4					4.4	
B_ALGAE	Bacillariophyceae	No/mL	46	307	74	74	506	243
	Chlorophyta	No/mL	390	822	95	263	1389	221
	Chrysophyceae	No/mL	0	74	21	0	11	0
	Cryptophyceae	No/mL	5	106	0	0	221	11
	Cyanophyta	No/mL	21	189	0	0	0	0
	Euglenophyta	No/mL	5	53	0	0	42	0
	Pyrrophyta	No/mL	0	0	0	0	0	0
	Total Algae	No/mL	470	1600	190	340	2200	480
	Unknown	No/mL	0	0	0	0	0	0
	Xanthophyceae	No/mL	0	0	0	0	0	0
B_CHL_A2	Chlorophyll	ug/L	7.6	4.0	1.5	6.0	5.9	1.2
BACTEROID	Animal Bact QPCR	copies/L				1100000	72000	2100000
	Bacteroides PCR					detected	Detected	Detected
	Human Bact QPCR	copies/L				0	0	0
C_GIARD_TC	Crypto Recovery	%	78	52	89	82	53	72
	Cryptosporidium	oocysts/L	0.05	<0.07	<0.05	<0.05	<0.09	<0.05
	Giardia	cysts/L	<0.05	<0.07	<0.05	<0.05	<0.09	<0.05

		Site	MUR 213			MUR 890		
		Location	Angle Crossing Murrumbidgee River			Pump Station Murrumbidgee River (East Side)		
		Date	24/03/2015	14/04/2015	19/05/2015	24/03/2015	14/04/2015	19/05/2015
		Time	9:40	8:30	8:50	8:40	15:40	10:40
Test	Analyte	Units						
	Giardia Recovery	%	35	54	83	77	58	73
	Volume Analysed	L	20	14	20	20	11	20.0
	Volume Concentrated	L	20.0	14.0	20.0	20.0	11.0	20.0
COL_TRUE	True	Pt-Co	29	88	37	30	95	38
DOC	DOC	mg/L	7	10	6	8	10	6
EDTA_NTA	EDTA	ug/L		<20			<20	
	NTA	ug/L		<20			<20	
GLYPH_MELB	Glyphosate	mg/L		<0.03			<0.03	
HARD_CA	Calcium	mg/L					20	
HARD_TOT	Total	mg/L					39.0	
MSM	Metsulfuron Methyl	ug/L		<5			<5	
MWI_D_AL	Diss_Al	mg/L		0.45			0.57	
MWI_D_CA	Diss_Ca	mg/L					8.0	
MWI_D_FE	Diss_Fe	mg/L	0.11	0.55	0.53	0.12	0.57	0.42
MWI_D_MG	Diss_Mg	mg/L					4.5	
MWI_D_MN	Diss_Mn	mg/L	0.006	0.006	0.012	0.008	0.005	0.007
MWI_D_NA	Diss_Na	mg/L					8.3	
MWI_T_FE	Total_Fe	mg/L	0.47	1.5	0.84	0.30	1.4	0.66
MWI_T_MN	Total_Mn	mg/L	0.056		0.021	0.032		0.014
MWIM_D_AL	Diss_Al	ug/L	22		100			
MWIM_T_SCR	Aluminium	ug/L					1100	
	Antimony	ug/L					<3	
	Arsenic	ug/L					<1	
	Barium	ug/L					18	
	Beryllium	ug/L					0.1	
	Cadmium	ug/L					<0.05	
	Chromium	ug/L					<2	
	Cobalt	ug/L					0.5	
	Copper	ug/L					2	
	Lead	ug/L					0.7	
	Manganese	ug/L					45	
	Molybdenum	ug/L					<1	

		Site	MUR 213			MUR 890		
		Location	Angle Crossing Murrumbidgee River			Pump Station Murrumbidgee River (East Side)		
		Date	24/03/2015	14/04/2015	19/05/2015	24/03/2015	14/04/2015	19/05/2015
		Time	9:40	8:30	8:50	8:40	15:40	10:40
Test	Analyte	Units						
	Nickel	ug/L					2	
	Selenium	ug/L					<2	
	Silver	ug/L					<1	
	Zinc	ug/L					<5	
MWM_T_HG	Total_Hg	ug/L					<0.1	
NW_H_TKNC	TKN_calc	mg/L N	0.37	0.53	0.25		0.54	
NW_H_TN	Total_N	mg/L N	0.37	0.61	0.25		0.68	
NW_L_NH3	Ammonia	mg/L N	0.002	0.022	0.003		0.014	
NW_L_NO2	Nitrite	mg/L N	<0.002	0.004	0.003		0.004	
NW_L_NO3	Nitrate	mg/L N	0.002	0.074	0.001		0.14	
NW_L_NOX	Oxidised_N	mg/L N	0.002	0.078	0.004		0.14	
NW_L_PO4	Ortho_P	mg/L P	0.005	0.018	0.012		0.018	
NW_L_TP	Total_P	mg/L P	0.025	0.060	0.020		0.060	
OC_PEST_L	4.4`-DDD	ug/L		<0.010			<0.010	
	4.4`-DDE	ug/L		<0.010			<0.010	
	4.4`-DDT	ug/L		<0.010			<0.010	
	Aldrin	ug/L		<0.010			<0.010	
	alpha-BHC	ug/L		<0.010			<0.010	
	alpha-Endosulfan	ug/L		<0.010			<0.010	
	beta-BHC	ug/L		<0.010			<0.010	
	beta-Endosulfan	ug/L		<0.010			<0.010	
	cis-Chlordane	ug/L		<0.010			<0.010	
	delta-BHC	ug/L		<0.010			<0.010	
	Dieldrin	ug/L		<0.010			<0.010	
	Endosulfan sulfate	ug/L		<0.010			<0.010	
	Endrin	ug/L		<0.010			<0.010	
	Endrin aldehyde	ug/L		<0.010			<0.010	
	Endrin ketone	ug/L		<0.010			<0.010	
	gamma-BHC	ug/L		<0.010			<0.010	
	Heptachlor	ug/L		<0.005			<0.005	
	Heptachlor epoxide	ug/L		<0.010			<0.010	

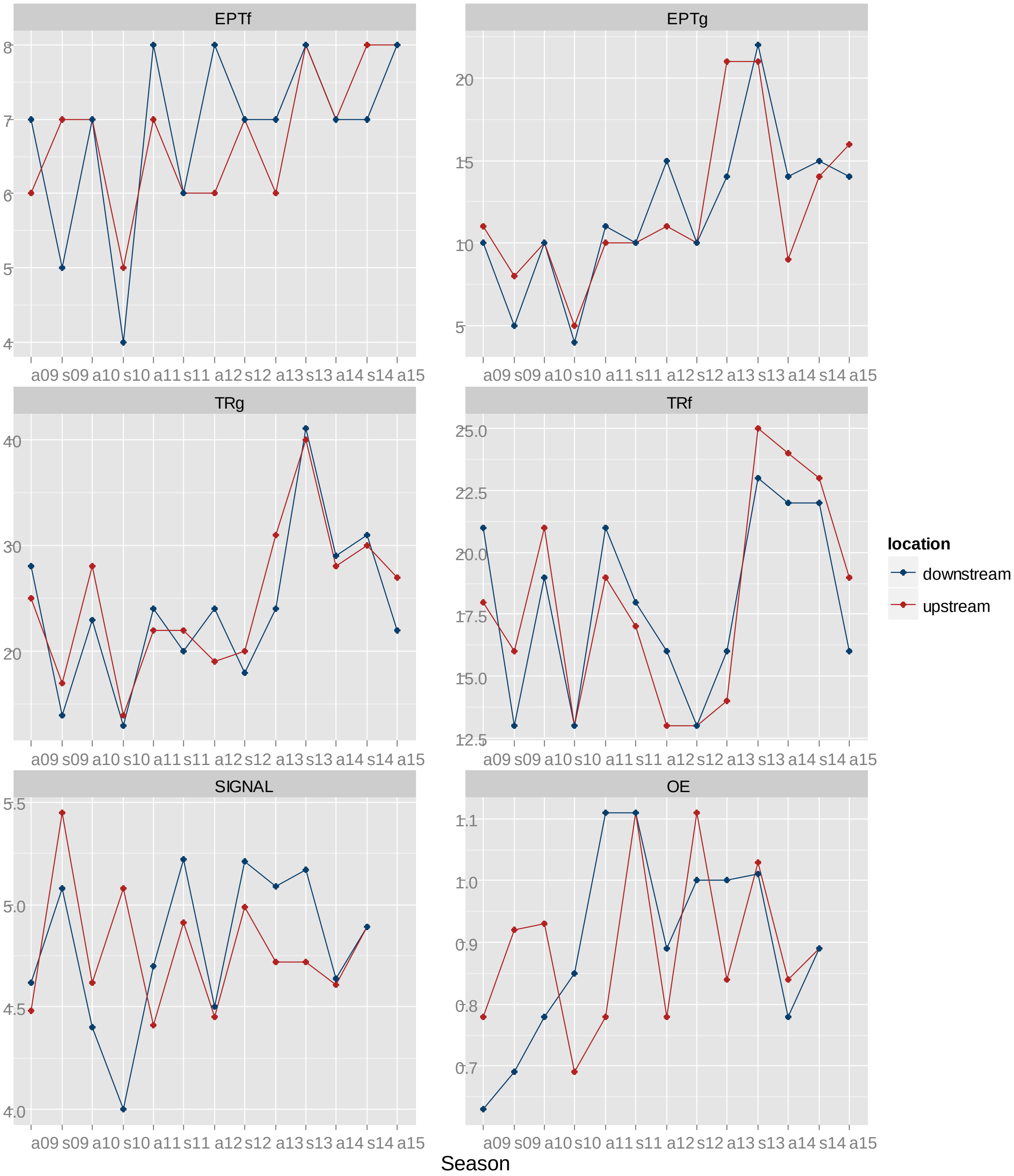
		Site	MUR 213			MUR 890		
		Location	Angle Crossing Murrumbidgee River			Pump Station Murrumbidgee River (East Side)		
		Date	24/03/2015	14/04/2015	19/05/2015	24/03/2015	14/04/2015	19/05/2015
		Time	9:40	8:30	8:50	8:40	15:40	10:40
Test	Analyte	Units						
	Hexachlorobenzene (HCB)	ug/L		<0.010			<0.010	
	Methoxychlor	ug/L		<0.010			<0.010	
	Oxychlordane	ug/L		<0.010			<0.010	
	trans-Chlordane	ug/L		<0.010			<0.010	
PHN_A_HB_L	2.4.5-T	ug/L		<0.01			<0.01	
	2.4.5-TP	ug/L		<0.01			<0.01	
	2.4.6-T	ug/L		<0.1			<0.1	
	2.4-D	ug/L		0.01			0.04	
	2.4-DB	ug/L		<0.01			<0.01	
	2.4-DP	ug/L		<0.01			<0.01	
	2.6-D	ug/L		<0.1			<0.1	
	4-Chlorophenoxyacetic Acid	ug/L		<0.01			<0.01	
	Clopyralid	ug/L		<0.05			<0.05	
	Dicamba	ug/L		<0.01			<0.01	
	Fluroxypyr	ug/L		<0.05			<0.05	
	MCPA	ug/L		<0.01			<0.01	
	MCPB	ug/L		<0.01			<0.01	
	Mecoprop	ug/L		<0.01			<0.01	
	Picloram	ug/L		<0.05			<0.05	
	Triclopyr	ug/L		<0.01			0.01	
PROFILE1	Conductance	uS/cm	160	130	160	150	120	150
	Diss_Oxygen	mg/L	8.0	9.3	10.6	8.7	9.7	10.9
	pH	pH units	7.7	7.5	7.7	7.6	7.8	7.8
	Temp	deg C	20.1	14.1	9.1	20.9	15.5	9.5
SOL_TDS1	TDS	mg/L	100	100	110		83	
TBT	Tributyltin	ngSn/L		<2			<2	
TOC	TOC	mg/L	7	10	6	7	11	7
TURB	Turbidity	NTU	5.4	19	3.4	2.8	18	3.3
UV254_ABS	UV254_Abs	abs/cm	0.21	0.37	0.20	0.22	0.38	0.20
XB_CYANO	Anabaena	No/mL	0	147	0	0	0	0

		Site	MUR 213			MUR 890		
		Location	Angle Crossing Murrumbidgee River			Pump Station Murrumbidgee River (East Side)		
		Date	24/03/2015	14/04/2015	19/05/2015	24/03/2015	14/04/2015	19/05/2015
		Time	9:40	8:30	8:50	8:40	15:40	10:40
Test	Analyte	Units						
	Anabaenopsis	No/mL	0	0	0	0	0	0
	Aphanizomenon	No/mL	0	0	0	0	0	0
	Aphanocapsa	No/mL	0	0	0	0	0	0
	Aphanothece	No/mL	0	0	0	0	0	0
	Chroococcus	No/mL	0	0	0	0	0	0
	Cylindrospermopsis	No/mL	0	0	0	0	0	0
	Merismopedia	No/mL	0	0	0	0	0	0
	Microcystis	No/mL	21	0	0	0	0	0
	Nodularia	No/mL	0	0	0	0	0	0
	Oscillatoria	No/mL	0	0	0	0	0	0
	Other	No/mL	0	0	0	0	0	0
	Phormidium	No/mL	0	0	0	0	0	0
	Planktolyngbya	No/mL	0	0	0	0	0	0
	Planktothrix	No/mL	0	0	0	0	0	0
	Pseudanabaena	No/mL	0	42	0	0	0	0
	Radiocystis	No/mL	0	0	0	0	0	0
	Spirulina	No/mL	0	0	0	0	0	0
	Total Cyanophyta	No/mL	21	189	0	0	0	0
	Tychonema	No/mL	0	0	0	0	0	0

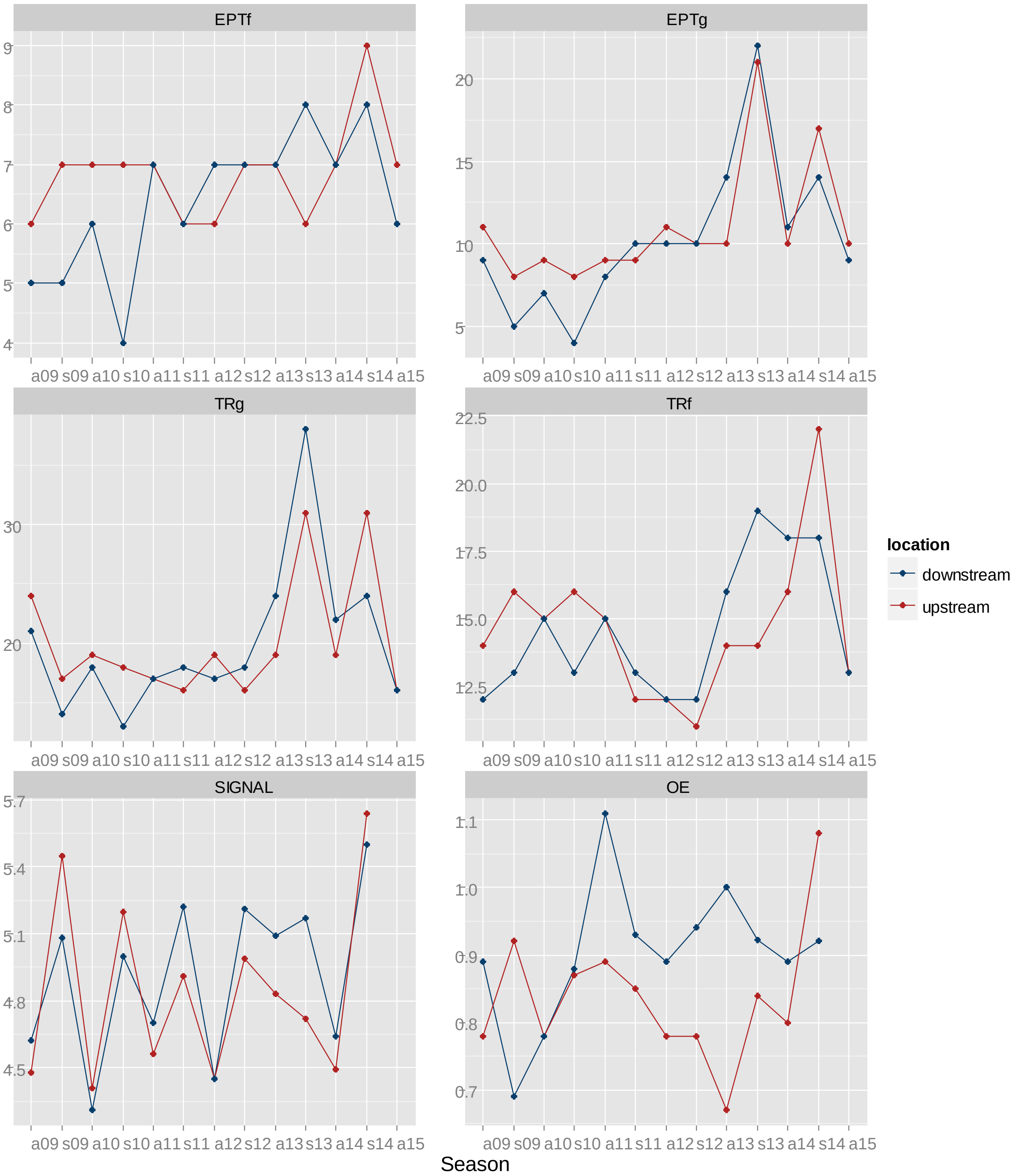
Appendix E - Historical macroinvertebrate indices

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

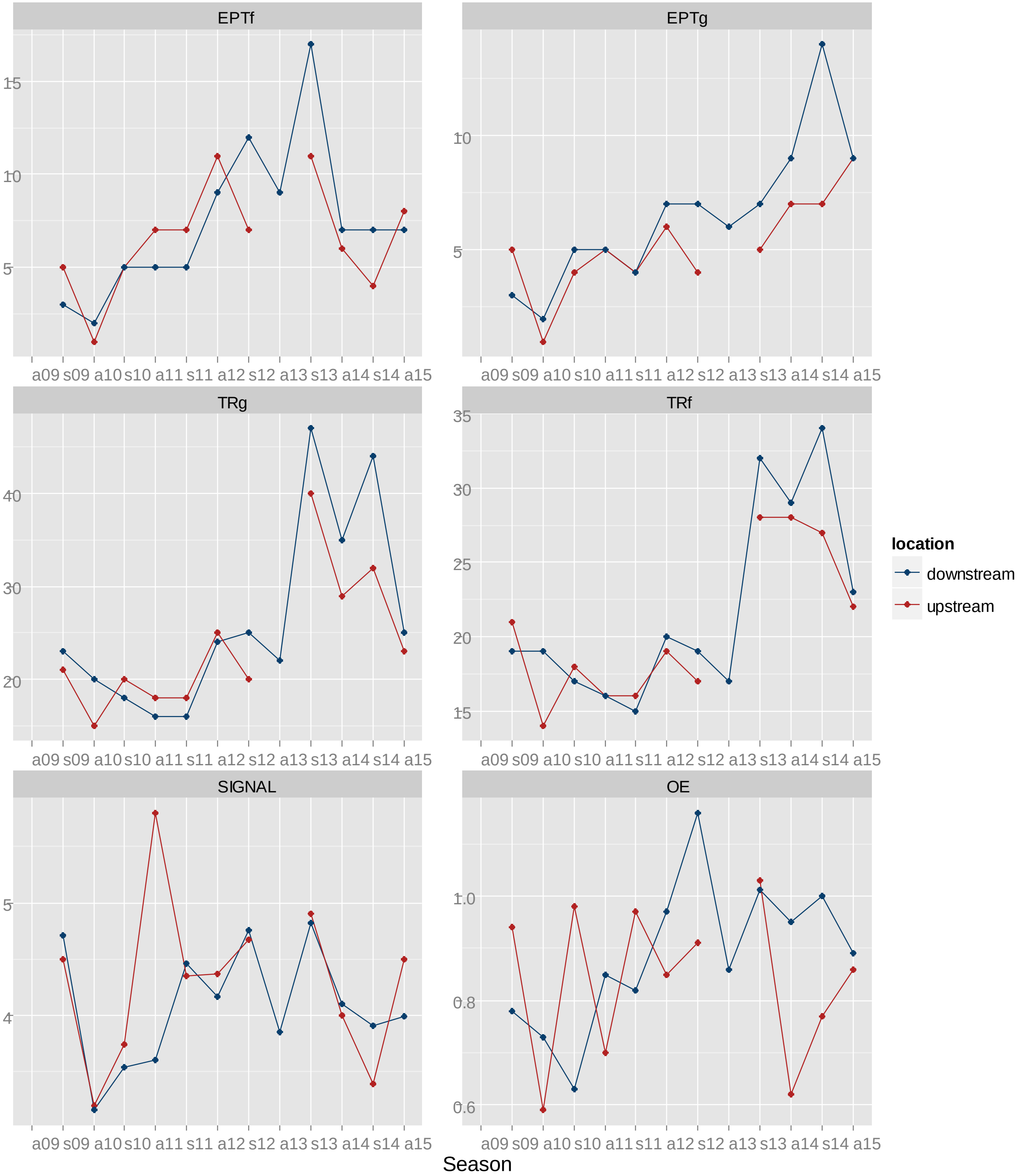
Angle Crossing EDGE - Macroinvertebrate indices between autumn 2009 and autumn 2015



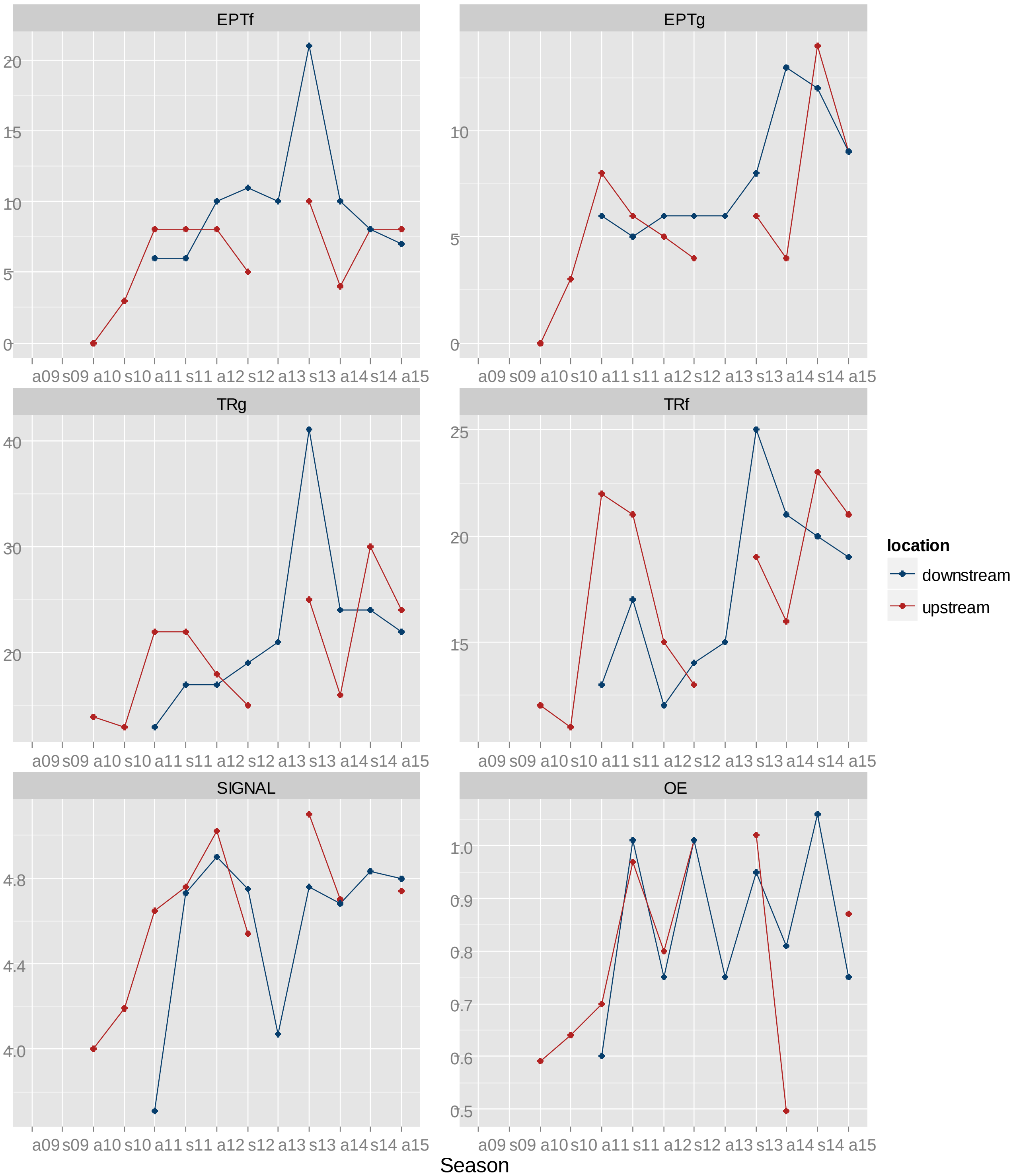
Angle Crossing RIFFLE - Macroinvertebrate indices between autumn 2009 and autumn 2015



Burra Creek EDGE - Macroinvertebrate indices between autumn 2009 and autumn 2015



Burra Creek RIFFLE- Macroinvertebrate indices between autumn 2009 and autumn 2015



Appendix F - Taxa predicted to occur with >50% probability, but were not collected

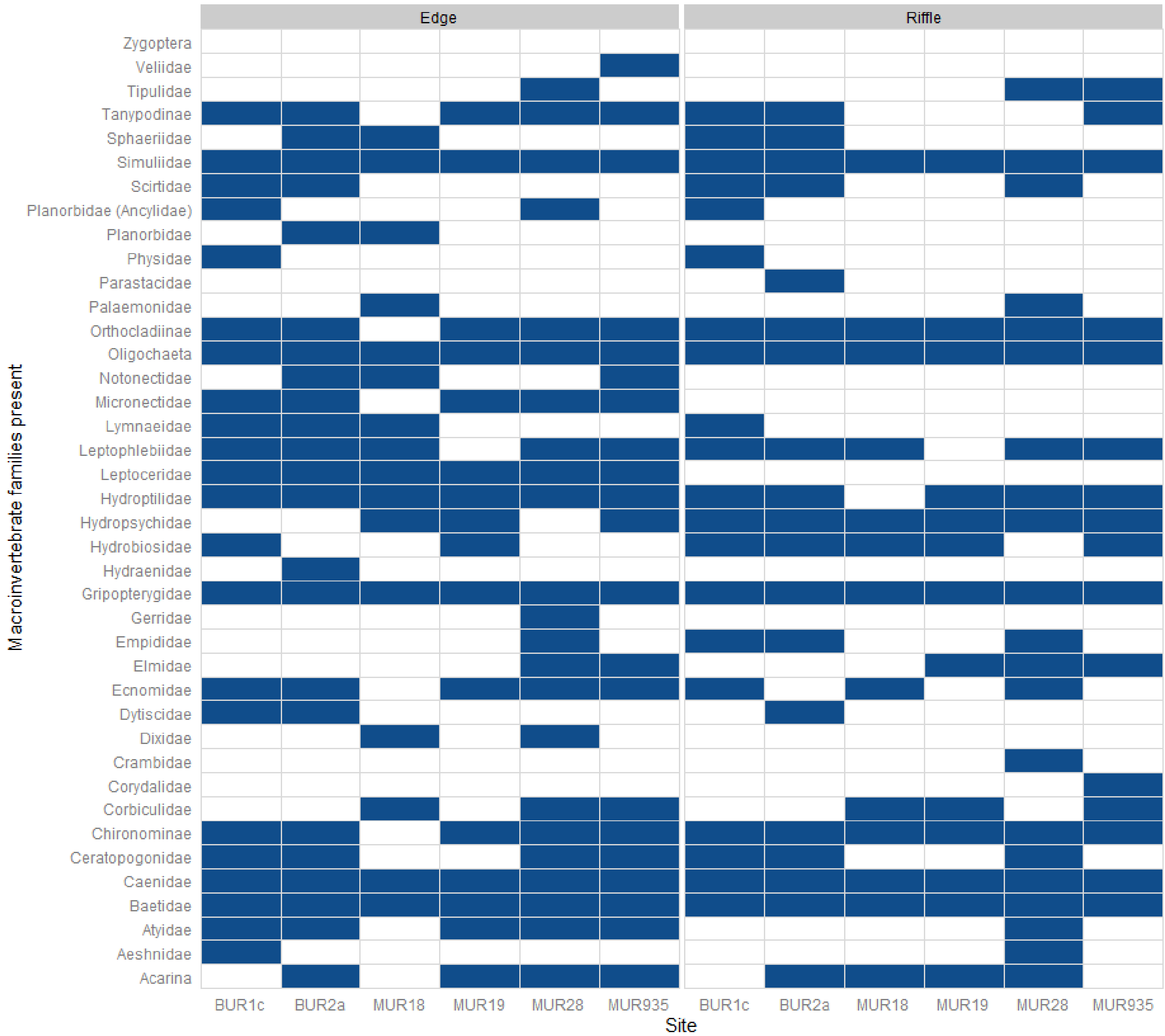
Appendix F1. Taxa predicted to occur with >50% probability but not collected in the riffle habitat

Site	Taxa	Hydrobiidae	Ancylidae	Oligochaeta	Acarina	Elmidae	Tipulidae	Podonominae	Tanypodinae	Chironominae	Beatidae	Gomphidae	Gripopterygidae	Hydrobiosidae	Hydropsychidae	Total Number of Missing Taxa
	SIGNAL-2	4	4	2	6	7	5	6	4	3	5	5	8	8	6	
BUR 1c		*0.54*	*0.54*			*1.00*		*0.57*				*0.51*		*0.84*		6
BUR 1c	Riffle	*0.54*				*1.00*		*0.57*				*0.51*				4
BUR 1c		*0.54*			*0.64*	*1.00*		*0.57*				*0.51*				5
BUR 2a		*0.55*	*0.55*			*1.00*		*0.57*	*0.68*			*0.51*		*0.84*	*0.90*	8
BUR 2a	Riffle	*0.55*	*0.55*			*1.00*		*0.57*				*0.51*			*0.90*	6
BUR 2a		*0.55*	*0.55*			*1.00*		*0.57*	*0.68*			*0.51*				6
MUR 18						*1.00*	*0.80*			*1.00*						3
MUR 18	Riffle					*1.00*	*0.80*									2
MUR 18				*0.80*		*1.00*	*0.80*			*1.00*			*0.60*			5
MUR 19							*0.80*				*0.80*				*1.00*	3
MUR 19	Riffle					*1.00*	*0.80*			*1.00*						3
MUR 19						*1.00*	*0.80*			*1.00*						3
MUR 28						*1.00*										1
MUR 28	Riffle												*0.60*			1
MUR 28													*0.60*			1
MUR 935																0
MUR 935	Riffle					*1.00*										1
MUR 935						*1.00*										1

Appendix F2. Taxa predicted to occur with >50% probability but not collected in the edge habitat

Site	Taxa	Planorbiidae	Hydrophilidae	Elmidae	Tanypodinae	Orthocladiinae	Chironominae	Beatidae	Leptophlebiidae	Caenidae	Corixidae	Synlestidae	Gripopterygidae	Ecnomidae	Conoesucidae	Leptoceridae	Total Number of Missing Taxa
	SIGNAL-2	2	2	7	4	4	3	5	8	4	2	7	8	4	7	6	
BUR 1c	Edge	*0.51*	*0.51*	*0.67*							*0.63*				*0.50*		5
BUR 1c		*0.51*	*0.51*	*0.67*										*0.52*	*0.50*	*0.96*	6
BUR 2a	Edge	*0.50*	*0.59*	*0.69*										*0.50*			4
BUR 2a		*0.50*	*0.59*	*0.69*					*0.95*					*0.50*			5
BUR 2a			*0.59*	*0.69*						*1.00*							3
MUR 18	Edge	*0.55*		*0.62*	*0.90*							*0.65*		*0.59*	*0.59*		6
MUR 18		*0.55*		*0.62*	*0.90*							*0.65*		*0.59*	*0.59*		6
MUR 19	Edge	*0.55*		*0.62*	*0.90*		*0.97*		*0.97*			*0.65*		*0.59*	*0.59*		8
MUR 19		*0.55*		*0.62*					*0.97*			*0.65*		*0.59*	*0.59*	*0.97*	7
MUR 19		*0.55*		*0.62*	*0.90*	*1.00*			*0.97*			*0.65*			*0.59*	*0.97*	8
MUR 28	Edge	*0.55*			*0.90*							*0.63*		*0.58*	*0.58*		5
MUR 28		*0.55*										*0.63*	*0.68*		*0.58*		4
MUR 28		*0.55*		*0.63*								*0.63*			*0.58*		4
MUR 935	Edge	*0.55*						*0.90*				*0.64*		*0.58*	*0.58*		5
MUR 935		*0.55*		*0.63*								*0.64*			*0.58*		4
MUR 935		*0.55*		*0.63*								*0.64*		*0.58*	*0.58*		5

Appendix G - Taxonomic inventory of macroinvertebrates collected from the riffle and edge habitats



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Document Status

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