Icon Water

Murrumbidgee Ecological Monitoring Program

Vegetation Assessment

2014

Executive summary

Icon Water completed the Murrumbidgee to Googong water transfer (M2G) project in August 2012 as a means of increasing future water security for the Australian Capital Territory (ACT) and surrounding region. The transfer involves the pumping of up to a nominal 100 ML/day from the Murrumbidgee River at Angle Crossing (southern border of the ACT) via a 12 km (~1 metre diameter) buried pipeline discharging into Burra Creek (immediately upstream of Williamsdale Road), that flows to Googong Reservoir via run of river.

Burra Creek is part of the Queanbeyan River Catchment, and is known to experience a wide variety of flow levels, including periods of no flow and spate events greater than 1000 ML/day. However the majority of the flow curve is at a very low volume with a median flow of 1.4 ML/day. Burra Creek is characterised by large emergent macrophyte beds, large pools along the length of the system and limestone bedrock.

Changes in flows could lead to changes in plant species composition and change the dominance of some species over others, and thus, a reduction in flora diversity.

Vegetation monitoring in Burra Creek and Murrumbidgee River aims to determine whether increased water flow from the operation of M2G may result in:

- *Irreversible and undesirable changes in the aquatic and riparian vegetation with respect to species composition (taxon richness) and their distribution;*
- *A change in the percentage of native taxa occupying the habitat, and their capacity to persist and to contribute to the functioning of the system; and,*
- *A change in the number of 'colonising' species (pioneer trees, shrubs and herbaceous species), invading the sites and causing ecosystem changes.*

This report provides the details of the Burra Creek and Angle Crossing vegetation assessments, conducted in June-July 2014, at two sites upstream and two sites downstream of the M2G discharge structure and one site upstream and one site downstream of the intake structure.

The key results from the riparian vegetation survey show that all sites are classified as poor to moderate or moderate to poor based on the vegetation condition assessment.

The flora assessments for each location are as follows:

BUR1a – **Poor to Moderate:** *Vegetation has been subject to high levels of disturbance and is significantly modified structurally, particularly the downstream half of the site. Significant disturbance from grazing stock with few shrubs and little original groundcover was observed. Vegetation is dominated by introduced species.*

BUR1c – **Poor to Moderate:** *Native vegetation coverage is relatively good however species diversity is still dominated by introduced species. High levels of disturbance was present with shrubs and trees completely absent from the site with the exception of some Salix* sp*. In-stream vegetation is predominantly native with introduced macrophytes present.*

BUR2a – **Poor to Moderate:** *Vegetation has been subject to high levels of disturbance, and has no original tree cover, some shrubs remain and little of its original groundcover. Vegetation has a high diversity of exotic species. The in-stream vegetation is dominated by native species while the riparian vegetation is poor, with ground layer dominated by exotic pasture grasses and no continuous or intact shrub and canopy layers. The dominant trees throughout the reach are introduced.*

BUR2c – **Poor:** *The site has been highly disturbed with high levels of weed invasion. Some native species remain, with in-stream vegetation dominantly native with some introduced species also present. While tree species were all Eucalyptus spp. at the site, the overall cover of native species was minimal.*

MUR18 – **Poor to Moderate:** *Vegetation has been highly disturbed with a large portion of species identified as introduced. Native species still maintain good coverage at the site with native trees shrubs and groundcover identified. Large portions of the site are bare sand banks.*

MUR19 – **Moderate to Poor***: Overall diversity was low, with large areas of bare sand bank. While tree coverage was all introduced species, the shrub coverage was significant, composing of large portions of native species. Few small weeds were present, with some introduced grasses observed.*

The level of introduced species at the Burra Creek sites is not surprising considering the impacts from the agricultural land and stock access to the creek in areas of the upper catchment. Even though the lower catchment area within the Googong Foreshores is free of grazing stock, the weeds still dominate the creek channel, likely a result of historical agricultural activities and the spread of seeds from upstream. M2G flows will not impact on vegetation on the upper banks of Burra Creek as 100 ML/d will generally increase the creek water level by no more than 0.3 to 0.5 metres.

Potential vegetation impact from the operation of M2G will be on the plants currently inhabiting the water's edge, which are able to be inundated for short periods. However, once operation of the M2G transfer commences, it could potentially be run for extended periods of weeks or months, which will alter the composition of the fringing vegetation favouring species that can withstand inundation for long periods, but also cause die-off of herbaceous flowering plants, grasses, and some emergent macrophyte species.

We have currently established a comprehensive baseline data set and in light of the short to medium term view to keep M2G into standby mode, any additional surveys are likely to only benefit the understanding of natural changes along Burra Creek. While this is important to the understanding of how the system changes, gross changes could be monitored through photographic methods during the standby period. However, it is recommended that full surveys are carried out along Burra Creek following the operation of the M2G pipeline for a period greater than 3 weeks. This will re-establish the current condition and allow impact assessment following the full operation of M2G.

In addition to the vegetation work, an assessment of potential platypus habitat was included in this component of the MEMP as this was the most comprehensive in terms of field work and spatial coverage throughout the length of Burra Creek.

Results of this survey indicated that there are sections of Burra Creek that provide adequate riffle and pool sequences for platypus habitation; however these are highly influenced by the intermittent dry nature of the stream with riffle sections often disappearing during periods of low flow.

No evidence of platypus was detected during the vegetation survey along Burra Creek, from the M2G discharge point at Williamsdale Road down to London Bridge at the upper end of the Googong reservoir backwater zone.

The dominant substrate found within Burra Creek pools is either sand or bedrock, with very few pools maintaining a cobbled substrate, while riffle habitats are mainly cobble and gravel, these are often highly silted. The dominance of the bedrock throughout Burra Creek, particularly in the central Zone 3 and 4 sections downstream of Burra Rd, significantly reduces the usability of the banks as burrow locations for platypus. The discontinuous to non-existent riparian vegetation found along the lower reaches of the creek currently do not provide adequate shelter to support platypus.

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1. Introduction

1.1 Background

Icon Water completed the Murrumbidgee to Googong water transfer (M2G) project in August 2012 as a means of increasing future water security for the Australian Capital Territory (ACT) and surrounding region. The transfer involves the pumping of up to a nominal 100 ML/day from the Murrumbidgee River at Angle Crossing (southern border of the ACT) via a 12 km buried pipeline discharging into Burra Creek (immediately upstream of Williamsdale Road) that flows to Googong Reservoir via run of river.

Burra Creek is part of the Queanbeyan River Catchment, located to the east of the ACT. The creek is a small ephemeral waterway, which runs along the western edge of the Tinderry Range into Googong Reservoir.

The majority of the creek's catchment is pastoral, agricultural land, in addition to which there are small rural holdings with the Tinderry Range comprised of natural dry sclerophyll forest, typical of the region.

Burra Creek is known to experience a wide variety of flow levels, including periods of no flow and spate events greater than 1000 ML/day. However the majority of the flow curve is at a very low rate with a median flow of 1.4 ML/day. Burra Creek is characterised by large emergent macrophyte beds, large pools along the length of the system, and limestone bedrock.

The flash events which dominate the higher periods of flow within the system potentially have a much greater impact upon the vegetation, particularly riparian vegetation. Impact on the vegetation from pumping is likely to be greatest during periods when the M2G pipeline is required to be operating for extended periods of time (mainly during drought).

The quality, condition, and extent of riparian vegetation is closely linked to the aquatic environment, usually in a predictable pattern. This pattern relies mostly on flood disturbances and geomorphic features of the stream, which are also important in determining riparian species distribution and vegetation associations (Evans, 2003).

In addition, anthropogenic influences (such as disturbances caused by pastoral land use) influence the species composition, which get established and thrive in the creek's habitat.

Some riparian species are highly tolerant of flooding and gain a growth advantage after flooding events. Therefore, flood tolerance of different species is important for the formation of a species gradient across the riparian zones.

Changes in flows could lead to changes in species composition and dominance of some species over others, and thus, a reduction in flora diversity.

In different channel types, changes in water levels could lead to either an increase or decrease in exposed bank areas. Uncolonised riparian banks could be readily encroached by terrestrial species, and colonising species, particularly introduced weeds.

1.2 Objectives of monitoring

Burra Creek's vegetation monitoring aims to determine whether increased water flows from the operation of M2G may result in:

- Irreversible and undesirable changes in the creek's aquatic and riparian vegetation with respect to species composition (taxon richness) and their distribution;
- A change in the percentage of native taxa occupying the habitat, and their capacity to persist and to contribute to the functioning of the system; and,

- A change in the number of ‘colonising’ species (pioneer trees, shrubs and herbaceous species), invading the sites and causing ecosystem changes.

The aim of the Murrumbidgee River vegetation monitoring is to determine whether the abstraction of water may result in:

- Irreversible and undesirable changes to the aquatic and riparian vegetation with respect to species composition (taxon richness) and their distribution;
- A change in the percentage of native taxa occupying the habitat, and their capacity to persist and to contribute to the functioning of the system;
- A change in the number of ‘colonising’ species (pioneer trees, shrubs and herbaceous species), invading the sites and causing ecosystem changes.

1.3 Purpose of this report

This report provides the details of the Burra Creek and Angle Crossing vegetation assessments, conducted in June and July 2014, at two sites upstream and two sites downstream of the M2G discharge structure and one site upstream and one site downstream of the intake structure. A walk was also undertaken from the M2G discharge point down to the London Bridge arch, to describe potential impacts of M2G operation on the downstream reaches of Burra Creek.

1.4 GHD disclaimer

This report has been prepared by GHD for Icon Water and may only be used and relied on by Icon Water for the purpose agreed between GHD and the Icon Water as set out in Section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Icon Water arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the season in which the investigations were undertaken and limited access to some sections of the riparian zone. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence vegetation not evident in the season of investigation) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Methodology

The methodology used in this report is based on the Ecological Monitoring Sub Plan (ACTEW Corporation, 2010) of the M2G Operation Environment Management Plan (OEMP; ACTEW Corporation, 2012). It was expected that once the pipeline was commissioned that water transfer would commence almost immediately. Due to Googong Reservoir currently being at full supply level there is no requirement to operate the M2G pipeline in a water supply capacity. The monitoring program has been modified due to the change in operational expectation of the M2G pipeline to reflect that only maintenance pumping is occurring and is in line with methods proposed by GHD (2013).

2.1 Vegetation Assessment Methods

For the purpose of this study, the riparian zone is defined as the area of terrestrial land immediately adjacent to the creek, including the stream bank and depressions alongside the stream that are affected by periodic inundation and hydraulic disturbances.

This zone contains varying landforms, steep or gently-sloping banks, alluvial deposits and groups of associated moisture-loving or moisture-tolerant vegetation that is different to those occupying the broader, adjacent, terrestrial habitat.

The assessment comprised transects at four sites, a Random Meander Survey and Photo Monitoring.

In these reaches, the species composition and relative abundance (cover) were obtained from walk-through surveys and transects, which extended across the stream channel from one bank to the other, covering the typical riparian zones.

Transects covered the range of geomorphic features in the stream channel (sand beds, pools, bedrock shelves, cascades, cobble bars and riffles), types of riparian vegetation and variations.

The vegetation monitoring at each site qualitatively assessed the following:

- Current ‘condition’ of riparian and ‘in-stream’ aquatic vegetation with regard to taxon richness (species composition), abundance, distribution of dominant species, nativeness and the occurrence of rare and threatened species;
- Distribution and relative abundance of native and exotic vegetation;
- Capacity of the vegetation to persist, through recruitment; and contribute to the functioning of the system during M2G operation.

2.2 Seasonal AUSRIVAS Assessments

General surveys of the vegetation are also conducted at each nominated site at the time of the routine the macroinvertebrate and periphyton sampling during spring and autumn.

The surveys follow the quantitative protocols outlined in the ACT AUSRIVAS field sampling sheets (Nichols *et al*., 2000) and include assessments of:

- percent cover of vegetation types in the riparian zone;
- instream vegetation (percent cover, composition);
- percent shading;
- distribution and relative abundance of native and exotic vegetation.

In addition to these quantitative measures, extent of predominant vegetation types is determined and permanent photographic locations established to assist in recognising trends of encroachment and/or inundation, invasion of exotics, and potential gains or losses of species.

Where positive identifications cannot be made, specimens were collected as voucher specimens with all major features (i.e. leaves, shoots, fruits and/or flowers), and later identified, using plant identification guides. These guides included Costermans (2009), Eddy *et al.* (1998), Falconer (2004), Moerkerk *et al.* (2004), Richardson *et al.* (2007) and Sainty & Jacobs (2003). Some specimens were further identified by a flora expert at the Australian National University.

In recent years there have been major changes to the in-stream vegetation due to the significant scouring that has occurred from high flows due to major storm events. Much of the scouring affected macrophyte beds in both the pool and riffle sections of Burra Creek. In monitoring of the riverine vegetation as indicated above, there shall be an additional focus on the impact and re-establishment of macrophyte beds. Where root zones (rhizomes) of emergent macrophytes have remained intact, re-establishment shall be much quicker than in areas where sediment beds were scoured to bedrock.

Each site was photographed to represent the site and location of transects and plots.

2.3 Vegetation Transects

Two sites upstream and two sites downstream of the discharge structure on Burra Creek were assessed based on data collected from three transects at each site. One site upstream of the intake structure on the Murrumbidgee River was assessed consisting of three transects, while the downstream site consisted of four transects. At Burra Creek sites the transects extended from the top of the left bank to the top of the right bank, while transects at Murrumbidgee River sites only covered a single bank, due to the centre of the river not containing vegetation and steep banks and blackberry infestations on the opposite bank at both sites.

Each transect potentially encompasses three floristic zones:

a. centre of river channel, except Murrumbidgee River pools;

b. channel edge, typical of approximately the 50$_{th}$ percentile baseflow level;

c. bank edge, depicted by higher flow events up to approximately the 1 in 1 year Average Recurrence Interval event.

The focus of Burra Creek shall be the channel region impacted by the nominal 100 ML/d transfer flow, while the focus at Angle Crossing is the vegetation which could potentially be impacted by the 100 ML/d flow reduction.

Transects cover a range of geomorphic features in the stream channel (including sand beds, pools, minor bedrock shelves, gravel, cobble, and riffles).

All species intercepting the transect were recorded and used to determine the percentage cover of each species. The figures were then combined and extrapolated to represent the vegetation of the entire area of each site.

Transects were recorded using GPS coordinates for use in future monitoring. The co-ordinates are provided in Appendix A with maps showing transect locations at sites.

All terrestrial and emergent plant species growing in or extending over each plot were recorded and assigned a visually assessed cover/abundance value based on the modified five-point Braun-Blanquet scale (Wikum & Shanholtzer, 1978) as shown in Table 2-1**.**

Table 2-1. Modified Braun-Blanquet scale

Cover Abundance Score	Species coverage within transect
1	1 Sparse <5% (3 or less individuals)
2	Common <5% (Consistent / many individuals throughout plot)
3	5-25%
4	25-50%
5	50-75%
6	75-100%

Species richness, abundance, weed and native species (including rare and threatened), overall condition assessment, and provision of habitat documented for each site (Table 2-2).

Table 2-2. Vegetation attributes for monitoring

Attribute	Assessment/Measurement
Taxon richness & Composition	Number of Taxa; Species List; Rare and endangered plants
Abundance	Abundance of species recorded at each site
Pest species	Species designated as a pest by the relevant governing body
Rare and threatened species	Species designated as rare or threatened by the relevant governing body
Nativeness	% Native Taxa; % Introduced Taxa
Provision of habitat	Presence, abundance and size/class structure of standing/fallen dead wood

Vegetation Condition Assessment

Individual transect and overall site condition assessments were completed taking into consideration the following parameters:

- Species diversity, composition and cover of native vegetation, including structure and structural complexity; and dominance of natives versus exotics;
- Habitat continuity and extent; intactness;
- Weed invasion and proximity to further disturbances, or relatively undisturbed areas.

Three categories, given in Table 2-3**,** were used with the above information to describe the 'condition' of the vegetation at the study sites.

Table 2-3. Condition categories used in flora habitat assessments

Condition	Attributes- Flora
Good	Vegetation retains a high number of indigenous species, assemblages of species and structural characteristics of the pre-European equivalent. Such vegetation has usually changed very little over time, is relatively undisturbed and displays resilience to weed invasion, due to intact ground cover, shrub and canopy layers.
Moderate	Vegetation generally retains its structural integrity, containing a moderate number of indigenous species, but has been highly disturbed, and has lost some component of its original species complement. Weed invasion is significant.
Poor	The Vegetation has been subject to high levels of disturbance and has lost most of its original species. It is significantly modified structurally, and left with only a discontinuous canopy of the original tree cover, very few shrubs and very little of its original groundcover. Vegetation is dominated by exotic species, replacing much of the indigenous ground cover. Environmental weeds are dominant or co-dominant with the original indigenous species.

2.4 Whole of Creek Assessment

A whole of Creek assessment was complemented by a full length walk from the M2G discharge structure to the upper reach of Googong Reservoir. A full species list of within channel, (i.e. bank full width) vegetation was undertaken including recording the extents of predominant vegetation types.

Photographic records were established to assist in recognising trends of encroachment and/or inundation, invasion of exotics, and potential gains or losses of species diversity. The creek has been split up into six Zones which are areas which have shown a similar vegetation composition. A map of these Zones is provided in Appendix B.

2.5 Platypus habitat suitability

During the full length creek walk, notes were taken on the suitability of areas for habitation by platypus. Features that were considered included:

- Creek substrate;
- Notes on instream habitat including percent cover by emergent and submerged macrophytes;
- Bank structure features such as:
    - The structure of the bank (consolidated or unconsolidated)
    - Bank material type;
    - Notes on the bank slope.
- Complexity of root structure within the bank and riparian zone;
- Riparian vegetation (extent of overhang, width and density);
- Continuity of riparian zone.

Other notes were taken with respect to optimal habitat features including whether there were overhangs or stumps present and also the presence or absence of logs in the Creek channel and whether or not there were platypus burrows observed during the survey.

3. Results & Discussion

3.1 Seasonal AUSRIVAS Assessments

3.1.1 Vegetation type cover of riparian zone

ACT AUSRIVAS assessment methodology provides estimates of vegetation type coverage within the riparian zone. These types are divided into four categories:

- Trees >10m;
- Trees <10m;
- Shrubs;
- Grasses, ferns and sedges (GFS).

This data has been collected through the duration of the Murrumbidgee Ecological Monitoring Program (MEMP). This data is presented in Figure 3-1 & Figure 3-2, presenting the results from the most recent seasons sampling event with comparisons to the long term mean values from the historical data recorded for the duration of the project.

Spring 2013

Results from the Burra Creek vegetation survey showed that proportions of vegetation type were consistent in spring 2013 with the historical survey results. Changes at BUR 1c and 2a were related to a reduction of shrubs during the current year. There were no shrubs recorded at these locations during spring 2013, while minor changes at all other sites resulted from changes in estimations of trees, both <10m and >10m. Changing shrub coverage at these sites is not uncommon as shrubs are particularly sparse at all Burra Creek sites, with minor changes in coverage particularly noticeable as a result.

Comparatively, during spring 2013 Angle Crossing sites showed some changes in vegetation type. Upstream this change was due to a decrease in trees >10m at MUR 15, which is due to the large scale willow removal program which took place in early-mid 2013 within the reach. Downstream sites varied from the long term means with some minor changes with an increase in shrub cover at MUR 19, an increase in GFS at MUR 23 and a decrease in GFS at MUR 28. Increases in the shrub coverage at MUR 19 is due to additional growth of all shrubs present at the site (particularly on the left bank), but also some increases in the area covered by blackberry bushes on the right bank, which is likely to be new season spring growth. The increase in GFS at MUR 23 may be related to new growth of sedges along the riparian zone and new grass establishment in areas disturbed by the September 2013 high flow event.

Autumn 2014

Overall vegetation cover results during autumn 2014 for Burra Creek were similar to the historical mean coverage presented in Figure 3-2. The exception to this was the increase in GFS coverage at BUR 2b, due to decreases in all other vegetation types at this site.

Angle Crossing autumn 2014 results were similar to those from spring 2013. However, unlike Burra Creek sites during autumn 2014, all sites displayed distinct changes when compared to the historical means. There was a large increase in the coverage of trees <10m at MUR 15 & 16. This was at the expense of GFS and particularly trees >10m coverages at MUR 15, while historical means showed that most of the change at MUR 16 was due to a reduction in shrub coverage. The change in the tree coverage at MUR 15 was the result of a large scale willow removal program which took place in early-mid 2013 within the reach. The increase in trees <10m at MUR 16 suggests an increase in juvenile trees which have self-seeded.

MUR 18 & 19 showed an increase of trees <10m at the expense of GFS and shrubs respectively. Comparatively, MUR 23 & 28 showed large increases in shrub coverage with a reduction in trees <10m and GFS coverage at both sites. These changes are minor in terms of alterations to the site as a whole and may be the result of changes perceived by the recorder.

Due to the scale at which vegetation data is collected by the AUSRIVAS methodology, it can be difficult to replicate the area being assessed (with seasonal measurements determining reaches), particularly when the AUSRIVAS data is not designed to be quantitatively assessed like it is here, specifically for riparian vegetation assessments. This data is simply collected to provide input into the AUSRIVAS model as required and assist interpretation of the model output, which may potentially be a limitation of using the AUSRIVAS methodology unrelated assessments.

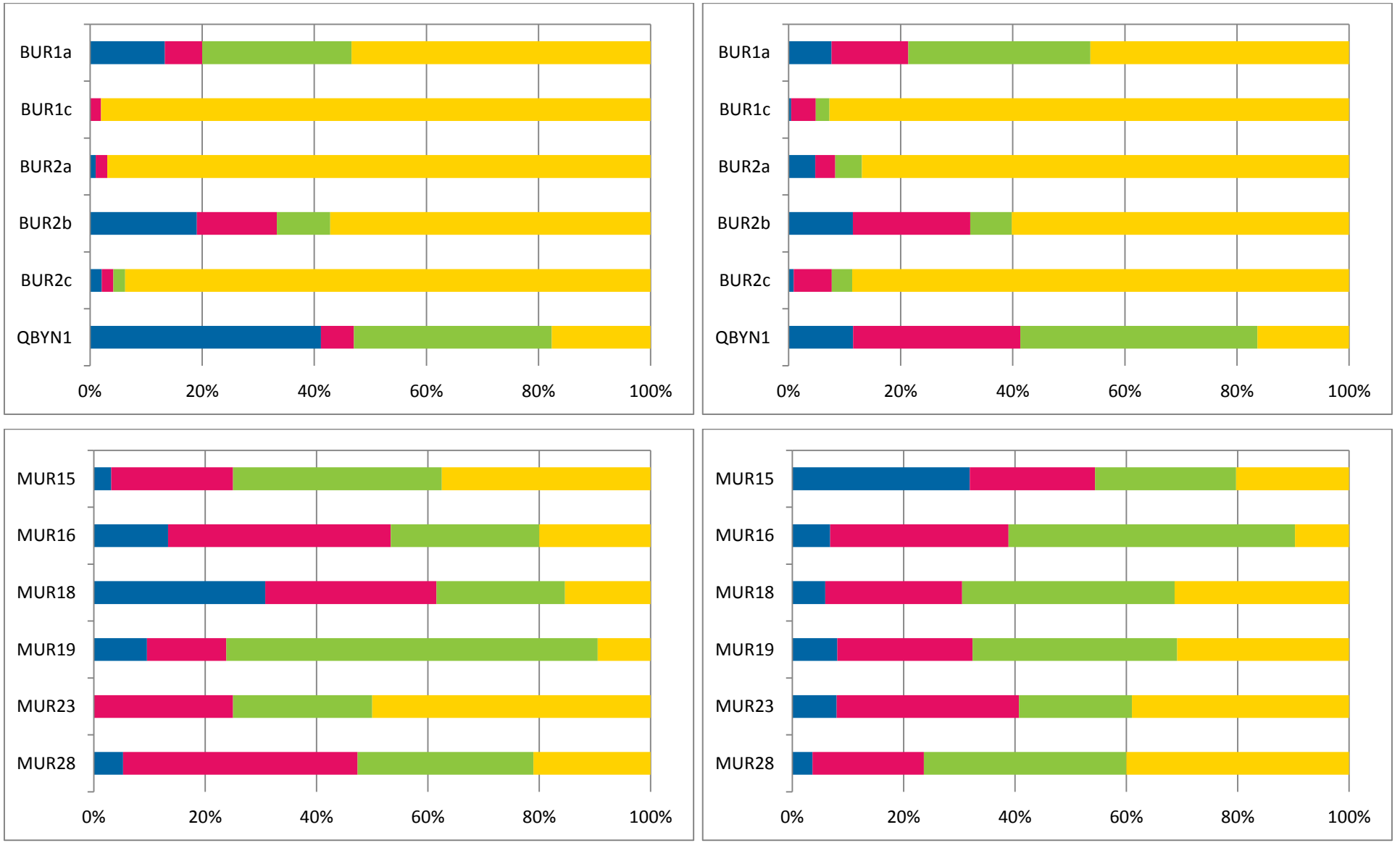

Figure 3-1. Cover of vegetation types in the riparian zone for spring 2013 (left) compared to historical spring means (right)

Note: Blue represents trees > 10m tall; Red represents trees < 10m tall; Green represents shrubs; Yellow represents grasses, ferns & sedges.

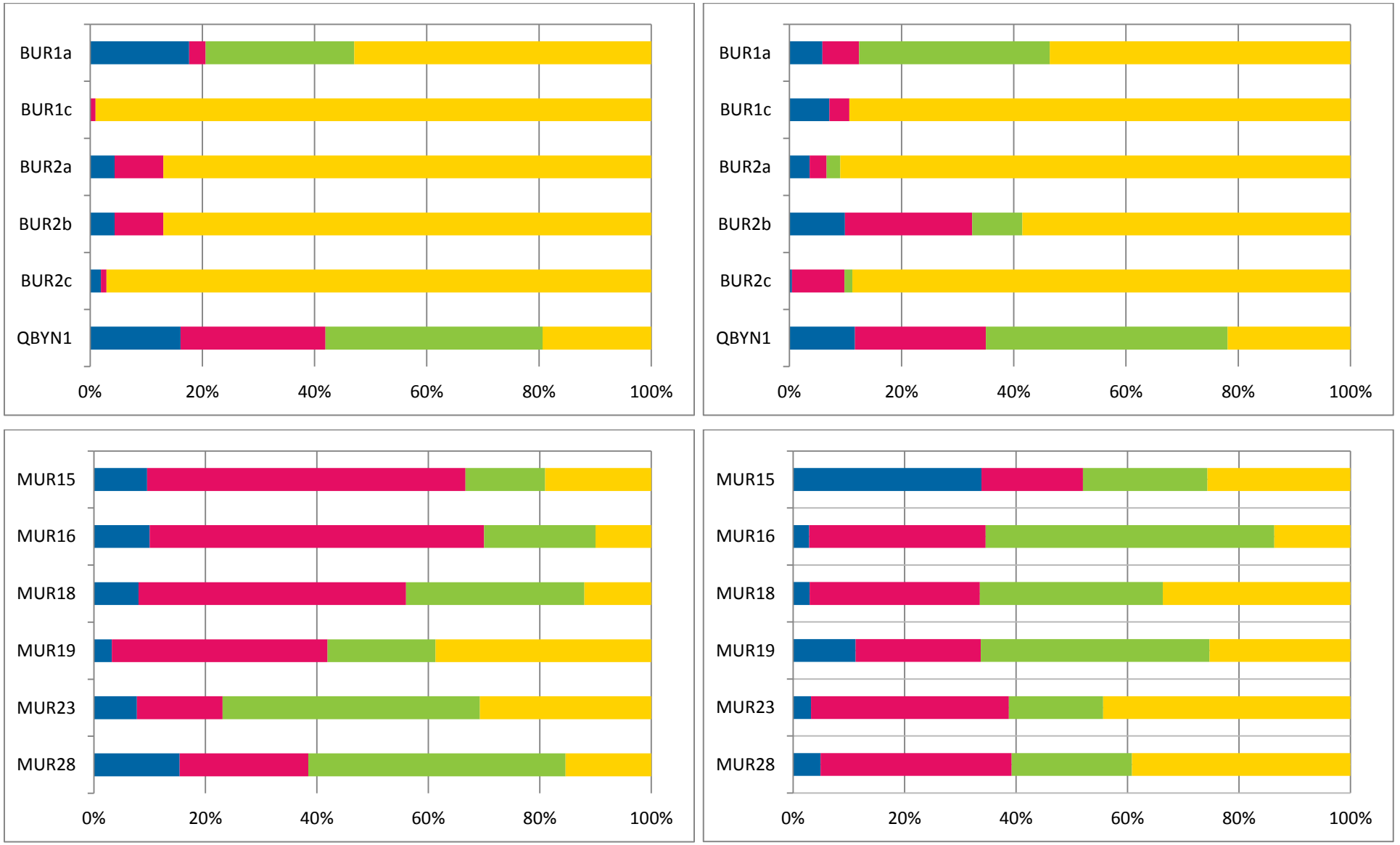

Figure 3-2. Cover of vegetation types in the riparian zone for autumn 2014 (left) compared to historical autumn means (right)

Note: Blue represents trees > 10m tall; Red represents trees < 10m tall; Green represents shrubs; Yellow represents grasses, ferns & sedges.

3.1.2 Instream vegetation

Instream vegetation was identified to genus level during seasonal AUSRIVAS assessments with species listed in Table 3-1 and Figure 3-2. Instream vegetation per cent cover for each site is displayed in Figure 3-3 and Figure 3-4 with comparisons to the long term means from previous sampling occasions during the MEMP project. AUSRIVAS assessments also divide each site into three locations, reach, riffle and edge, with each location being given an instream vegetation ranking from 1 to 5. These rankings represent a range of instream vegetation cover.

The rankings are:

- Category 1 (< 10%)
- Category 2 (10 – 35%)
- Category 3 (35 – 65%)
- Category 4 (65 - 90%)
- Category 5 (> 90%)

Rankings from the three site locations during the current seasons have been displayed in Figure 3-5 and Figure 3-6 with comparisons to historical means.

Spring 2013

Instream vegetation composition during spring 2013 is shown in Table 3-1. Most sites recorded moderate richness values, compared to historical richness values in Burra Creek, with BUR 2a recording the lowest richness values during a spring season since the inception of the MEMP (3). While richness scores at Angle Crossing sites showed a higher diversity with all sites no more than one genus from the historical maximum richness, with the exception of MUR 15 which recorded a richness of 5 (maximum richness for MUR 15 was 10 during 2009). Both BUR 2b and MUR 28 were at the opposite end of the scale showing the highest richness values recorded during a spring season with 6 and 5 genera recorded respectively.

Instream vegetation cover during spring 2013 was quite variable with some sites being recorded very close to historical means while other sites were more than 50% different compared to historical means (Figure 3-3). Spring results which deviated substantially from the means in Burra Creek were found at BUR 1c, 2a and 2b, with differences of 53.5, 22.5 and 40% respectively. The deviations from the means at Angle Crossing sites are lower than those recorded in Burra Creek, this is expected as the larger system size would create a much more stable environment for macrophyte establishment and growth. The larger deviations are 16.6, 18 and 31.6% at MUR 18, 19 and 23 respectively.

The rankings given to the three locations at each site for spring 2013 are presented in Figure 3-5. This figure shows that most spring sites and historical site means lie between the ranks of 1 – 3. BUR 1c showed the highest macrophyte cover across all locations with ranks for both reach and riffle locations far exceeding the historical means of ranks 1 and 1.5 respectively. High coverage was also recorded at BUR 2c from the edge location, with the highest rank of 5 being assigned. Angle Crossing sites overall showed similar results to those of the historical means (Figure 3-5). Substantial deviations from the historical were restricted to only three occasions. MUR 15 was recorded as rank 4 for the riffle location, while the historical mean was a rank of 4, while also in the riffle location MUR 23 was assessed as having a rank of 4, compared to the historical mean of 2.4. While the largest deviation recorded from the Angle Crossing sites was from MUR 23, where rank 1 was given to the reach location, while the historical mean is more the two ranks higher at 3.2.

Autumn 2014

Instream vegetation composition from autumn 2014 is detailed in Table 3-2, which also displays richness minimums and maximums from the historical sampling throughout the MEMP at those sites. Sites upstream of the discharge point on Burra Creek showed very little species diversity, recording the lowest or equal lowest richness values recorded at those sites. Comparatively, the downstream and control sites showed moderate richness values. All Angle Crossing sites, excluding MUR 15 and MUR18 showed either the highest or equal highest richness values at those sites since the inception of the MEMP during autumn. MUR 18, however, showed the equal lowest richness of 4. The low number is consistent for this site with 4 macrophyte genera being recorded during 2009, 2012, 2013 and in the present survey. This is also the first year where more than 5 macrophyte genera have been identified at MUR 23 during autumn.

At the Burra Creek sites, the largest difference between autumn 2014 coverage and the historical data was found at BUR 2b (26.3%), followed by BUR 1c and 1a at 20.0 and 14.3% respectively. Angle Crossing sites showed higher similarity between historical means and autumn 2014 values than Burra Creek sites, with the largest difference found at MUR 18 of 14.2%.

The macrophyte coverage rankings displayed in Figure 3-6 show the results from autumn 2014 with comparisons to the historical means. At the Burra Creek sites, rankings at BUR 1c for all three locations were assessed as rank 5, the highest level of coverage of >90%.

There is a difference of two rankings between the historical mean and the ranking given to BUR 2a for the reach, which is the largest difference of all sites across all locations for the Burra Creek sites. From the Angle Crossing sites MUR 23 also received the rank of 5 (>90%) for two locations (reach and edge), while the riffle location was only ranked as 3 during autumn 2014. Instream vegetation coverage was ranked higher than the historical means across all locations at MUR 15, 19 and 23, while comparatively MUR 18 ranked below the historical means at the three locations.

Table 3-1. Instream vegetation identified during spring 2013

Site	Waterway	Macrophytes (genus names)	Richness (2013)	Minimum Richness (Year)	Maximum Richness (Year)
BUR1a	Burra Creek	*Juncus*, *Isolepis*	2	1 (2011)	6 (2009, 2012)
BUR1c	Burra Creek	*Myriophyllum*, *Eleocharis*, *Juncus*, *Typha*	4	3 (2011)	6 (2012)
BUR2a	Burra Creek	*Potamogeton*, *Juncus*, *Phragmites*	3	3 (2013)	8 (2008)
BUR2b	Burra Creek	*Myriophyllum*, *Potamogeton*, *Phragmites*, *Ranunculus*, *Typha*, *Isolepis*	6	3 (2009)	6 (2010, 2013)
BUR2c	Burra Creek	*Myriophyllum*, *Potamogeton*, *Carex*, *Eleocharis*, *Juncus*	5	4 (2012)	7 (2011)
QBYN1	Queanbeyan River	*Myriophyllum*, *Carex*, *Eleocharis*, *Juncus*, *Ranunculus*	5	0 (2011)	10 (2009)
MUR15	Murrumbidgee River	*Myriophyllum*, *Callitriche*, *Cyperus*, *Juncus*, *Polygonum*	5	0 (2008)	10 (2009)
MUR16	Murrumbidgee River	*Myriophyllum*, *Crassula*, *Juncus*, *Ranunculus*	4	1 (2012)	5 (2010)
MUR18	Murrumbidgee River	*Myriophyllum*, *Potamogeton*, *Callitriche*, *Eleocharis*, *Juncus*, *Polygonum*	6	0 (2008)	7 (2010)
MUR19	Murrumbidgee River	*Myriophyllum*, *Vallisneria*, *Carex*, *Cyperus*, *Juncus*, *Paspalum*, *Polygonum*	7	4 (2008, 2009)	8 (2011)
MUR23	Murrumbidgee River	*Myriophyllum*, *Callitriche*, *Cyperus*, *Eleocharis*, *Juncus*, *Phragmites*, *Ranunculus*	7	5 (2008, 2009, 2012)	8 (2011)
MUR28	Murrumbidgee River	*Potamogeton*, *Cyperus*, *Polygonum*, *Phragmites*, *Ranunculus*	5	2 (2008, 2012)	5 (2013)

Table 3-2. Instream vegetation identified during autumn 2014

Site	Waterway	Macrophytes	Richness (2014)	Minimum Richness (Year)	Maximum Richness (Year)
BUR1a	Burra Creek	*Juncus*	1	1 (2014)	6 (2009)
BUR1c	Burra Creek	*Myriophyllum*, *Eleocharis*, *Typha*	3	3 (2013, 2014)	4 (2012)
BUR2a	Burra Creek	*Myriophyllum*, *Eleocharis*, *Juncus*, *Phragmites*, *Typha*	5	2 (2012)	8 (2009, 2010)
BUR2b	Burra Creek	*Callitriche*, *Carex*, *Eleocharis*, *Juncus*, *Phragmites*, *Typha*	6	3 (2009)	7 (2011, 2013)
BUR2c	Burra Creek	*Chara*, *Myriophyllum*, *Callitriche*, *Eleocharis*, *Juncus*, *Polygonum*, *Typha*	7	3 (2012)	9 (2013)
QBYN1	Queanbeyan River	*Myriophyllum*, *Potamogeton*, *Carex*, *Cyperus*, *Eleocharis*, *Juncus*, *Polygonum*, *Ranunculus*	8	1 (2012)	11 (2009)
MUR15	Murrumbidgee River	*Myriophyllum, Vallisneria, Callitriche, Carex, Eleocharis, Juncus, Ranunculus*	7	3 (2013)	10 (2009)
MUR16	Murrumbidgee River	*Myriophyllum, Cyperus, Eleocharis, Juncus*	4	0 (2012)	4 (2009, 2014)
MUR18	Murrumbidgee River	*Myriophyllum, Callitriche, Juncus, Phragmites*	4	4 (2009, 2012, 2013, 2014)	6 (2010)
MUR19	Murrumbidgee River	*Myriophyllum, Callitriche, Carex, Cyperus, Eleocharis, Juncus, Polygonum, Ranunculus*	8	4 (2009)	8 (2014)
MUR23	Murrumbidgee River	*Myriophyllum, Callitriche, Cyperus, Eleocharis, Juncus, Paspalum, Polygonum, Phragmites, Ranunculus*	9	5 (2009, 2010, 2011, 2012, 2013)	9 (2014)
MUR28	Murrumbidgee River	*Myriophyllum, Potamogeton, Carex, Cyperus, Eleocharis, Juncus, Polygonum, Ranunculus*	5	1 (2012)	5 (2014)

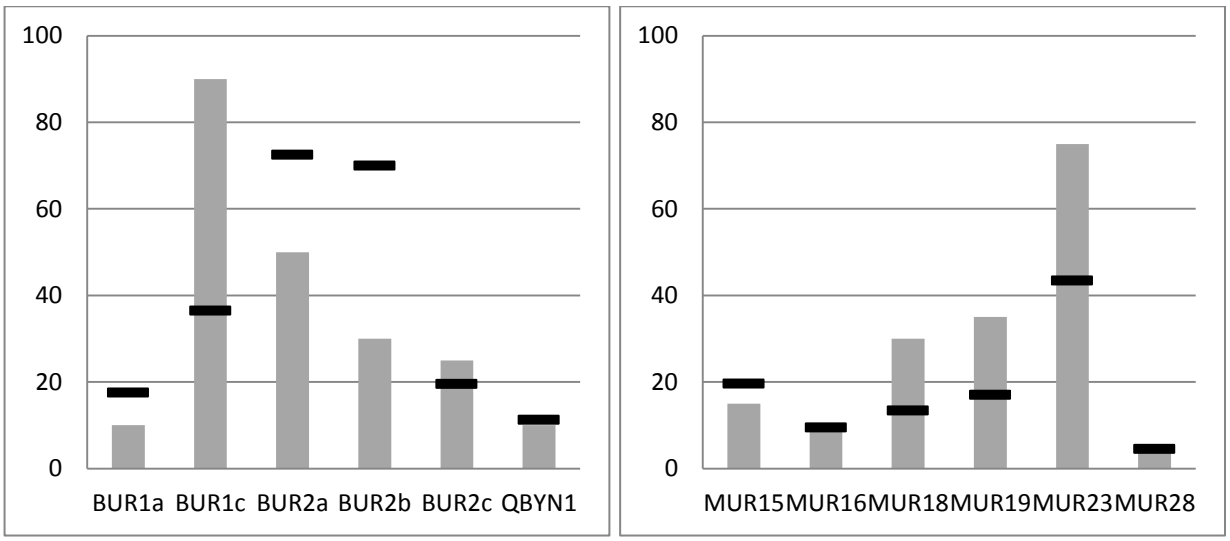

Figure 3-3. Instream vegetation cover (%) at Burra Creek and Angle Crossing sites during spring 2013 compared to historical means

Note: Grey bars show current season results; black lines represent historical means.

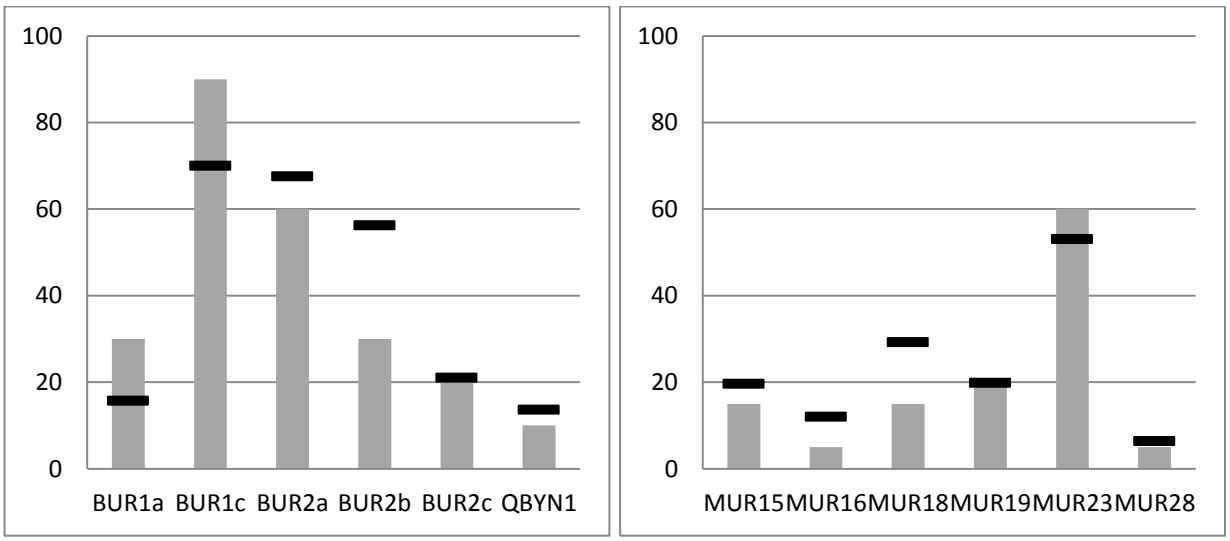

Figure 3-4. Instream vegetation cover (%) at Burra Creek and Angle Crossing sites during autumn 2014 compared to historical means

Note: Grey bars show current season results; black lines represent historical means.

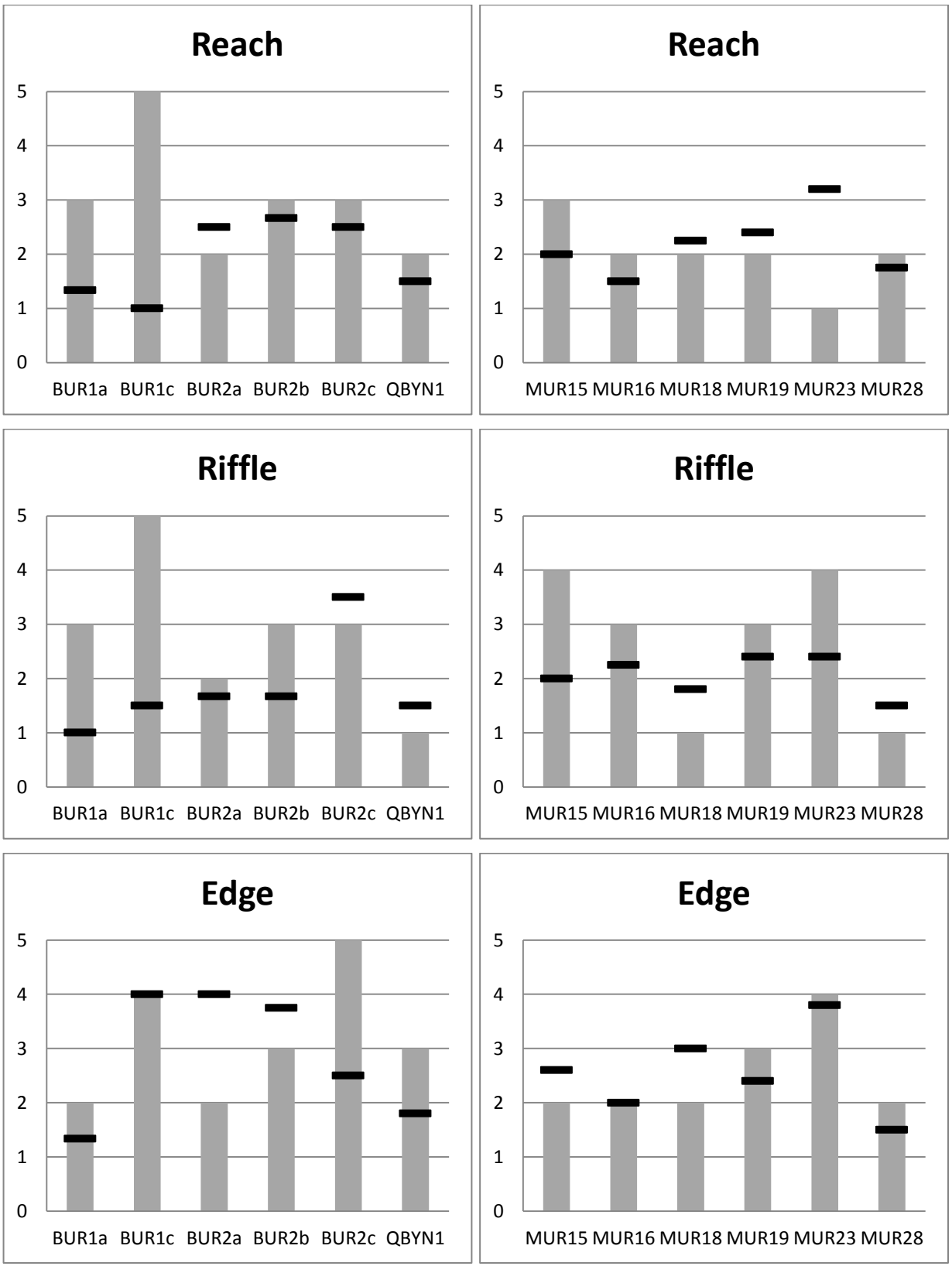

Figure 3-5. Instream vegetation recorded during spring 2013 compared to historical means separated by location

Note: Grey bars show current season results; black lines represent historical means.

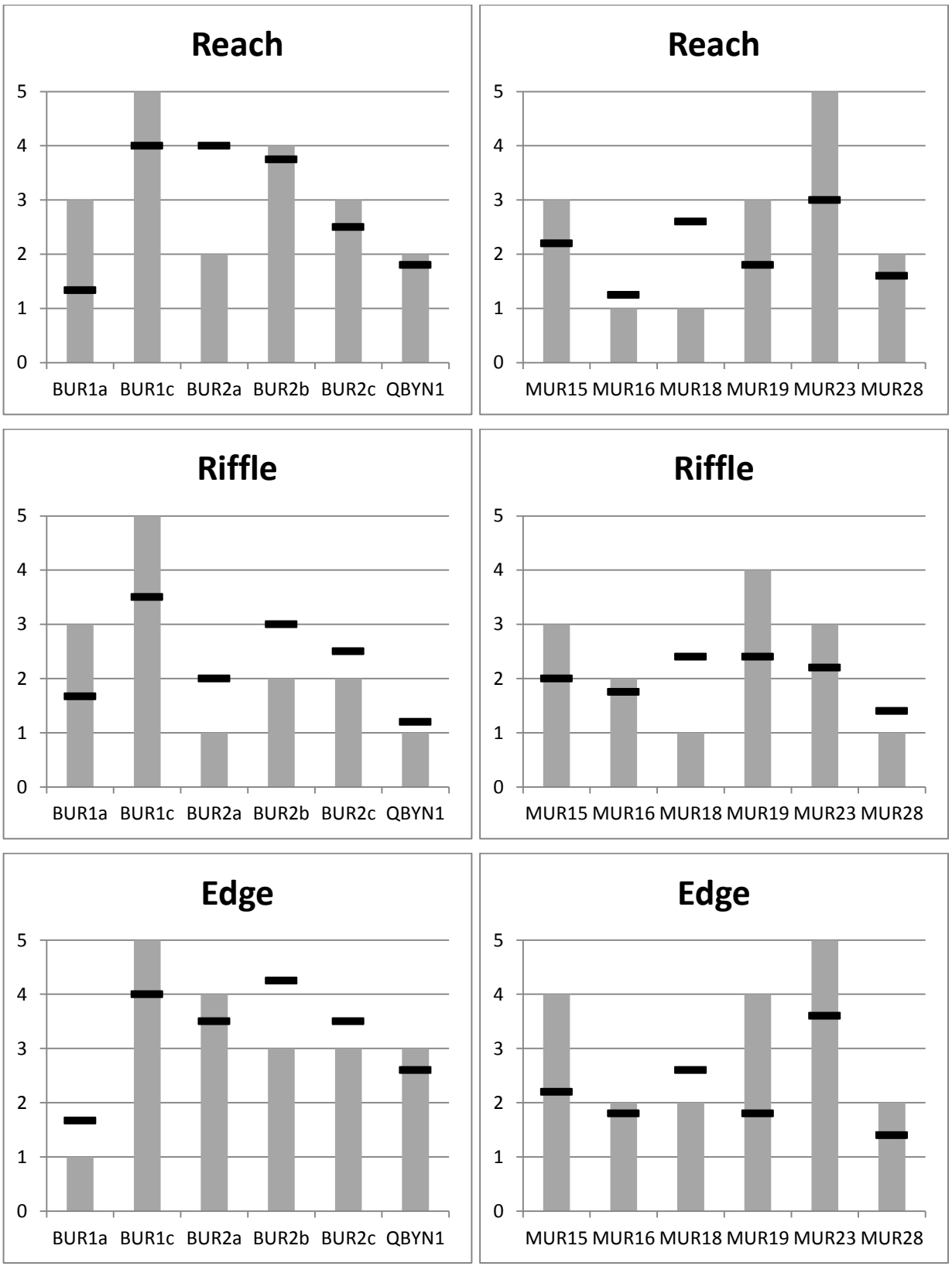

Figure 3-6. Instream vegetation recorded during autumn 2014 compared to historical means separated by location

Note: Grey bars show current season results; black lines represent historical means.

3.1.3 Shading

Shading of the waterway as per cent cover for each site is displayed in Figure 3-7 and Figure 3-8 with comparisons to the long term means from previous sampling occasions during the MEMP project. Each site is given a shading ranking from 1 to 5 with each ranking defining a range of shading per cent cover.

The rankings are:

- Category 1 (< 5%)
- Category 2 (6 – 25%)
- Category 3 (26 – 50%)
- Category 4 (51 - 75%)
- Category 5 (> 76%)

Spring 2013

Shading in spring 2013 was consistently low across all sites with rankings of either 1 or 2 (Figure 3-7). For both systems, the farthest upstream site was ranked 2, while all sites downstream of this point were ranked 1. This increased shading level at MUR 15 and BUR 1a corresponds to increased riparian vegetation at these sites, with a high proportion of large native trees and BUR 1a compared to other Burra Creek sites and some large overhanging trees present at MUR 15. This pattern is seen in the historical means also, with all means between rank 1 and 2, with the furthest upstream sites ranked either 2 or slightly higher.

Autumn 2014

Shading in autumn 2014 was similar to spring 2013 with consistently low rankings across all sites (Figure 3-8). All Murrumbidgee sites were ranked as 1, with historical means for all sites between rank 1 and 2. This was also the case for all downstream Burra Creek sites however the two upstream sites were both ranked 2, which also matched historical means of 2 for BUR 1a and between rank 2 and 3 for BUR 1c. Increased riparian vegetation, particularly large native trees increase the shading levels at BUR 1a, while increased shading at BUR 1c is the result of large stands of macrophytes covering most of the creek channel.

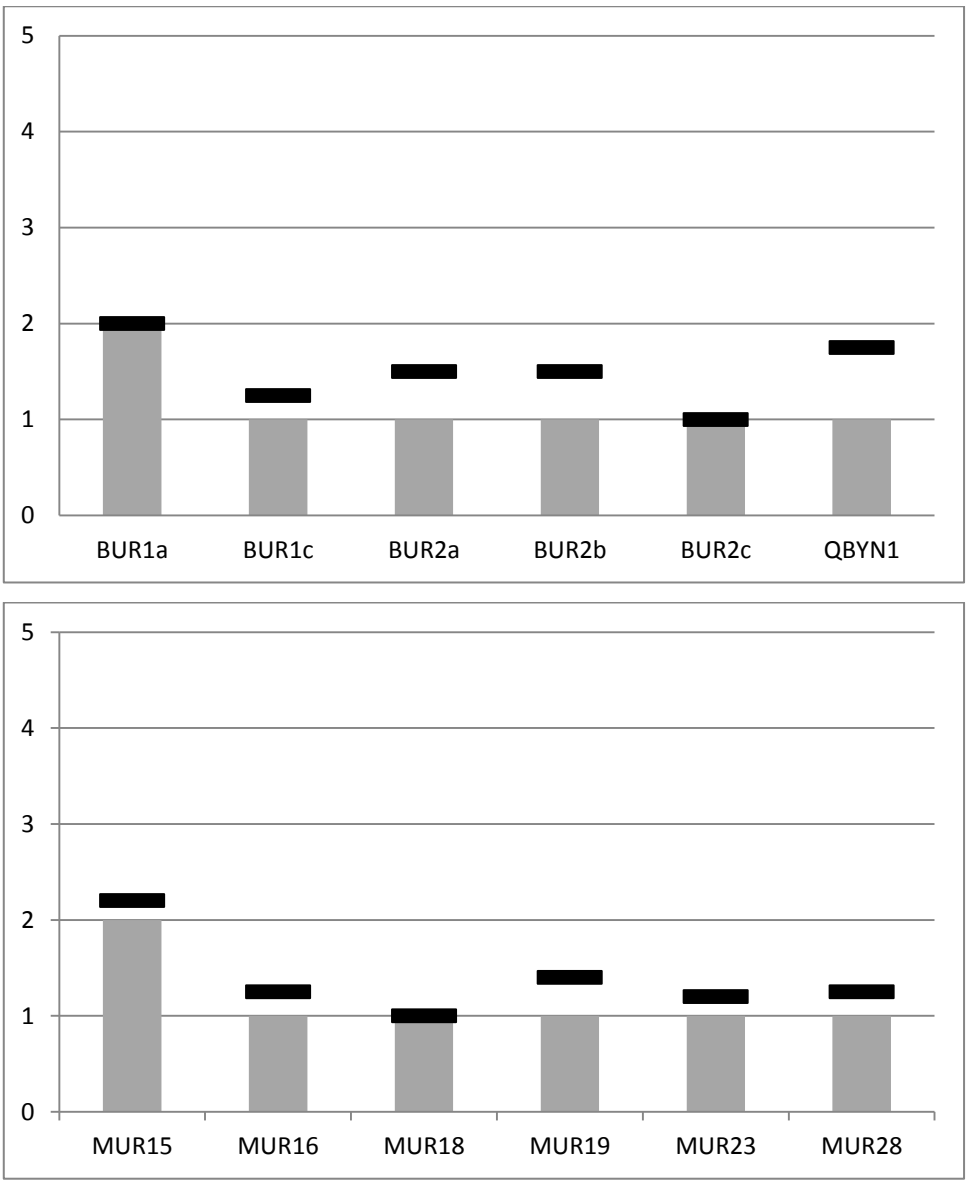

Figure 3-7. Shading of Burra Creek and the Murrumbidgee River during spring 2013 compared to historical spring means

Note: Grey bars show current season results; black lines represent historical means.

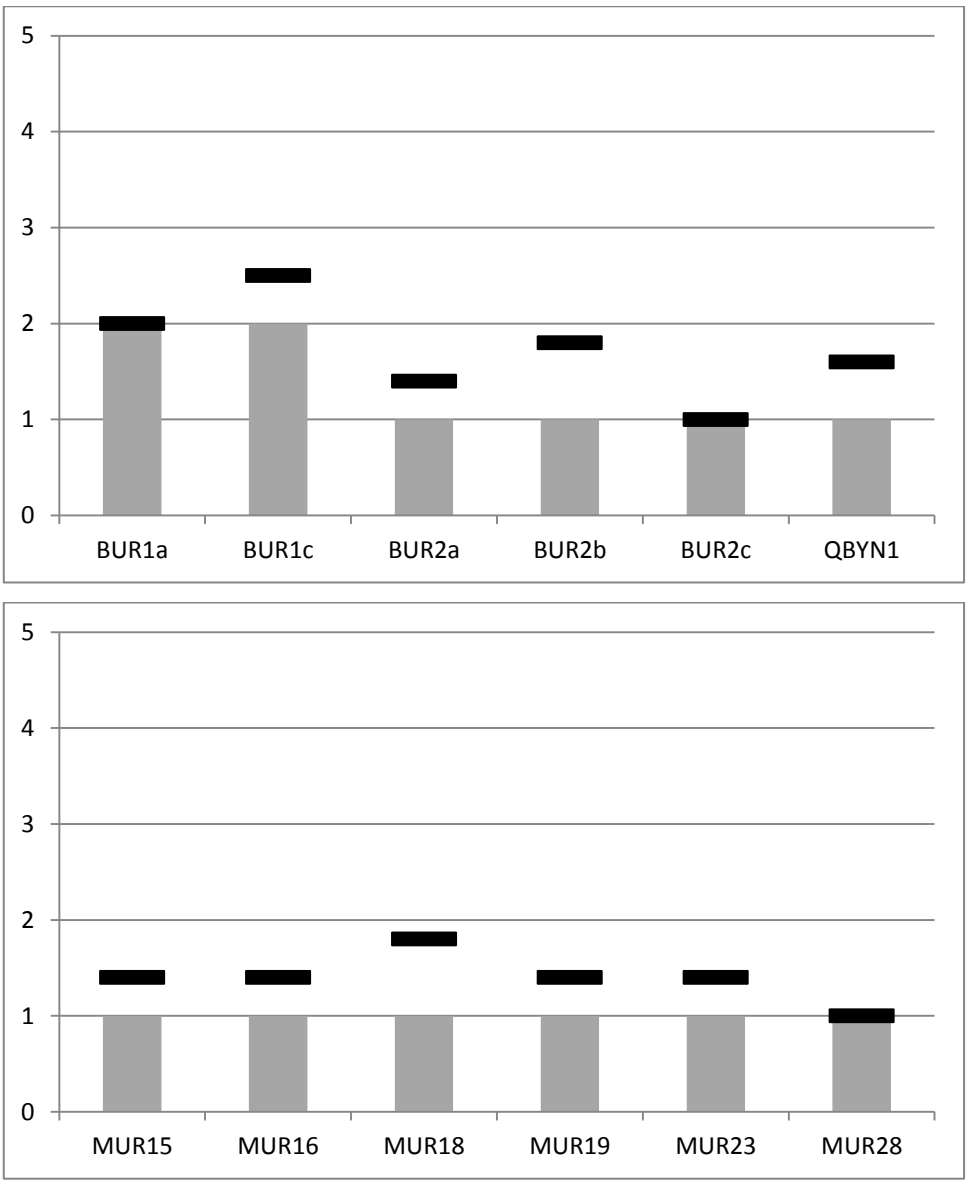

Figure 3-8. Shading of Burra Creek and the Murrumbidgee River during autumn 2014 compared to historical means

Note: Grey bars show current season results; black lines represent historical means.

3.1.4 Vegetation abundance by location – Native vs Exotic

Spring 2013

Abundances of native and introduced species are presented in Figure 3-9. The abundance of native species at both BUR 1a and BUR 2a were very similar to the abundances shown in the historical data, however, native species abundances for the remaining Burra Creek and Queanbeyan River sites are quite different from the historical means. This change is likely due to the sample run being completed during mid-October instead of the usual November. This slight change in sampling of between 2-6 weeks during spring is a period of high growth for many of the introduced weeds at these sites. Less growth at the time of sampling may have significantly reduced the overall appearance of these introduced species, resulting in a reduced abundance estimate at these sites for spring 2013.

Native and introduced abundances for the Murrumbidgee River sites during spring 2013 are also presented in Figure 3-9. Most sites recorded similar native and introduced abundances to the historical means, however MUR 15 & 18, two of the upstream sites showed reduced abundances of native species compared to the

historical means by approximately 20% and 30% respectively. These changes in abundances at the two upstream sites may be related to increased weed establishment following disturbance by high flow during September 2013 or human activities, particularly at MUR 15 with both sides of the river private land.

Autumn 2014

The abundances for the native and introduced species at sites during autumn 2014 is shown in Figure 3-10, with comparisons to historical means. The only site which displays a major change in the abundance of native species (approximately a 40% increase) is BUR 2a. All other sites from all waterways were similar to the recorded historical means. The change at BUR 2a is due to an increased local dominance of native macrophytes (*Phragmites australis* and *Schoenoplectus validus*) which have spread to cover a large portion of the site.

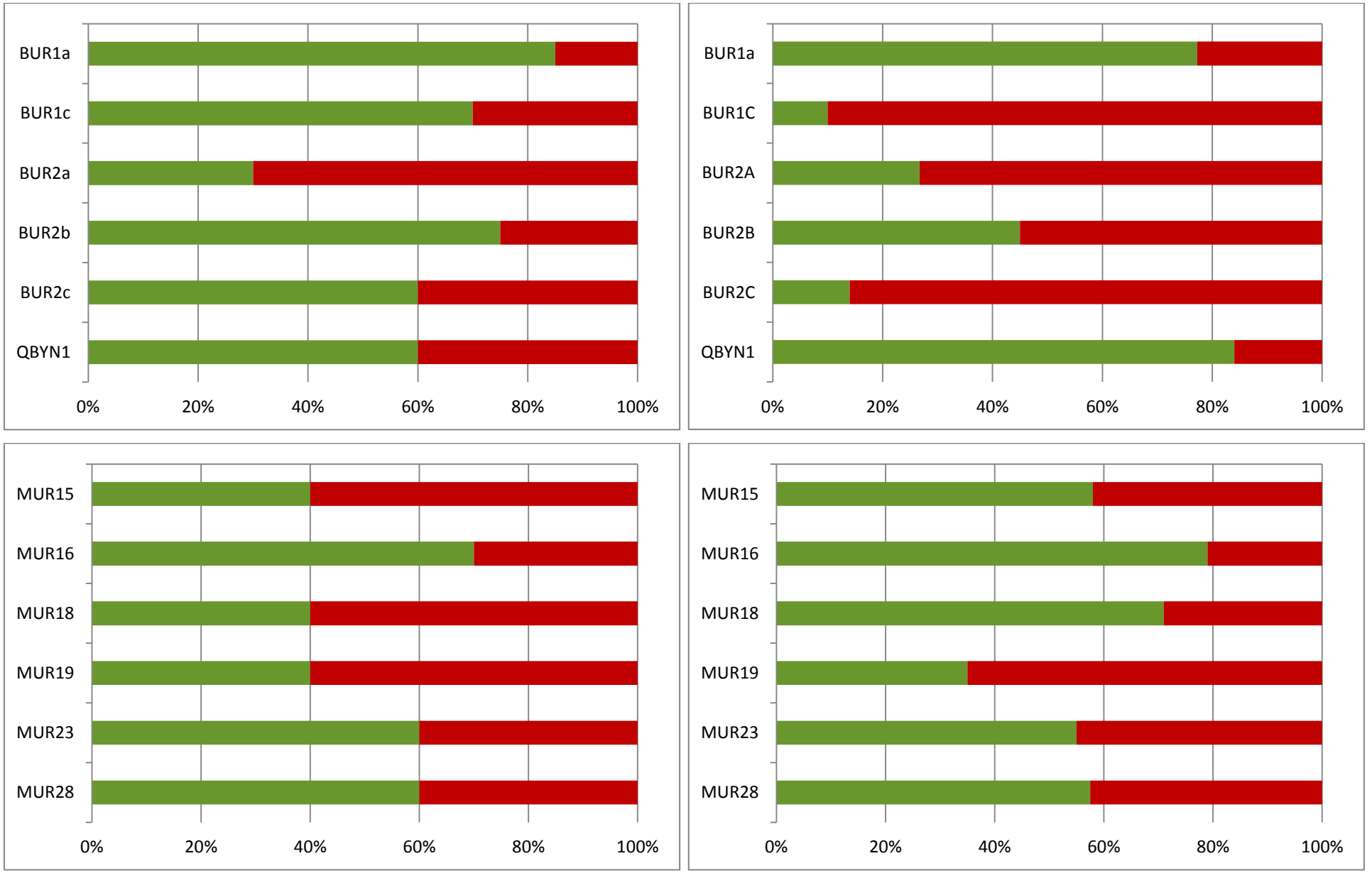

Figure 3-9. Native (in green) and exotic (red) vegetation species abundance during spring 2013 (left) compared to historical spring means (right)

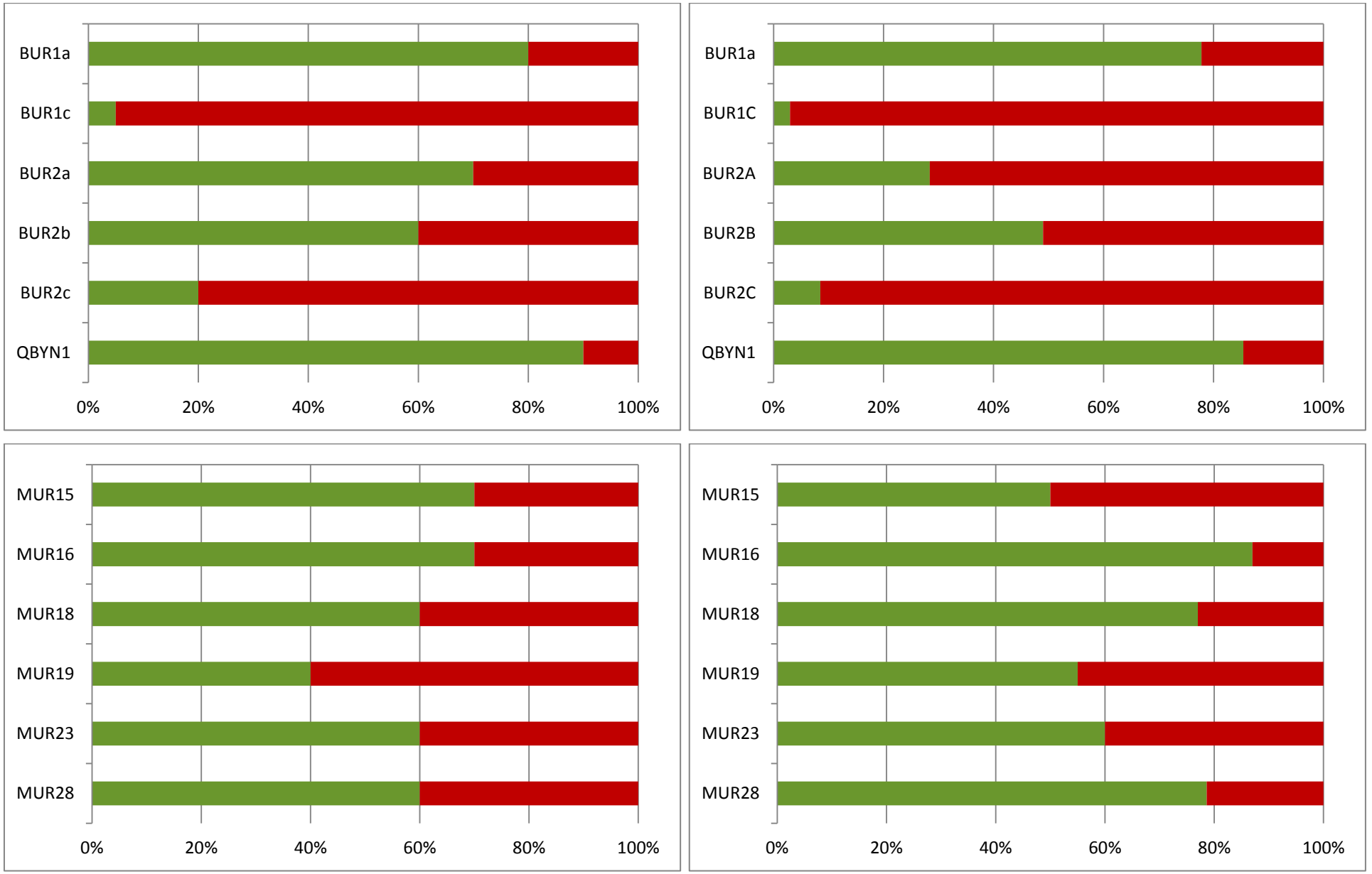

Figure 3-10. Native (in green) and exotic (red) vegetation species abundance during autumn 2014 (left) compared to historical autumn means (right)

3.2 Transects

Summaries of each site assessed through a number of transects are provided in the section below. During the transect survey a total of 84[1] species were identified with 26 native species and 47 introduced species (Table 3-3). Individual site and overall Burra Creek and Angle Crossing species diversity are presented in Table 3-3. Figure 3-11 shows the percent coverage of transects at each site by both native and introduced species, while Figure 3-12 shows coverage of vegetation, water and bare ground at each site.

Details of transect locations at each site are provided in Appendix A, which also includes co-ordinates for each end of the transects.

Full species lists for each site are provided in Appendix C.

A full plot of all species coverage at each site is also provided in Appendix D.

Table 3-3. Species diversity observed at study locations

Location	Species Richness	Native	Introduced
All Sites	84	26	47
Burra Creek Sites	72	23	41
Angle Crossing	33	6	21
BUR 1a	43	12	25
BUR 1c	23	7	15
BUR 2a	26	7	16
BUR 2c	42	10	28
MUR 18	28	5	18
MUR 19	15	4	8

Note: Some species were not identifiable to species level, resulting in the number of native an introduced species not adding up to the total richness as these species could not be correctly aligned to either category.

[1] 11 species were not able to be identified to species level and therefore plant origin was unable to be determined.

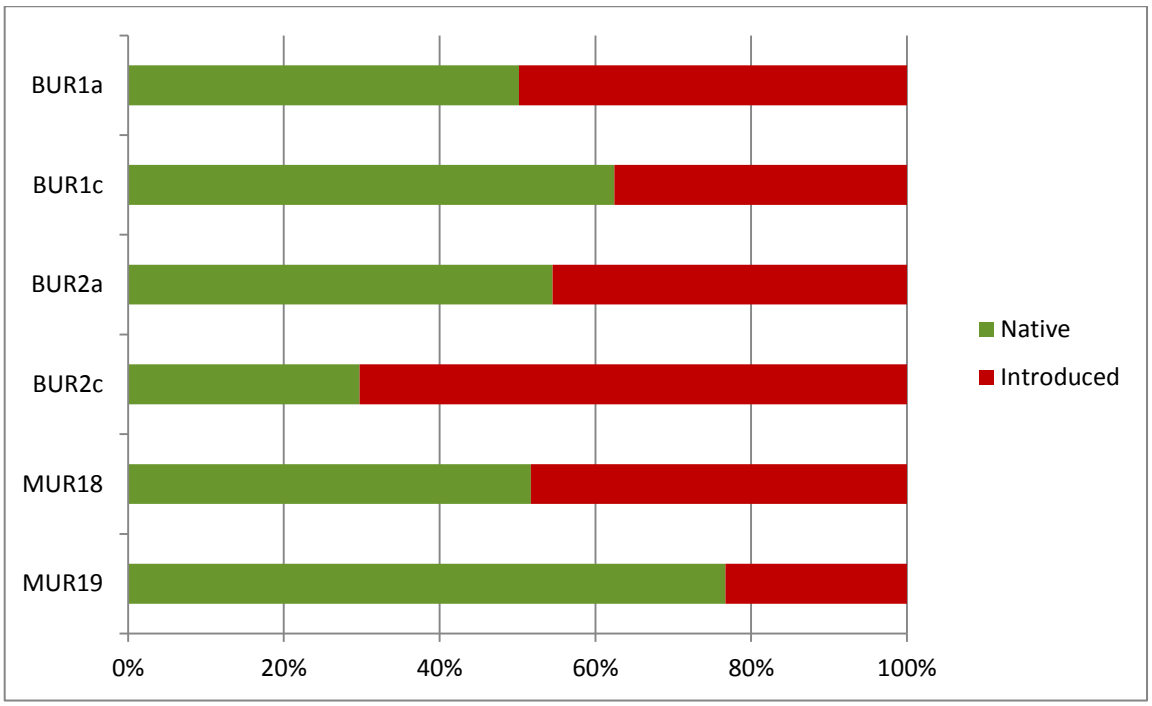

Figure 3-11. Percentage cover of transects by native and introduced species

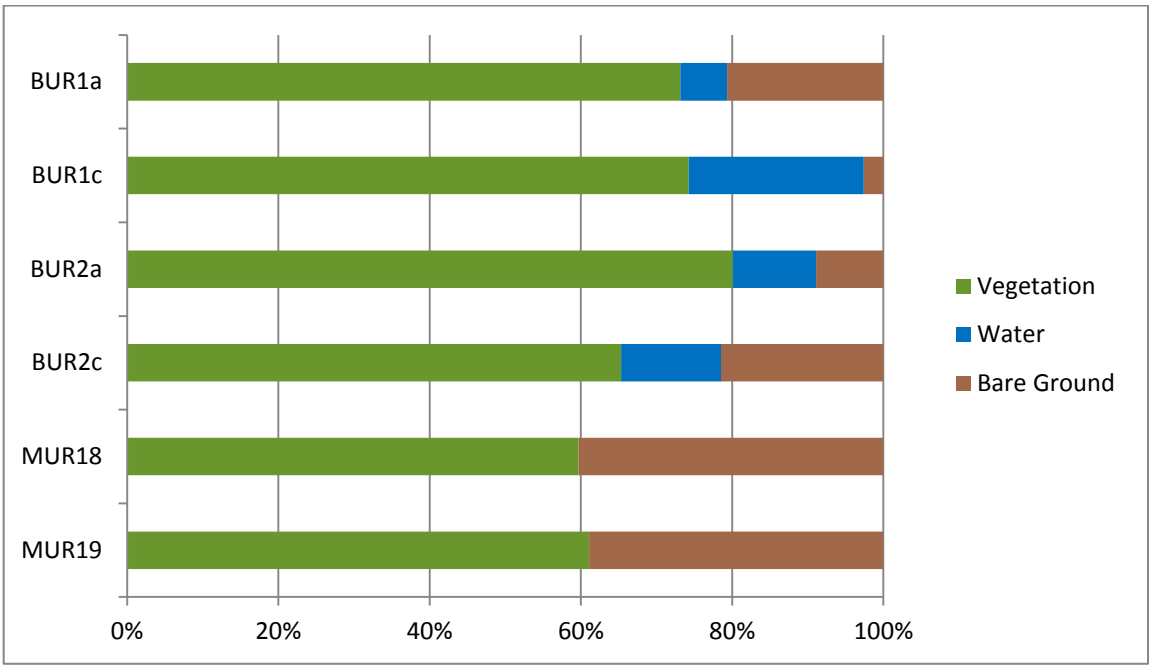

Figure 3-12. Percentage cover of transects by vegetation, open water and bare ground

Burra Creek

3.2.1 BUR 1a

BUR 1a had the highest species diversity of any site with a species richness of 43 consisting of 12 native species and 25 introduced species (six species were not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). Although the number of introduced species was more than double the number of native species Figure 3-11 shows that the coverage of transects at this site was almost exactly 50% native to 50% introduced, which is consistent with the assessment from 2011 (ALS, 2011). Site photos are shown in Plate 3-1.

Vegetation at the site was predominantly grasses and sedges with species such as *Poa labillardieri*, *Paspalum sp.*, *Phalaris sp.*, *Hordeum leporinum*, *Carex appresa* and *Juncus usitatus,* with particular dominance on the right bank. Shrub vegetation was sparse with some sections of *Kunzea ericoides* and *Leptospermum phylicoides* along the left bank. There were no trees were recorded along any of the transects at this site. Disturbed areas on the left bank (likely from stock access) had been colonised by numerous weeds such as *Trifolium sp.*, *Carduus* sp., *Acetosella vulgaris* and *Hypochaeris radicata*.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, two species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government are *Eragrostis curvula* and *Rubus fruiticosus* (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

Plate 3-1. BUR 1a transect 1 (left) and transect 3 (right)

3.2.2 BUR 1c

The vegetation coverage at BUR 1c was unique amongst the sites assessed during this study as it was dominated by grass species along both banks with aquatic macrophytes dominating all space within the creek channel itself. The only other vegetation are two *Salix sp.* at each end of the site, although only one of these trees was captured along one of the transects. There were no shrubs and very few forbs observed. Species richness was 23 at BUR 1c the lowest of all Burra Creek sites with 7 native species identified and 15 introduced species (1 species was not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). Although BUR 1c had the equal lowest native species richness of all Burra Creek sites it actually had the largest native percent coverage of with over 60% (Figure 3-11). BUR 1c also had the least bare ground of any site with less than 5% and the largest water cover, more than 20% (Figure 3-12). Site photos are presented in Plate 3-2.

The dominant grass species found along the banks at BUR 1c included the native *Poa labillardieri*, and introduced species *Phalaris minor* and *Paspalum dilatatum*. The dominant macrophytes within the channel itself were all native species and included *Schoenoplectus validus*, *Eleocharis atricha*, *Typha orientalis* and *Isolepis habra*. These macrophytes accounted for a large portion of the native species coverage at the site with *S. validus* alone accounting for almost 40% of the overall site coverage.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, two species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government are *Rubus fruiticosus* and *Salix* sp (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

Plate 3-2. BUR 1c transect 1 (left) and transect 3 (right)

3.2.3 BUR 2a

Vegetation at BUR 2a was dominated by *Phragmites australis*, particularly the upstream end of the site. The remaining coverage was grasses including the native *Paspalum distichum* and the introduced *Phalaris aquatic*, *Phalaris minor* and *Eragrostis curvula*. Diversity at BUR 2a was showed a species richness of 27 with 7 native species and 16 introduced species (4 species were not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). Although less than half of the species are native the dominance of the native macrophyte *Phragmites australis* has increased the coverage of native species at the site to over 50% compared to the coverage of introduced species (Figure 3-11), which is approximately 20% lower than during the 2011 assessment at this site (ALS, 2011). This decrease in native coverage since 2011 is likely due to increased levels of introduced grasses.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, *Eragrostis curvula* was observed which has been listed as noxious weeds by the NSW government and/or has been declared as a pest species by the ACT Government (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014). Site photos are shown in Plate 3-3.

Plate 3-3. BUR 2a transect 2 (left) and transect 3 (right)

3.2.4 BUR 2c

BUR 2c had the highest number of introduced species of all Burra Creek sites with 28 species observed, compared to 10 native species and an overall richness for the site of 42 (four species were not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). The dominance of introduced species is highlighted in Figure 3-11 which shows the coverage of native species at BUR 2c to be approximately 30%, which is the lowest cover of native species compared to introduced species of all sites. During the 2011 assessment native coverage was recorded at 80% (ALS, 2011), resulting in a decrease in native coverage by 50%. This change is due to an decrease in native grass coverage and replacement by opportunistic weed species, likely following disturbance by high flow events. Site photographs are presented in Plate 3-4.

While vegetation was dominated by forbs, BUR 2c was similar to BUR 1a as there was no overall dominant species at the site. As indicated by the introduced species richness introduced forbs were more abundant at this site than any other Burra Creek site. The more abundant of these species included *Medicago arabica*, *Acetosella vulgaris*, *Plantago lanceolata*, *Modiola caroliniana*, *Verbena bonariensis*, *Conyza bonariensis*, *Erodium cicutarium*, *Trifolium sp.* and *Hirschfeldia incana*. In-stream macrophytes were also quite diverse and included the native *Cyperus polystachyos*, *Eleocharis acuta*, *Isolepis habra*, *Schoenoplectus validus* and *Typha orientalis*, as well as the introduced *Mentha* x *piperita var. piperita* and *Veronica anagallis-aquatica*. *Eucalyptus* spp. were present at the site with *Eucalyptus pauciflora* observed on a single transect.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, four species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government are *Eragrostis curvula* and *Hypercium perforatum, Populus sp.* and *Carduus pycnocephalus* (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

Plate 3-4. BUR 2c transect 1 (left) and transect 3 (right)

Murrumbidgee River

In previous surveys both banks of the Murrumbidgee River have been surveyed at MUR 18 and 19. However, for this assessment only a single bank was assessed with the right bank at MUR 18 and the left bank at MUR 19. This was due to difficulty in accessing the opposite banks due to a number of factors and including large infestations of blackberry (*Rubus fruiticosus*), steep banks with difficult access and deep pools preventing crossing without a boat.

3.2.5 MUR 18

MUR 18 was characterised by largesloping sand banks. This habitat is particularly unstable with roots held loosely in top sand, which results in many establishing plants being removed during inundation from high flow events. Site photos are shown in Plate 3-5.

Unlike the Burra Creek sites, trees were much more common at MUR 18 with the native *Acacia dealbata* and the introduced *Salix* sp*.* contributing significantly to bank stability along the water line. Native shrubs were also contributing significantly to bank stabilisation with established natives *Callistemon sieberi* and *Leptospermum phylicoides* also found along the immediate shoreline, with some introduced *Rubus fruiticosus* also along the lower bank.

The upper bank at MUR 18 was sparse with large sections of bare ground, likely where sand movement due to high flow events has prevented establishment of more vegetation. The vegetation on the upper bank consisted of mainly introduced weeds which are quick to establish after disturbance, these included *Raphanus raphanistrum*, *Hypercium humifusum*, *Acetosella vulgaris*, *Plantago lanceolata*, *Verbena bonariensis*, *Torilis sp.*, *Taraxacum sp.*, *Hirschfeldia incana* and *Brassica nigra*.

MUR 18 had the highest species richness of the two Murrumbidgee River sites with a total of 28 species recorded including 5 native species and 18 introduced species 9 (five species were not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). Coverage of native species compared to the introduced species was split approximately 50/50 as shown in Figure 3-11, with the large coverage of the native trees and shrubs accounting for the small number of native species recorded at the site. Approximately 40% of the transect area was bare, while the remaining area was vegetated (Figure 3-12). Native coverage has reduced following assessments during both 2009 and 2011 where native coverage was recorded at approximately 75% during both assessments (GHD, 2011). Reduction in native species coverage during this period is likely the result of large scale sand deposition during the high flow of March 2012 altering the substrate, which is more suited to weed annuals, compared to native perennial species.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, three species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government are *Eragrostis curvula*, *Salix* sp*.* and *Rubus fruiticosus* (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

Plate 3-5. MUR 18 transect 1 (left) and opposite bank at the end of transect 2 (right) showing the blackberry infestation

3.2.6 MUR 19

MUR 19 had the lowest species richness of all sites during this study with 15 species recorded, including 4 native species and 8 introduced species (three species were not able to be identified to species level and therefore plant origin was unable to be determined) (Table 3-3). The transect area which was recorded as bare ground was very similar to MUR 18 at approximately 40% (Figure 3-12). Site photos are presented in Plate 3-6.

Plate 3-6. MUR 19 transect 1 (left) and opposite bank at the end of transect 1 (right) showing blackberry infestation

Site characteristics at MUR 19 were similar to MUR 18 with large sloping sand banks. The lower bank was characterised by the same dominance of trees and shrubs maintaining bank stabilisation, with almost the same species diversity of *Salix sp.*, *Acacia dealbata*, *Rubus fruiticosus* and *Callistemon sieberi*. *C. sieberi* was dominant at MUR 19 contributing over 50% of the transect coverage at the site which is responsible for the >75% native species coverage at MUR 19 as shown in Figure 3-11. There were some introduced weeds observed such as *Plantago lanceolata*, *Verbena bonariensis*, and *Conyza bonariensis*, however their abundance and diversity was much lower than the upstream Murrumbidgee River site. Small sections of grasses were observed at MUR 19 including species such as *Carex* sp., *Paspalum* sp., and *Cyperus eragrostis* which were mostly absent from the upstream Murrumbidgee River site.

There were no threatened species listed by either NSW or ACT governments which were observed at the site (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). However, two species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government are *Salix sp.* and *Rubus fruiticosus* (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

3.2.7 Comparison of site characteristics

NMDS plot shown in Figure 3-13 shows the separation of the Burra Creek sites and the Murrumbidgee sites. While this is not unexpected, the surprising result is the similarity of BUR 1a & 2c with greater than 40% similarity. These two sites share similar species richness with 20 species found at both sites and have a similar abundance of bare ground. This has changed since the assessment during 2011 when BUR 1a and 1c were more similar with BUR 2a & 2c separate. BUR 1c was unique in its species composition with such dominance of aquatic vegetation, when compared to other sites, but most of all compared to BUR 1a which showed the least aquatic vegetation of all Burra Creek sites.

Figure 3-14 shows the same sites with individual transects represented. For Burra Creek all transects for BUR 1a, 1c & 2c were found to be more than 40% similar to transects from the same site. Transect 1 & 2 from BUR 2a were more than 40% similar to each other, while Transect 3 was more similar to the transects from BUR 2c. Species richness were similar at all transects from BUR 2a, but a larger abundance of bare ground at the site more similar to those at BUR 2c may be the reason for Transect 3 to be closely related to BUR 2c transects than others from the same site. All Murrumbidgee River Transects were found to be more than 40% similar with the exception of Transect 1 from MUR 19. These two sites were relatively similar with site characteristics, species composition, the dominance of trees and shrubs all similar. However, the difference for Transect 1 at MUR 19 could be related to two differences, *Carex* sp. and *Paspalum* sp. were present along this transect and were either absent or found in much lower abundances in all other Murrumbidgee River transects and this was the only transect not to record any bare ground.

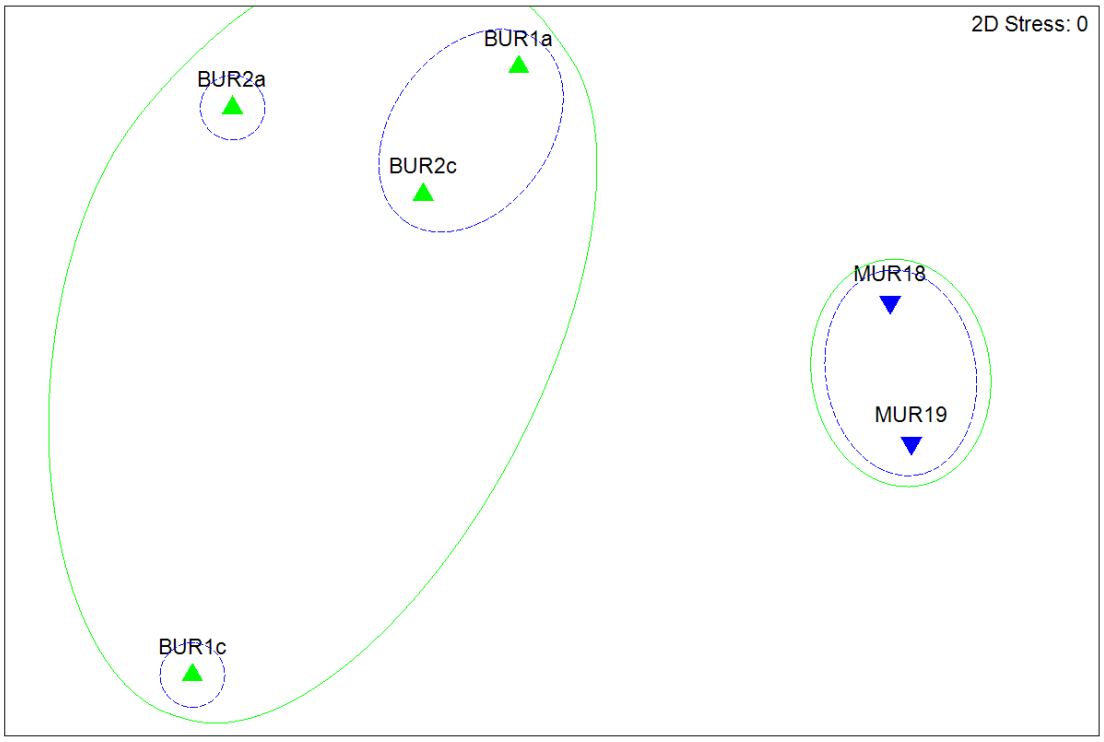

Figure 3-13. Non-metric multidimensional scaling of sites

Note: Green ellipses represent 20% similarity and the blue ellipses represent 40% similarity. Green points are Burra Creek sites and blue points are Murrumbidgee River sites.

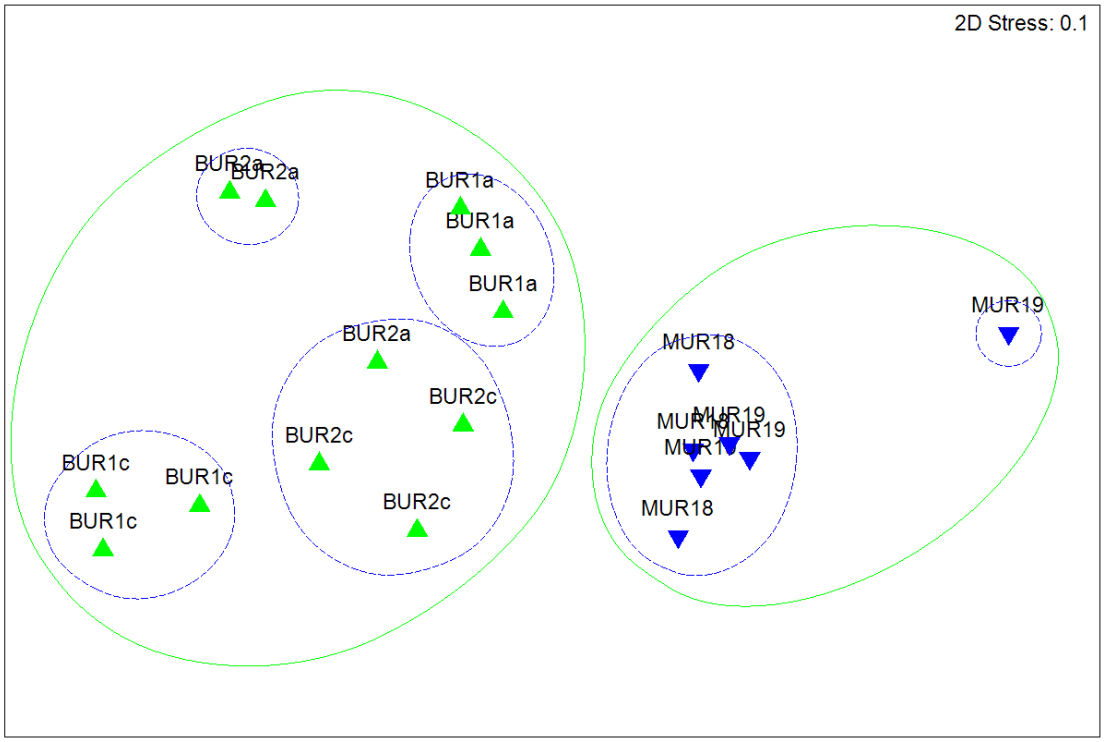

Figure 3-14. Non-metric multidimensional scaling of sites representing individual transects

Note: Green ellipses represent 20% similarity and the blue ellipses represent 40% similarity. Green points are Burra Creek site and blue points are Murrumbidgee River sites.

3.3 Whole of Burra Creek Assessment

A full species list of all species which were identified along the creek between the M2G discharge structure and London Bridge is available in Appendix E. Vegetation which could potentially encroach significantly on Burra Creek was recorded. Four species were determined to have the potential to encroach significantly on the creek to potentially impede flows and movement of fauna which were *Phragmites australis*, *Schoenoplectus validus*, *Typha orientalis* and *Rubus fruiticosus*. The large patches of these species were mapped and are presented in Appendix F.

3.3.1 Zone 1

Zone 1 comprises the reach of Burra Creek immediately upstream of Pool 16 through to London Bridge. Zone 1 is characterised by large sand bars throughout the Zone, moderately sloped banks in the upstream areas with steep eroding banks in the downstream areas. Large portions of lower banks, including sand bars are bare within this Zone with small weed species and grasses encroaching less on the creek, potentially due to the higher flows which are received in the downstream part of the creek.

Large stands of macrophytes were common in the downstream half of Zone 1, particularly *Shoenoplectus validus*, and the highest abundance of *Typha orientalis* of any Zone (Appendix F). Other in-stream vegetation included *Phragmites australis*, *Eleocharis* sp., *Isolepis habra, Veronica anagallis-aquatica*, *Chara sp.* and *Cyperus sp.* Both *Mentha x piperata var. 'piperata'* and *Callitriche stagnalis* were very common throughout the whole Zone both in-stream and along the water's edge.

Some of the weeds inhabiting the lower bank and sand bars included *Hypercium perforatum*, *Silybum marianum*, *Echium plantagineum* and *Verbascum thapsus* among others. These were found largely on

areas which were otherwise bare, likely recently disturbed from high flow events. The upper bank consisted of a variety of grasses including the native *Poa labillardieri*, *Paspalum* sp., *Phalaris* sp., *Carex albula*, and *Nassella trichotoma*.

Poplulus sp. were common throughout the Zone with the downstream area (downstream of Pool 6) consisting mainly of *Eucalyptus* spp. *Rosa rubiginosa* was also present along the creek, while *Populus* sp. juveniles were common from pool 11 through to 13 (Plate 3-7).

Plate 3-7. Zone 1 at Pool 12 showing a juvenile *Populus sp.* on the left bank

3.3.1 Zone 2

Zone 2 comprises the reach of Burra Creek immediately upstream of Pool 29 through to the upstream end of Pool 16. This Zone is characterised by moderately sloped sandy banks surrounded by native and introduced grasslands. There are areas of shallower pools connected by riffle Zones of silty substrate with high density pasture grasses up to the water's edge. Where the riparian zone comprised cobbles and pebbles on a sandy substrate, pasture grasses were replaced by broad leaved weeds.

In-stream vegetation was extensive through this Zone with a high diversity and some areas of domination by select species. Sections of creek were dominated by *Phragmites australis*, *Shoenoplectus validus* and *Typha orientalis* (Plate 3-8) (Appendix F). Other common species included *Mentha* x *piperata* var. *'piperata'* (particularly in high abundances along the water's edge), *Isolepis habra*, *Eleocharis atricha* and *Eleocharis acuta*, while some of the more uncommon species found were *Ranunculus amphitrichus*, *Chara* sp. and *Elatine gratioloides*.

Large sections of the riparian zone were dominated by pasture grasses with *Poa labillardieri* and *Cenchrus longisetus* covering large areas, and *Phalaris sp.* to a lesser extent. Uncommon native species were also occasionally present with *Themeda triandra* and *Lomandra longifolia* observed. Small broad leafed weeds were uncommon occurring opportunistically along unvegetated sandy sections of bank. Larger shrub coverage was mostly introduced with *Rubus fruiticosus* and *Rosa rubiginosa* present on the upper riparian zone, particularly between pools 25 and 26, with a number of large clumps of *R. fruiticosus* noted. The native shrub *Kunzea ericoides* was found in patches, while

tree cover was also patchy with *Eucalyptus* p. occurring sporadically with some smaller *Acacia dealbata* also present.

Plate 3-8. Zone 2 downstream of Pool 28 dominated by *Typha orientalis*

3.3.1 Zone 3

Zone 3 comprises the reach of Burra Creek immediately downstream of Pool 36 through to the upstream end of Pool 29. This Zone was characterised by large areas of bedrock and boulders through gorge like areas with steep banks and cliffs of up to 90° (Plate 3-9). The occassional sand bar and soft sediment pool are also present within this Zone.

This Zone has more shrubs and trees dominated with *Eucalyptus* species,., *Kunzea ericoides*, *Calliseton sieberi* and *Crataegus monogyna*. *C. sieberi* was found closer to the water than the other large flora, between rocks and bedrock sections. Fewer broad leafed weed species occur within this Zone however were still found growing in the sand between boulders and along both banks, including *Sonchus* sp. and *Polygonum prostratum*. In the downstream area of this Zone the substrate becomes looser with some larger weeds becoming quite common including multiple thistles, *Verbena bonariensis*, *Hirschfeldia incana*, *Conyza* sp. and *Echium plantagineum*. There are few areas which have been dominated by potential encroachment species, likely due to the limited habitable substrate within the gorge area.

The difficult conditions presented in this area resulted in the presence of some native species which were not observed anywhere else along Burra Creek. These species included *Chellanthes* sp., *Dianella longifolia* and *Wahlenbergia communis*.

In-stream vegetation composition was diverse including *Mentha* x *piperata* var. *'piperata'*, *Elatine gratioloides*, *Isolepis habra* and *Eleocharis acuta*. *Phragmites australis*, *Scoenoplectus validus* and *Tyhpa orientalis* were present in smaller patches than in other Zones, particularly at the downstream ends of pools and in riffle sections where the stream width was narrower.

Plate 3-9. Bedrock and boulder dominated substrate in Zone 3

3.3.1 Zone 4

Zone 4 comprises the reach of Burra Creek immediately upstream of pool 46 through to the upstream end of Pool 36. The majority of this Zone is bedrock and boulders, with the upper riparian zone comprising a sandy substrate. The bank in this Zone ranged from gently sloping-steep with the surrounding area part of the Googong Foreshores area, with ungrazed native and introduced grasslands with some small patches of light scrub.

Due to the large areas of bedrock through this Zone, aquatic vegetation was sporadic throughout, with small concentrated patches where suitable substrate was available, mostly along the edges of pools. Despite this diversity was relatively high in this Zone and included, *Phragmites australis*, *Typha orientalis*, *Callitriche stagnalis*, and *Mentha* x *piperata* var. *'piperata'* among others. Multiple large dominant stands of *P. australis* were present throughout the Zone.

Small weeds were found along the sandy banks between boulders and sections of bedrock with species including *Conyza* sp., *Hypercium perforatum* and *Hirschfeldia incana*. The upper bank showed consistent ground cover of pasture grasses such as *Phalaris* sp. and *Poa* spp., while tree cover was sparse there were areas of dense cover, mainly from *Eucalyptus* spp. and *Acacia dealbata*, with some occurrence of *Salix* sp. Shrub species were mostly introduced including *Pyracantha angustifolia* and *Solanum nigram*, with some native *Kunzea ericoides* also present.

3.3.1 Zone 5

Zone 5 comprises the reach of Burra Creek immediately downstream of pool 64 through to upstream of Pool 46. This Zone is characterised by riffles consisting of cobbles and pebbles and pools dominated by a sand substrate, however, there was some areas of bedrock. Surrounding area is mostly grazing, with significant stock damage present along the creek, particularly in the upstream section of Zone 5.

Sections of creek were dominated by *Phragmites australis*, while there were only one or two patches of *Typha orientalis* and *Shoenoplectus validus*. Other in-stream vegetation included *Callitriche stagnalis* which was common in most pools and slow moving areas with some uncommon patches of

Ranunculus amphitrichus in the downstream pools. *Carex* spp. were common along the edges of pools as were *Poa* spp., while in the downstream part of the Zone *Isolepis habra* was dominant (Plate 3-11).

Tree coverage was sparse in places in the upper riparian zone with mainly *Populus* sp. and *Salix* sp. present with *Eucalyptus* spp. less common. Most ground vegetation was predominantly pasture grasses including *Poa* spp., *Paspalum* spp. and *Phalaris* sp. Other vegetation in this region composed of some larger introduced shrubs including *Rubus friuticosus*, which was found in numerous large stands as well as individual plants throughout the whole Zone, as well as *Rosa rubiginosa*, *Pyracantha angustifolia* and *Solanum nigram*. Weeds were also common in the upper riparian zone including numerous types of thistles, *Taraxacum sp.* and *Medicago arabica* among others.

Plate 3-10. Bedrock pools with *Phragmites australis* inhabiting soft sediment sections in Zone 4

Plate 3-11. *Isolepis habra* (left) and *Callitriche stagnalis* (right) in Zone 5

3.3.1 Zone 6

Zone 6 comprises the reach of Burra Creek immediately downstream of the M2G pipeline discharge pool through to the upstream end of Pool 64. This Zone comprises several pools connected by riffle habitat of silty substrate, cobbles and some boulders.

In-stream vegetation is dominated by *Phragmites australis* and *Schoenoplectus validus*, particularly in pools and in slow moving riffles. *Isolepis habra* and *Eleocharis atricha* inhabit shallow sections and along the water's edge.

The upper riparian zone is characterised by steep banks along most of the Zone and is vegetated predominantly by pasture grasses, mainly *Phalaris* sp., *Paspalum* sp. and *Poa* spp., and a high diversity of weeds. Juvenile *Poplulus* sp. were common from pool 69A through to 69B. *Rubus friuticosus* infestations were noted around at the upstream area near to the discharge structure (Plate 3-12).

Plate 3-12. *Rubus fruiticosus* (left) and juvenile *Populus sp.* around Pool 69B in the upstream section of Zone 6

3.3.2 Potential future impacts from M2G

Most of the riparian vegetation along the length of Burra Creek is out of the impact area from M2G. Only the vegetation which is close to the channel could be affected by the potential 100 ML/d pumping. This system experiences much larger high flow events than the 100 ML/d, however these flows are quick to peak and the time it takes for the full event to flow through the system is typically relatively short. As a result of this the current vegetation which has established within and around the creek is able to withstand this period of inundation.

Although most of the species present along the water's edge, such as *Isolepis habra* which inhabits the water's edge more than any other species along the length of Burra Creek, are able to withstand inundation for periods. However, these species are not submerged macrophytes and are not able to survive under sustained inundation for longer periods. The operation of the M2G pipeline behaves differently to a natural high flow event, particularly in relation to the length of time which the pumps are run for. During periods of sustained drought when the pipeline is required it is possible that the pumping will run for extended periods. It is during these periods of extended pumping when it is expected that the vegetation will l begin to die off. Extended pumping for periods longer than approximately 3 weeks may start to have significant detrimental impacts upon the inundated vegetation. Zone C and D are likely to be least impacted by this due to the substrate found in those Zones which has limited the amount of vegetation along the immediate creek edge.

Other current impacts to the riparian vegetation evident during the assessment include introduced flora and introduced fauna, in particular feral pigs (*Sus scrofa*). The occurrence of feral pigs has been evident in the channel of Burra Creek, beginning in the downstream area near London Bridge, including areas right up to the water's edge for approximately 12-18 months. During the assessment, evidence of feral pig foraging particularly within the lower riparian zone was observed through Zone's 1 – 3. These areas are degraded regardless of whether the vegetation is native or introduced, with the areas relatively frequent within these zones. This damage is currently the main concern for the riparian zone with the increased disturbance potentially leading to erosion points and/or further colonisation by opportunistic weed species such as those already common in the riparian zone of Burra Creek (Plate 3-13).

Foraging by feral pigs loosens up soil and destroys established vegetation, impacting significantly on the local ecology (Department of the Environment, 2015). However, when this occurs within the creek channel, further detriment is caused by creating areas on increased erosion during high flow events. The operation of M2G could also increase this erosion as disturbed areas are present right up to the water's edge and will be inundated during the operation of the pipeline.

There were no threatened species listed by either NSW or ACT governments which were observed along the assessed sections of Burra Creek (Environment and Heritage NSW, 2015; Environment and Planning Directorate ACT, 2015). Eleven species which have been listed as noxious weeds by the NSW government and/or have been declared as a pest species by the ACT Government were observed during the assessment and are shown in Table 3-4 (Department of Primary Industries NSW, 2015; Territory and Municipal Services ACT, 2014).

Plate 3-13. Evidence of feral pigs in Zone 3 (left) and Zone 2 (right)

Table 3-4. Species listed as weeds species by relevant governing body

Species	Common Name
Crataegus monogyna	Hawthorn
Echium plantagineum	Patterson's Curse
Eragrostis curvula	African Lovegrass
Hypercium perforatum	St. John's Wort
Nassella trichotoma	Serrated Tussock
Pyracantha angustifolia	Orange Firethorn
Rosa rubiginosa	Sweet Briar
Rubus fruiticosus	Blackberry
Salix alba	White Willow
Salix babylonica	Weeping Willow
Salix sp.	Willow

3.4 Platypus habitat

The assessment of potential platypus habitat was included in this (the vegetation) component of the MEMP because this was the most comprehensive in terms of field work and spatial coverage through the length of Burra Creek.

Ideal habitat for platypus (*Ornithorhynchus anatinus*) is earthen banks with overhanging vegetation and roots which provide river shading and burrowing locations. Preferential substrate is boulder and cobbles as this provides ideal habitat for macroinvertebrates, the main portion of their diet. Platypuses are also found to be more common in rivers and streams which have riffle pool sequences (Divljan, 2014).

The habitat which is present in Burra Creek varies in comparison to this definition of ideal habitat as described by Divljan (2014). Burra Creek does have sections of creek which provide riffle and pool sequences; however these are highly influence by the ephemeral nature of the stream with riffle sections often reducing significantly during periods of low flow. The dominant substrate found within Burra Creek pools is either sand or bedrock, with very few pools maintaining cobbled substrate, while riffle habitats are mainly cobble and gravel, these are often highly silted. The dominance of the bedrock throughout Burra Creek (particularly in Zone 3 and 4) significantly reduces the usability of the banks as burrow locations for Platypus. While the discontinuous to non-existent riparian vegetation found along the lower reaches of the creek do not provide adequate shelter to support platypus.

There are two small sections along the creek length which provide the necessary minimum habitat requirements for platypus, these are Pool 48 and 49 - 52 and Pool 22 – 26. However, the limitations provided by Burra Creek include:

- Large sections of creek inadequate for platypus reducing movement and foraging potential;
- Large bedrock sections reducing usability of bank areas for burrows;
- Reduced flows during summer and autumn, significantly reducing riffle areas and foraging areas, and;
- The limited areas which have been assessed as adequate habitat may not provide enough usable habitat to support a single adult platypus.

Platypus may potentially use the lower reaches of Burra Creek as a foraging area, with burrow location likely to be found on the Queanbeyan River which provides habitat very similar to that described above by Divljan (2014) as ideal. While it is possible that platypus may inhabit Burra Creek solely, this is believed to be very unlikely due to the reasons discussed above.

4. Conclusions

4.1 Vegetation Condition assessment

Table 4-1 summarises the results of the vegetation and habitat conditions of the assessed sites. These assessments relate to the species diversity, disturbance, weed invasion and general health of the present vegetation.

Table 4-1. Summary of Vegetation Condition Assessment

Site Code	Condition	Comments
BUR 1a	**Poor-Moderate**	Vegetation has been subject to high levels of disturbance and is significantly modified structurally, particularly the downstream half of the sites. Significant disturbance from grazing stock with few shrubs and little of its original groundcover. Vegetation is dominated by introduced species.
BUR 1c	**Moderate-Poor**	Native vegetation coverage is relatively good however species diversity is still dominated by introduced species. High levels of disturbance was present with shrubs and trees completely absent from the site with the exception of some *Salix sp*. In-stream vegetation is predominantly native with some introduced macrophytes present.
BUR 2a	**Poor-Moderate**	Vegetation has been subject to high levels of disturbance, and has no original tree cover, some shrubs remain and little of its original groundcover. Vegetation has a high diversity of exotic species. The in-stream vegetation is dominated by native species while the riparian vegetation is poor, with ground layer dominated by exotic pasture grasses and no continuous or intact shrub and canopy layers. The dominant trees throughout the reach are introduced.
BUR 2c	**Poor**	The site has been highly disturbed with high levels of weed invasion. Some native species remain, with in-stream vegetation dominantly native with some introduced species also present. While tree species were all *Eucalyptus* spp. at the site, the overall cover of native species was minimal.
MUR 18	**Poor-Moderate**	Vegetation has been highly disturbed with a large portion of species identified as introduced. Native species still maintain good coverage at the site with native trees shrubs and groundcover identified. Large portions of the site are bare sand banks.
MUR 19	**Moderate-Poor**	Overall diversity was low, with large areas of bare sand bank. While trees coverage was all introduced species, the shrub coverage was significant composing of large portions of native species. Few small weeds were present, with some introduced grasses observed.

The number of introduced species at the Burra Creek sites is not surprising considering the impacts from the agricultural lands and stock access to the creek in areas of the upper catchment. While the lower catchment (the area within the Googong Foreshores) is free form grazing stock, weeds still dominate the creek channel which is a result of historical agricultural activities and the spread of

seeds from upstream. M2G will not impact on vegetation on the upper bank of Burra Creek as 100 ML/d will be insufficient to increase the water level to reach the upper banks. The potential impact point from the operation of M2G will be on the vegetation currently inhabiting the water's edge, which are adapted to be able to withstand short periods of inundation. However, once operation of the M2G pipeline has commenced for water supply purposes, it could potentially be run for extended periods which may alter the composition of the fringing vegetation, favouring species which can withstand inundation for longer periods.

Vegetation at the Murrumbidgee River sites was structurally different to that at Burra Creek with trees and shrubs dominating the water line at both the upstream and downstream sites. Impacts from the M2G operation on MUR 19 are very unlikely, and in the event of an impact it is expected to be minimal. This is due to the nature of the site and the current native vegetation which is found. A reduction in the water level by pumping a nominal 100 ML/d is a minor change for the Murrumbidgee River which experiences much larger natural fluctuations throughout the year. High flow events impact upon the vegetation at these sites not only through inundation but also through the movement of the large sandy banks. The natural changes to bank morphology and water level that are currently seen in the Murrumbidgee River and Burra Creek are greater than the potential changes from the operation of M2G, which could almost be argued to have no impact on the downstream vegetation.

4.2 Recommendations

Following the conclusions of this study the following action is recommended:

1. We have currently established a comprehensive baseline data set and in light of the short to medium term view to park M2G into standby mode which means that any additional surveys will likely only be beneficial to understanding natural changes in the Burra Creek catchment. While this is important to our understanding of how the system changes, such gross changes should be monitored through photographic methods during the standby period. However, it is recommended that full surveys are carried out in Burra Creek prior to and following the operation of the M2G pipeline for a period of greater than three weeks. This will re-establish the baseline condition following the full operation of M2G, so potential changes that follow can be analysed in the context of the response to pumping.

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Appendices

Appendix A - Vegetation transect locations

Appendix A. Locations of the vegetation transects at Burra Creek and Murrumbidgee River sites

		Left Side		Right Side	
Site	Transect	Latitude	Longitude	Latitude	Longitude
BUR1	1	-35.59796	149.22783	-35.59758	149.22770
BUR1	2	-35.59796	149.22776	-35.59768	149.22758
BUR1	3	-35.59803	149.22755	-35.59785	149.22728
BUR1C	1	-35.55681	149.22100	-35.55681	149.22111
BUR1C	2	-35.55650	149.22110	-35.55653	149.22121
BUR1C	3	-35.55623	149.22118	-35.55626	149.22130
BUR2A	1	-35.55361	149.22511	-35.55373	149.22528
BUR2A	2	-35.55356	149.22513	-35.55353	149.22528
BUR2A	3	-35.55348	149.22516	-35.55343	149.22526
BUR2C	1	-35.51883	149.26125	-35.518616	149.26160
BUR2C	2	-35.51815	149.261483	-35.518316	149.26156
BUR2C	3	-35.51768	149.261283	-35.517583	149.26150
MUR18	1	-35.58568	149.107883	-35.58560	149.10826
MUR18	2	-35.58503	149.107983	-35.58510	149.10831
MUR18	3	-35.58448	149.10785	-35.58465	149.10823
MUR19	1	-35.58281	149.109333	-35.58285	149.10930
MUR19	2	-35.58256	149.10983	-35.58265	149.10986
MUR19	3	-35.58086	149.11095	-35.580983	149.11110
MUR19	4	-35.58046	149.11095	-35.58045	149.11098

1:2,000 (at A4)

0 10 20 40 60 80

Meters

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

Numbered Vegetation Transect

Burra Creek

M2G Discharge Structure

Burra Creek Vegetation Transects: BUR 1a & BUR 1c

Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-15101
Revision	B
Date	23 Jan 2015

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Veg Surveys_BUR1&1C.mxd

Level 7, 16 Marcus Clarke Street Canberra ACT 2601 Australia T 61 2 6113 3200 F 61 2 6113 3299 E cbrmail@ghd.com W www.ghd.com

Data source: GHD, Burra Creek Vegetation Assessment, Revision B, 23/1/2015. Created by:jpcox

1:2,000 (at A4)

0 10 20 40 60 80

Meters

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

Numbered Vegetation Transect

Burra Creek

Burra Creek Vegetation Transects: BUR 2a & BUR 2c

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-15101
Revision	B
Date	23 Jan 2015

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Veg Surveys_BUR2&2A.mxd

Level 7, 16 Marcus Clarke Street Canberra ACT 2601 Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: GHD, Burra Creek Vegetation Assessment, Revision B, 23/1/2015. Created by:jpcox

LEGEND

Numbered Transects

Murrumbidgee River

MUR 18

MUR 19

1:3,000 @ A4

0 12.5 25 50 75 100

Metres

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

GHD

Murrumbidgee River Vegetation Transects: MUR 18 & MUR 19

Murrumbidgee Ecological Monitoring Program

ACTEW Water

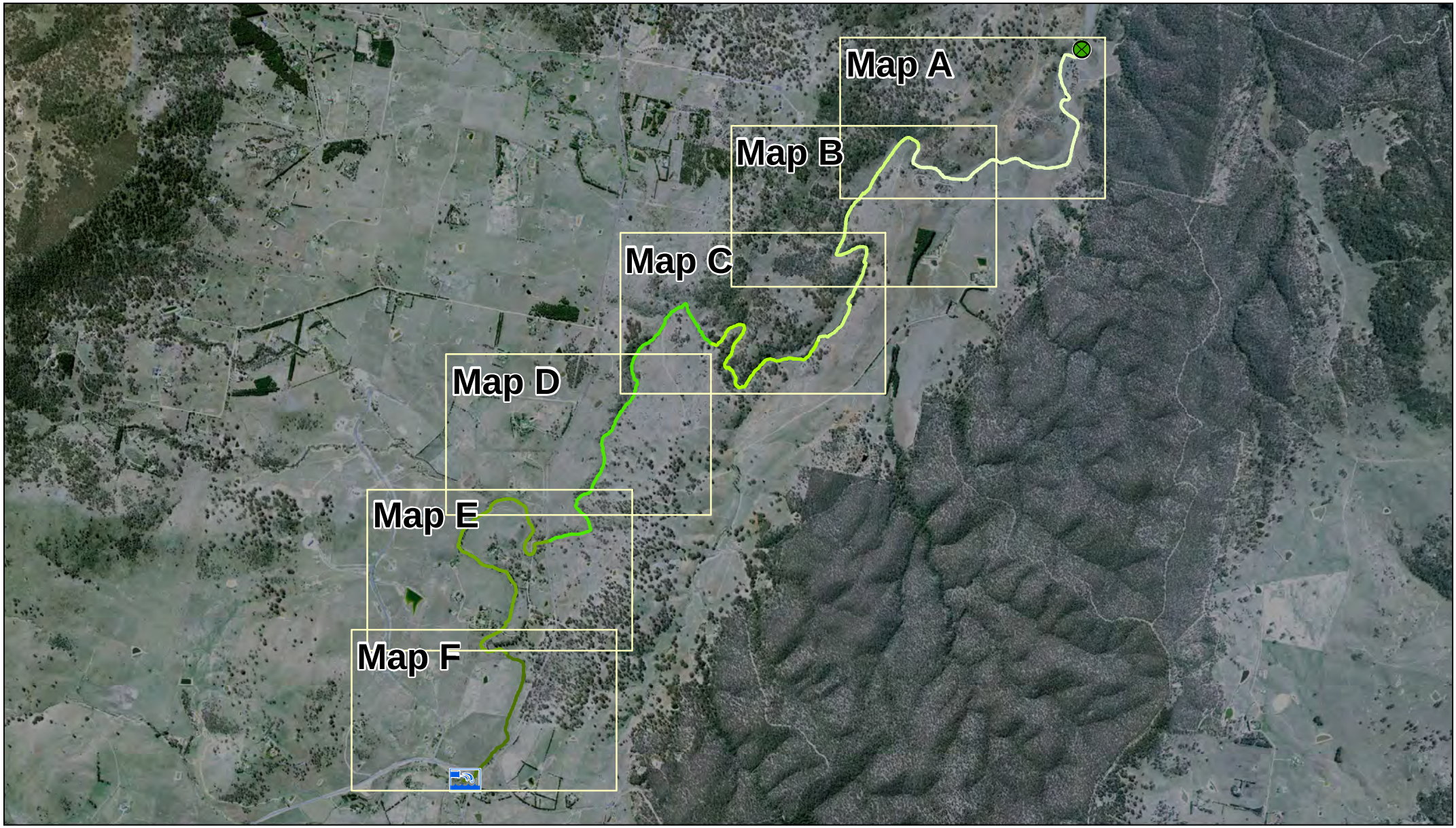
Job Number	23-15101
Revision	A
Date	23 Jan 2015

Level 7, 16 Marcus Clarke Street Canberra ACT 2601 Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

G:\23\14302\GIS\Maps\Vegetation Surveys\AC Transects.mxd

Data source: GHD, Burra Creek Vegetation Assessment, Revision A, 23/01/2015. Created by:jpcox

Appendix B - Burra Creek vegetation Zones



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0 0.125 0.25 0.5 0.75 1

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Detailed Maps

M2G Discharge Structure

London Bridge Arch

Burra Creek: Vegetation Zones Overview

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-15101
Revision	D
Date	19 Feb 2015

G:\23\14302\GIS\Maps\Vegetation Surveys\2314302_Veg Zones_Overview.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: ACTEW Water, Vegetation Zones Overview, Version D 01/07/2013. Created by:jpcox

1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program

ACTEW Water

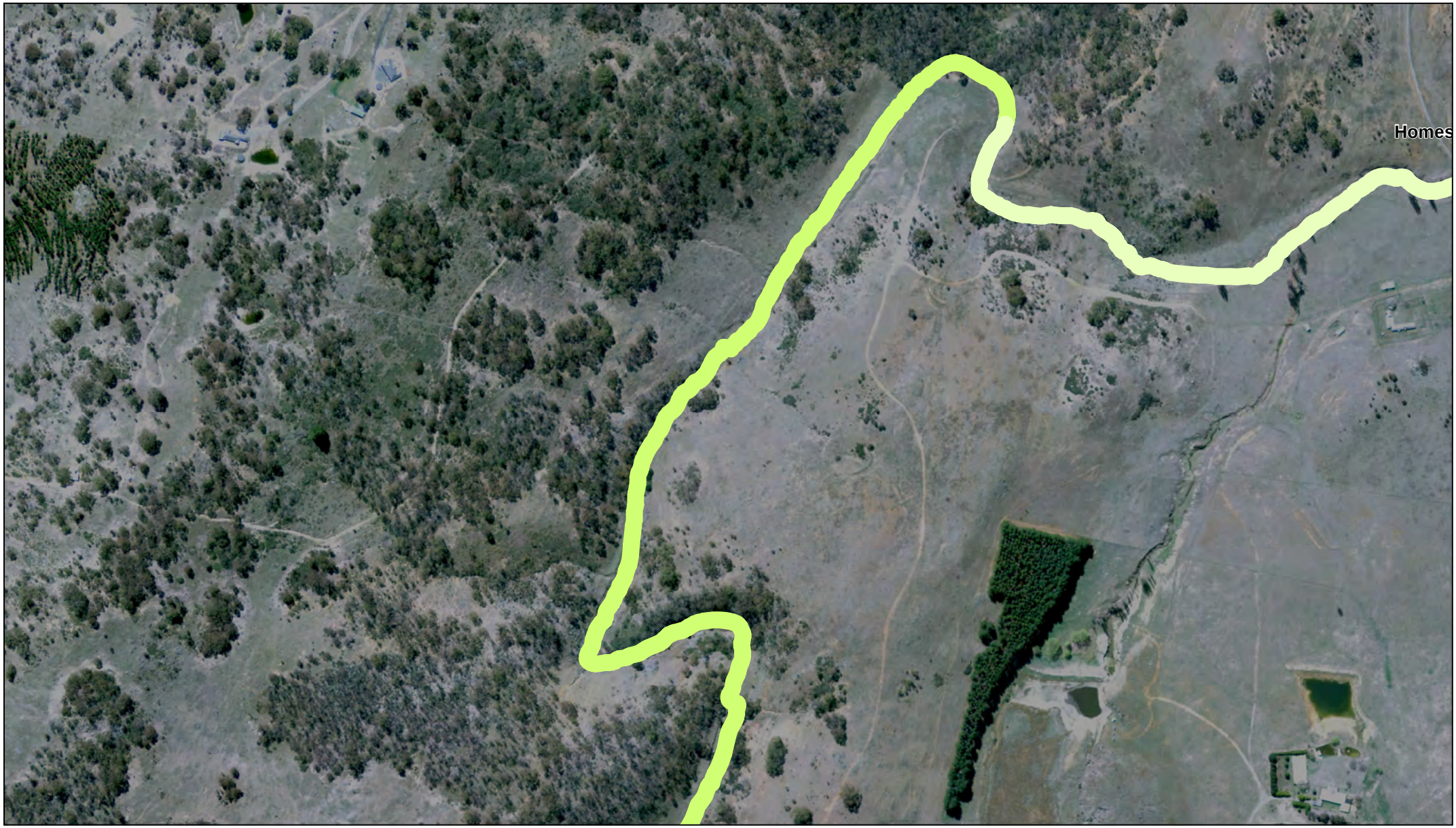
Job Number 23-15101
Revision E
Date 19 Feb 2015

Map A

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: GHD, Version E 19/02/2015. Created by:jpcox



1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program

ACTEW Water

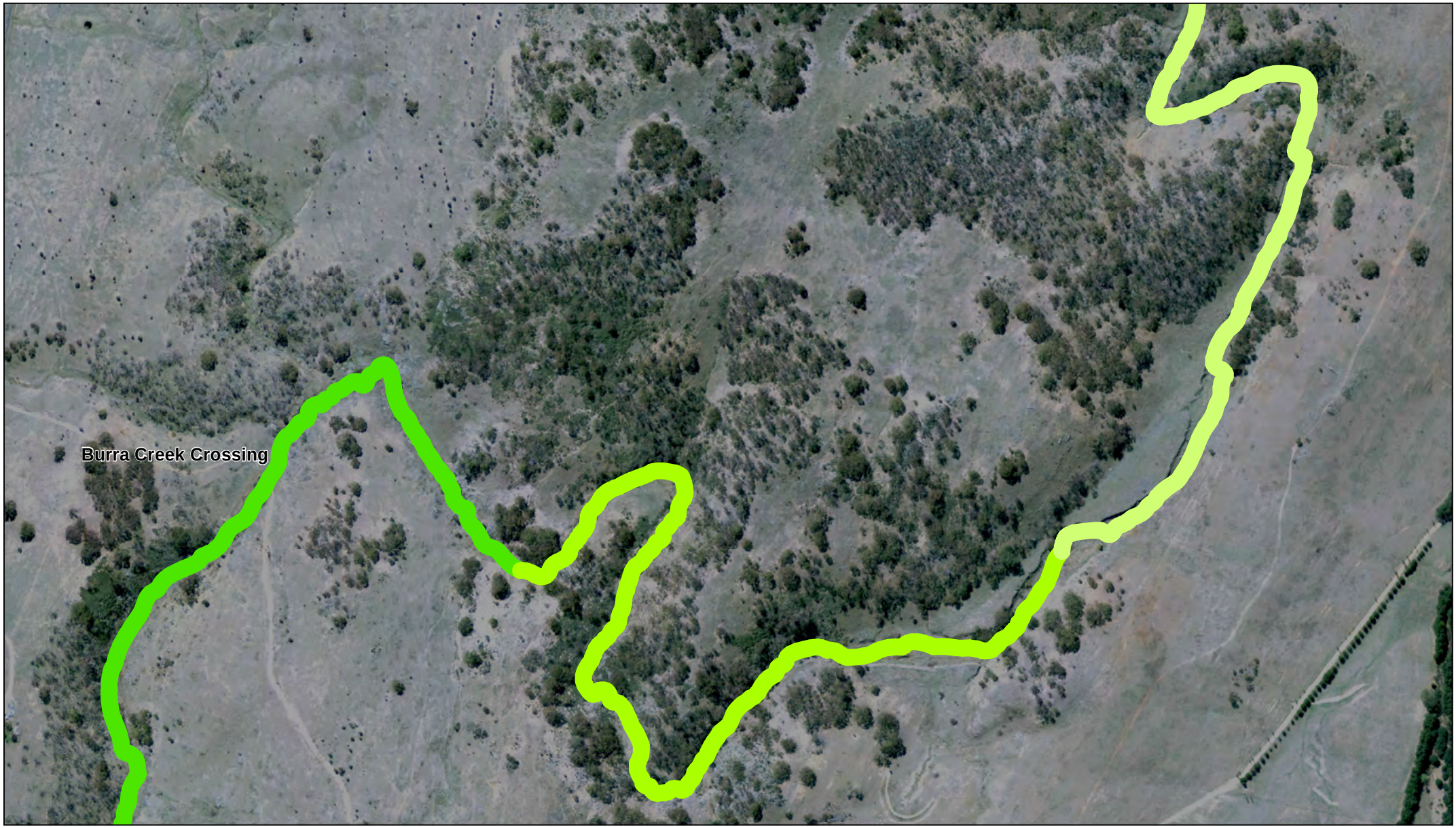
Job Number 23-15101
Revision E
Date 19 Feb 2015

Map B

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: GHD, Version E 19/02/2015. Created by:jpcox



1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number 23-15101
Revision E
Date 19 Feb 2015

Map C

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: GHD, Version E 19/02/2015. Created by:jpcox

1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number 23-15101
Revision E
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Map D

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

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0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
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M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number 23-15101
Revision E
Date 19 Feb 2015

Map E

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

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1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Vegetation Zone

1 4
2 5
3 6

GHD

Burra Creek: Vegetation Zones

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-15101
Revision	E
Date	19 Feb 2015

Map F

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: GHD, Version E 19/02/2015. Created by:jpcox

Appendix C - Site assessment species list

Appendix C. Species observed at all sites

Family	Species	Common Name	Origin	BUR 1a	BUR 1c	BUR 2a	BUR 2c	MUR 18	MUR 19
Apocynaceae	*Torilis* sp.	Parsley	Introduced					■	
Asteraceae	*Brachyscome rigidula*	Leafy Daisy	Native	■					
Asteraceae	*Carduus pycnocephalus*	Slender Thistle	Introduced				■		
Asteraceae	*Carduus* sp.	Thistle	Introduced	■					
Asteraceae	*Chrysocephalum apiculatum*	Common Everlasting	Native	■					
Asteraceae	*Conyza bonariensis*	Flax-Leaf Fleabane	Introduced	■	■	■	■		■
Asteraceae	*Conzya parva*	Small Fleabane	Introduced	■		■	■		
Asteraceae	*Gamochaeta* sp.	Cudweed	Introduced	■					
Asteraceae	*Hypochaeris radicata*	Cat's-Ears	Introduced	■	■	■			■
Asteraceae	*Silybum marianum*	Variegated Thistle	Introduced	■				■	
Asteraceae	*Sonchus asper*	Prickly Sowthistle	Introduced				■		
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	Introduced	■	■				
Asteraceae	*Sonchus* sp.	Sowthistle	Introduced	■					
Asteraceae	*Taraxacum* sp.	Dandelion	Introduced	■	■	■	■	■	
Brassicaceae	*Brassica nigra*	Black Mustard	Introduced					■	
Brassicaceae	*Hirschfeldia incana*	Buchan Weed	Introduced	■		■	■	■	
Brassicaceae	*Nasturtium officinale*	Watercress	Introduced				■		
Brassicaceae	*Raphanus raphanistrum*	Wild Radish	Introduced					■	
Caryophyllaceae	*Cerastium vulgare*	Common Mouse-Ear Chickweed	Introduced					■	■
Cyperaceae	*Carex albula*	New Zealand Hair Sedge	Introduced		■	■	■		
Cyperaceae	*Carex appresa*	Tall Sedge	Native	■					
Cyperaceae	*Carex* sp.	Sedge	Native						■
Cyperaceae	*Cyperus eragrostis*	Umbrella Sedge	Introduced						■
Cyperaceae	*Cyperus polystachyos*	Bunchy Flat-Sedge	Native				■		
Cyperaceae	*Cyperus* sp.	Flat-Sedge		■			■		
Cyperaceae	*Eleocharis acuta*	Common Spike-Rush	Native				■		

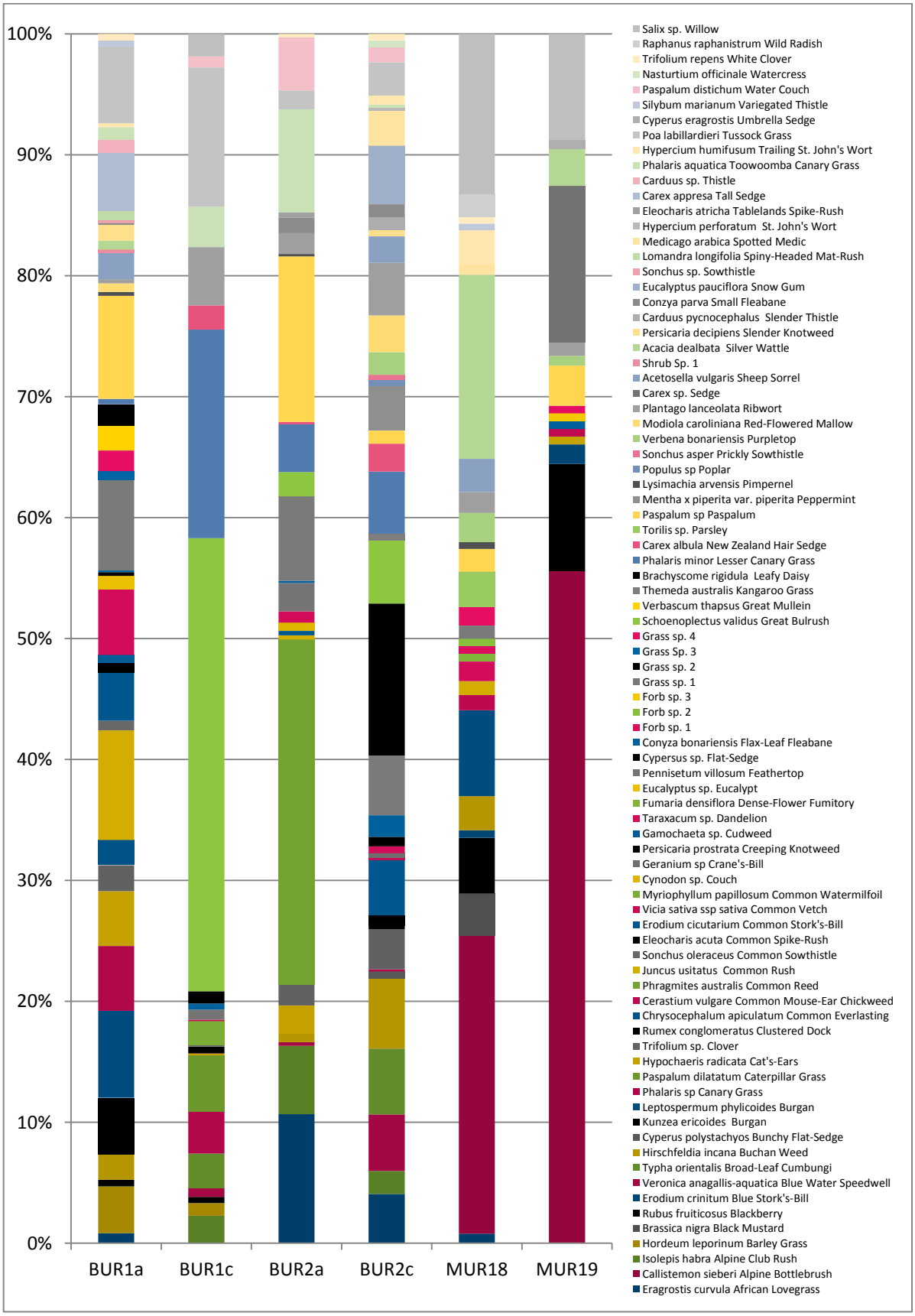
Family	Species	Common Name	Origin	BUR 1a	BUR 1c	BUR 2a	BUR 2c	MUR 18	MUR 19
Cyperaceae	*Eleocharis atricha*	Tablelands Spike-Rush	Native						
Cyperaceae	*Isolepis habra*	Alpine Club Rush	Native						
Cyperaceae	*Schoenoplectus validus*	Great Bulrush	Native						
Fabaceae	*Medicago arabica*	Spotted Medic	Introduced						
Fabaceae	*Trifolium repens*	White Clover	Introduced						
Fabaceae	*Trifolium* sp.	Clover	Introduced						
Fabaceae	*Vicia sativa ssp sativa*	Common Vetch	Introduced						
Geraniaceae	*Erodium cicutarium*	Common Stork's-Bill	Introduced						
Geraniaceae	*Erodium crinitum*	Blue Stork's-Bill	Native						
Geraniaceae	*Geranium* sp	Crane's-Bill	Introduced						
Haloragaceae	*Myriophyllum papillosum*	Common Watermilfoil	Native						
Hypericaceae	*Hypercium humifusum*	Trailing St. John's Wort	Introduced						
Hypericaceae	*Hypercium perforatum*	St. John's Wort	Introduced						
Juncaceae	*Juncus usitatus*	Common Rush	Native						
Lamiaceae	*Mentha x piperita var. piperita*	Peppermint	Introduced						
Lomandraceae	*Lomandra longifolia*	Spiny-Headed Mat-Rush	Native						
Malvaceae	*Modiola caroliniana*	Red-Flowered Mallow	Introduced						
Mimosaceae	*Acacia dealbata*	Silver Wattle	Native						
Myrtaceae	*Callistemon sieberi*	Alpine Bottlebrush	Native						
Myrtaceae	*Eucalyptus pauciflora*	Snow Gum	Native						
Myrtaceae	*Eucalyptus* sp.	Eucalypt	Native						
Myrtaceae	*Kunzea ericoides*	Burgan	Native						
Myrtaceae	*Leptospermum phylicoides*	Burgan	Native						
Papaveraceae	*Fumaria densiflora*	Dense-Flower Fumitory	Introduced						
Plantaginaceae	*Plantago lanceolata*	Ribwort	Introduced						
Plantaginaceae	*Veronica anagallis-aquatica*	Blue Water Speedwell	Introduced						
Poaceae	*Cynodon* sp.	Couch							
Poaceae	*Eragrostis curvula*	African Lovegrass	Introduced						
Poaceae	*Hordeum leporinum*	Barley Grass	Introduced						
Poaceae	*Paspalum dilatatum*	Caterpillar Grass	Introduced						

Family	Species	Common Name	Origin	BUR 1a	BUR 1c	BUR 2a	BUR 2c	MUR 18	MUR 19
Poaceae	*Paspalum distichum*	Water Couch	Native						
Poaceae	*Paspalum* sp.	Paspalum							
Poaceae	*Pennisetum villosum*	Feathertop	Introduced						
Poaceae	*Phalaris aquatica*	Toowoomba Canary Grass	Introduced						
Poaceae	*Phalaris minor*	Lesser Canary Grass	Introduced						
Poaceae	*Phalaris* sp.	Canary Grass	Introduced						
Poaceae	*Phragmites australis*	Common Reed	Native						
Poaceae	*Poa labillardieri*	Tussock Grass	Native						
Poaceae	*Themeda australis*	Kangaroo Grass	Native						
Polygonaceae	*Acetosella vulgaris*	Sheep Sorrel	Introduced						
Polygonaceae	*Persicaria decipiens*	Slender Knotweed	Native						
Polygonaceae	*Persicaria prostrata*	Creeping Knotweed	Native						
Polygonaceae	*Rumex conglomeratus*	Clustered Dock	Introduced						
Primulaceae	*Lysimachia arvensis*	Pimpernel	Introduced						
Rosaceae	*Rubus fruiticosus*	Blackberry	Introduced						
Salicaceae	*Populus* sp.	Poplar	Introduced						
Salicaceae	*Salix* sp.	Willow	Introduced						
Scrophulariaceae	*Verbascum thapsus*	Great Mullein	Introduced						
Typhaceae	*Typha orientalis*	Broad-Leaf Cumbungi	Native						
Verbenaceae	*Verbena bonariensis*	Purpletop	Introduced						
	Forb species. 1								
	Forb species. 2								
	Forb species. 3								
	Grass species. 1								
	Grass species. 2								
	Grass species. 3								
	Grass species. 4								
	Shrub species. 1								

Note: Grey cells indicate species were present at that site

Appendix D - Species coverage

Appendix D. Species coverage at each site



Appendix E - Whole of creek assessment species list

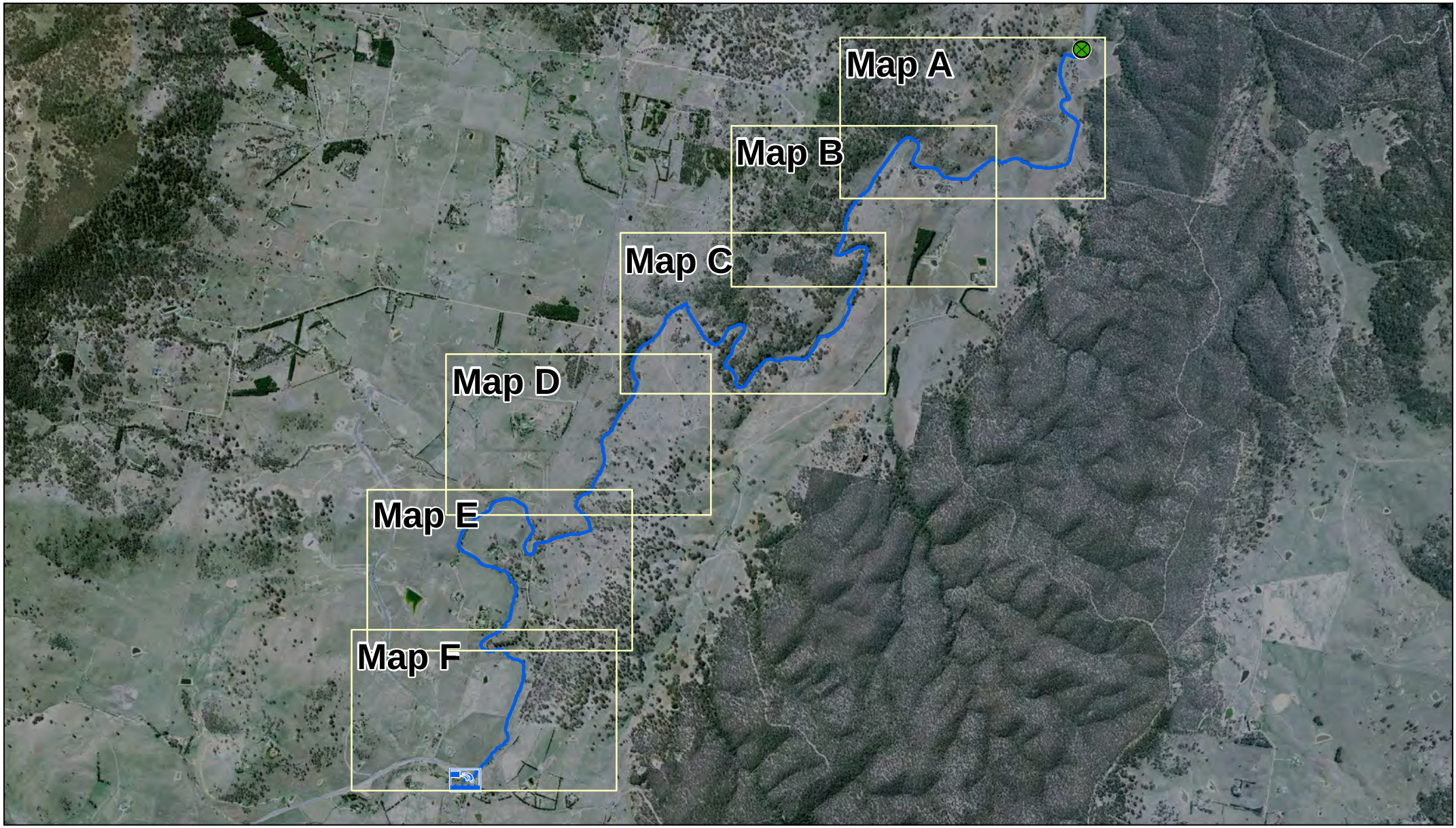
Appendix E. Whole of creek assessment species list

Family	Species	Common Name	Origin
Aizoaceae	*Mesembryanthemum crystalimum*	Common Ice Plant	Introduced
Asteraceae	*Brachyscome rigidula*	Leafy Daisy	Native
Asteraceae	*Carduus pycnocephalus*	Slender Thistle	Introduced
Asteraceae	*Chrysocephalum apiculatum*	Common Everlasting	Native
Asteraceae	*Cirsium vulgare*	Spear Thistle	Introduced
Asteraceae	*Conyza bonariensis*	Flax-Leaf Fleabane	Introduced
Asteraceae	*Conzya parva*	Small Fleabane	Introduced
Asteraceae	*Cotula coronopifolia*	Water Buttons	Introduced
Asteraceae	*Gamochaeta* sp.	Cudweed	Introduced
Asteraceae	*Hypochaeris radicata*	Cat's-Ears	Introduced
Asteraceae	*Leontodon saxatilis*	Hairy Hawkbit	Introduced
Asteraceae	*Pseudognaphalium luteoalbum*	Jersey Cudweed	Introduced
Asteraceae	*Sonchus asper*	Prickly Sowthistle	Introduced
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	Introduced
Asteraceae	*Taraxacum* sp.	Dandelion	Introduced
Boraginaceae	*Echium plantagineum*	Patterson's Curse	Introduced
Brassicaceae	*Brassica nigra*	Black Mustard	Introduced
Brassicaceae	*Hirschfeldia incana*	Buchan Weed	Introduced
Brassicaceae	*Nasturtium officinale*	Watercress	Introduced
Brassicaceae	*Nasturtium officinale*	Watercress	Introduced
Campanulaceae	*Wahlenbergia communis*	Tufted Bluebell	Native
Characeae	*Chara* sp.	Musk Grass	Native
Cyperaceae	*Carex albula*	New Zealand Hair Sedge	Introduced
Cyperaceae	*Carex appresa*	Tall Sedge	Native
Cyperaceae	*Cypersus* sp.	Flat-Sedge	
Cyperaceae	*Cyperus polystachyos*	Bunchy Flat-Sedge	Native
Cyperaceae	*Eleocharis acuta*	Common Spike-Rush	Native
Cyperaceae	*Eleocharis atricha*	Tablelands Spike-Rush	Native
Cyperaceae	*Isolepis habra*	Alpine Club Rush	Native
Cyperaceae	*Schoenoplectus validus*	Great Bulrush	Native
Elatinaceae	*Elatine gratioloides*	Waterwort	Native
Euphorbiaceae	*Euphorbia peplus*	Petty Spurge	Introduced
Fabaceae	*Medicago arabica*	Spotted Medic	Introduced
Fabaceae	*Senna pendula var. glabrata*	Easter Cassia	Introduced
Fabaceae	*Trifolium campestre*	Hop Clover	Introduced
Fabaceae	*Trifolium repens*	White Clover	Introduced
Fabaceae	*Trifolium* sp.	Clover	Introduced
Fabaceae	*Vicia sativa ssp sativa*	Common Vetch	Introduced
Geraniaceae	*Erodium cicutarium*	Common Stork's-Bill	Introduced
Geraniaceae	*Geranium* sp	Crane's-Bill	Introduced
Haloragaceae	*Myriophyllum aquaticum*	Parrots Feather	Introduced

Family	Species	Common Name	Origin
Hypericaceae	*Hypercium humifusum*	Trailing St. John's Wort	Introduced
Hypericaceae	*Hypercium perforatum*	St. John's Wort	Introduced
Juncaceae	*Juncus usitatus*	Common Rush	Native
Lamiaceae	*Mentha x piperita var. piperita*	Peppermint	Introduced
Lamiaceae	*Plectranthus neochilus*	Dogbane	Introduced
Lomandraceae	*Lomandra longifolia*	Spiny-Headed Mat-Rush	Native
Malvaceae	*Modiola caroliniana*	Red-Flowered Mallow	Introduced
Mimosaceae	*Acacia dealbata*	Silver Wattle	Native
Myrtaceae	*Callistemon sieberi*	Alpine Bottlebrush	Native
Myrtaceae	*Eucalyptus pauciflora*	Snow Gum	Native
Myrtaceae	*Eucalyptus* sp.	Eucalypt	Native
Myrtaceae	*Kunzea ericoides*	Burgan	Native
Phormiaceae	*Dianella longifolia*	Smooth Flax Lily	Native
Pittosporaceae	*Bursaria spinosa*	Sweet Bursaria	Native
Plantaginaceae	*Bacopa monnieri*	Water Hyssop	Native
Plantaginaceae	*Callitriche stagnalis*	Water Starwort	Introduced
Plantaginaceae	*Plantago lanceolata*	Ribwort	Introduced
Plantaginaceae	*Plantago major*	Greater Plantain	Introduced
Plantaginaceae	*Veronica anagallis-aquatica*	Blue Water Speedwell	Introduced
Poaceae	*Austrostipa scabra*	Corkscrew	Native
Poaceae	*Cenchrus longisetus*	White Foxtail	Introduced
Poaceae	*Cynodon* sp.	Couch	
Poaceae	*Eragrostis curvula*	African Lovegrass	Introduced
Poaceae	*Nassella trichotoma*	Serrated Tussock	Introduced
Poaceae	*Paspalum dilatatum*	Caterpillar Grass	Introduced
Poaceae	*Paspalum distichum*	Water Couch	Native
Poaceae	*Paspalum* sp.	Paspalum	
Poaceae	*Phalaris aquatica*	Toowoomba Canary Grass	Introduced
Poaceae	*Phalaris minor*	Lesser Canary Grass	Introduced
Poaceae	*Phalaris* sp.	Canary Grass	Introduced
Poaceae	*Phragmites australis*	Common Reed	Native
Poaceae	*Poa labillardieri*	Tussock Grass	Native
Poaceae	*Poa* sp.		
Poaceae	*Themeda australis*	Kangaroo Grass	Native
Polygonaceae	*Acetosella vulgaris*	Sheep Sorrel	Introduced
Polygonaceae	*Persicaria decipiens*	Slender Knotweed	Native
Polygonaceae	*Polygonum prostratum*	Wireweed	Introduced
Polygonaceae	*Rumex conglomeratus*	Clustered Dock	Introduced
Polygonaceae	*Rumex crispus*	Curled Dock	Introduced
Primulaceae	*Lysimachia arvensis*	Pimpernel	Introduced
Pteridaceae	*Cheilanthes* sp.	Rock Fern	Native
Ranunculaceae	*Ranunculus amphitrichus*	Small River Buttercup	Native
Ranunculaceae	*Ranunculus inundatus*	River Buttercup	Native
Rosaceae	*Acaena ovina*	Sheep's Burr	Native
Rosaceae	*Crataegus monogyna*	Hawthorn	Introduced

Family	Species	Common Name	Origin
Rosaceae	*Pyracantha angustifolia*	Orange Firethorn	Introduced
Rosaceae	*Rosa rubiginosa*	Sweet Briar	Introduced
Rosaceae	*Rubus fruiticosus*	Blackberry	Introduced
Salicaceae	*Populus nigra*	Lombardy Poplar	Introduced
Salicaceae	*Populus* sp.	Poplar	Introduced
Salicaceae	*Salix alba*	White Willow	Introduced
Salicaceae	*Salix babylonica*	Weeping Willow	Introduced
Salicaceae	*Salix* sp.	Willow	Introduced
Scrophulariaceae	*Verbascum virgatum*	Twiggy Mullein	Introduced
Solanaceae	*Solanum nigram*	Black-berry Nightshade	Introduced
Typhaceae	*Typha orientalis*	Broad-Leaf Cumbungi	Native
Verbenaceae	*Verbena bonariensis*	Purpletop	Introduced
	Forb species. 1		
	Forb species. 2		
	Forb species. 3		
	Grass species. 1		
	Grass species. 2		

Appendix F - Dominant vegetation maps



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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Burra Creek

Detailed Maps

M2G Discharge Structure

London Bridge Arch

Burra Creek
Areas of Dominant Vegetation Overview

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-15101
Revision	E
Date	19 Feb 2015

G:\23\14302\GIS\Maps\Vegetation Surveys\2314302_Veg Zones_Overview.mxd

Level 7, 16 Marcus Clarke Street, Canberra, ACT, 2601, Australia **T** 61 2 6113 3200 **F** 61 2 6113 3299 **E** cbrmail@ghd.com **W** www.ghd.com

Data source: ACTEW Water, Dominant Vegetation Overview, Version E 19/02/2015. Created by:jpcox

1 : 6,070 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

M2G Discharge Structure

London Bridge Arch

Dominant Vegetation

- *Phragmites australis*
- *Rubus fruticosus*
- *Schoenoplectus validus*
- *Typha orientalis*

Burra Creek
Areas of Dominant Vegetation
Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-15101
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Date	19 Feb 2015

Map A

G:\23\14302\GIS\Maps\Vegetation Surveys\23_14302_Vegetation Zones.mxd

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Metres

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M2G Discharge Structure

London Bridge Arch

Dominant Vegetation

Phragmites australis

Rubus fruticosus

Schoenoplectus validus

Typha orientalis

Burra Creek
Areas of Dominant Vegetation
Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-15101
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Map B

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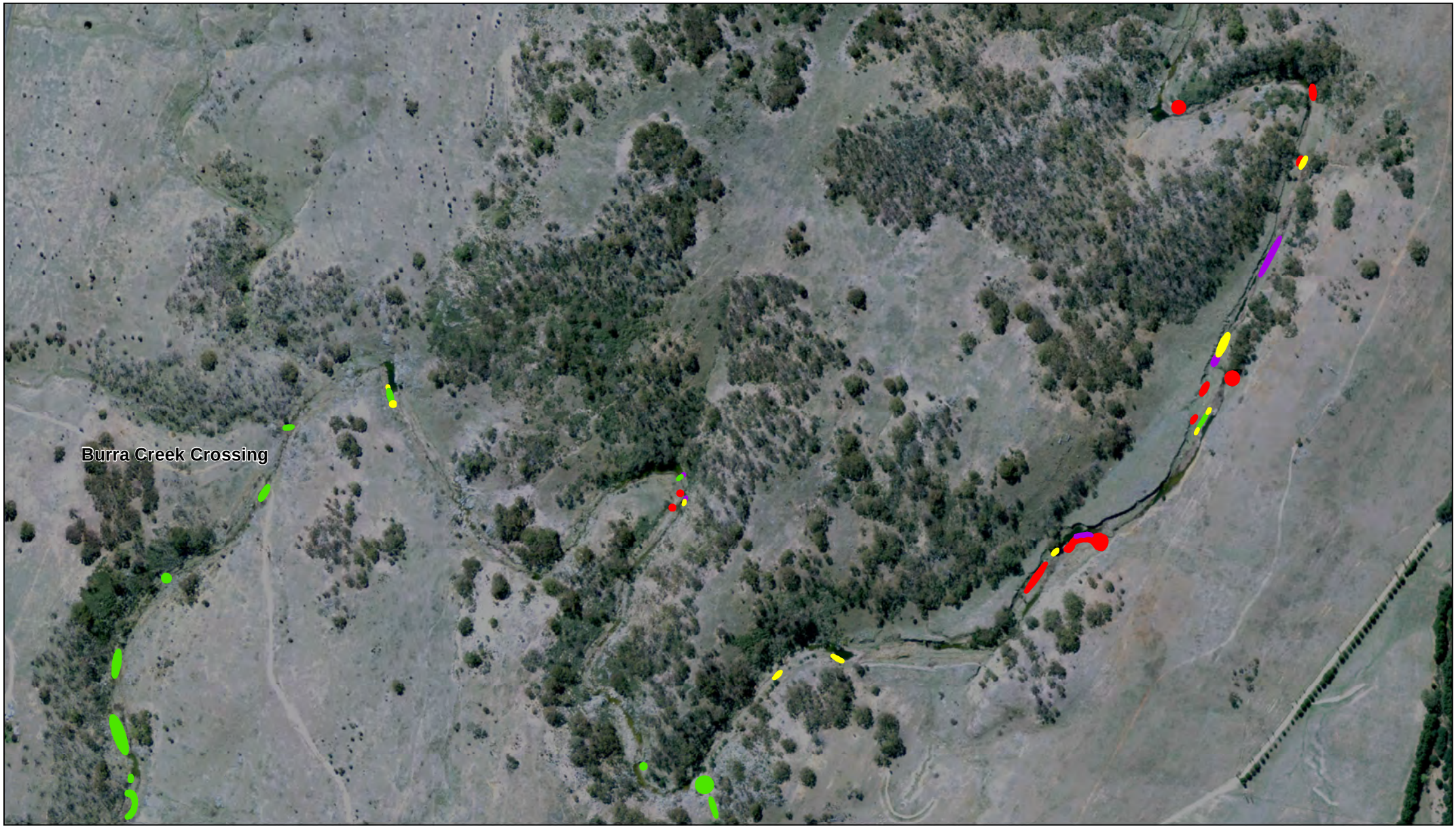

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Metres

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Horizontal Datum: GDA 1994
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M2G Discharge Structure

London Bridge Arch

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- *Rubus fruticosus*
- *Schoenoplectus validus*
- *Typha orientalis*

Burra Creek
Areas of Dominant Vegetation

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-15101
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Map C

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M2G Discharge Structure

London Bridge Arch

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Phragmites australis

Rubus fruticosus

Schoenoplectus validus

Typha orientalis

Burra Creek
Areas of Dominant Vegetation
Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number 23-15101
Revision E
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Map D

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M2G Discharge Structure

London Bridge Arch

Dominant Vegetation

Phragmites australis

Rubus fruticosus

Schoenoplectus validus

Typha orientalis

Burra Creek
Areas of Dominant Vegetation
Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-15101
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Map E

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Burra Creek
Areas of Dominant Vegetation
Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-15101
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Map F

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Data source: GHD, Version E 19/02/2015. Created by:jpcox

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	Josh Cox	Phil Taylor		Norm Mueller		11/02/2015
2	Josh Cox			Norm Mueller		26/02/2015

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