Inland Waters & Catchment Ecology

Katarapko Floodplain Vegetation Condition Monitoring 2015 Report

Jason Nicol, Susan Gehrig, Kate Frahn and Josh Fredberg

SARDI Publication No. F2015/000582-1
SARDI Research Report Series No. 867

SARDI Aquatics Sciences
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October 2015

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This publication may be cited as:
Nicol, J.M, Gehrig, S.L., Frahn, K.A. and Fredberg, J.F. (2015). Katarapko Floodplain Vegetation Condition Monitoring 2015 Report. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2015/000582-1. SARDI Research Report Series No. 867. 30pp.

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Printed in Adelaide: October 2015

SARDI Publication No. F2015/000582-1
SARDI Research Report Series No. 867

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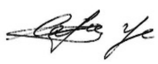
Signed: 

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ACKNOWLEDGEMENTS

The authors thank Arron Strawbridge for field assistance. Benita Dillon, Andy Harrison, Todd Wallace and Chris Bice for comments on early drafts of this report. Funding for condition monitoring has been provided by the South Australian Riverland Floodplain Integrated Infrastructure Program (SARFIIP). SARFIIP has been initiated to improve the flexibility of managing the system via new infrastructure and operational solutions. The purpose of SARFIIP is to improve the ecological condition of Riverland floodplains, including the Pike and Katarapko Floodplains, using environmental regulators to deliver environmental water. SARFIIP seeks to introduce variability in patterns of flooding and to mimic aspects of the natural water regime. The intent is to improve the condition of floodplain biotic communities and to improve biological connectivity between the main River Murray channel and its floodplain environments. The infrastructure proposed to be constructed on the Pike and Katarapko Floodplains will have a similar function to the Chowilla environmental regulator. SARFIIP, in conjunction with the Riverine Recovery Program (RRP), aims to create an interconnected mosaic of manageable floodplains between Lock 3 and the South Australian Borders with New South Wales and Victoria. This is to be achieved through the integrated operation of River Murray locks 4, 5 and 6, and purpose-built infrastructure on Katarapko, Pike and Chowilla Floodplains.

EXECUTIVE SUMMARY

Floodplain ecosystem degradation, as a result of river regulation and water abstraction, is widespread throughout the lower River Murray in South Australia. Most native floodplain understorey species are adapted to periodic floodplain inundation, but the frequency, duration and magnitude of such events have been greatly reduced from compared to pre-regulation (Maheshwari *et al.* 1995). In the absence of regular inundation, floodplain species are initially replaced by terrestrial species and secondly, salt tolerant species, or conditions may become so hostile that plants cannot survive, and are replaced by bare soil. This can have serious implications for riverine and terrestrial trophodynamics, as a source of carbon that is produced at regular intervals is now only available periodically.

Environmental regulators that enable inundation under flows that would not normally inundate floodplain habitats have been constructed (e.g. Chowilla) or are proposed for several sites on the lower River Murray. These regulators may reinstate aspects of the inundation regime and provide conditions suitable for the recruitment of native floodplain species. Such an environmental regulator has been proposed for the Katarapko system under the *South Australian Riverland Floodplain Integrated Infrastructure Project* (SARFIIP). The Katarapko Anabranch system bypasses Lock and Weir Number 4 resulting in a 3 m head differential between its upstream inlets (e.g. Bank J) and the confluence of Katarapko Creek and the River Murray. This head differential provides the opportunity to undertake engineered floodplain inundation events through the use of an environmental regulator. Information regarding the plant community prior to construction of the proposed regulator is required to evaluate the benefits (or dis-benefits) of engineered floodplain inundation.

A total of 60 condition monitoring sites were established on the Katarapko Floodplain and surveyed in April 2015. Each site consisted of three 1 x 15 m quadrats running parallel to elevation contours that are divided into 1 x 1 m cells and the presence of species in each cell recorded to give a score between zero and 15 for each species. This technique has been used throughout the lower River Murray and has been shown to be an effective method to detect change in plant communities through time and in response to interventions.

A total of 52 taxa (including 11 exotics and two species listed as rare in South Australia) from 18 families, were recorded across the in April 2015. The five most frequently encountered taxa (accounting for 45% of quadrat presences) were *Atriplex* spp., *Calotis hispidula, Sclerolaena stelligera, Sclerolaena divaricata and Disphyma crassifolium* ssp. *clavellatum*.

Multivariate analysis of quadrat data classified sites into six groups using Cluster Analysis (at 30% similarity) and Indicator Species Analysis produced a list of representative taxa for each grouping:

1. "Dryland" characterised by the terrestrial taxa *Atriplex* spp*., Bulbine bulbosa, Chenopodium nitrariaceum*, *Disphyma crassifolium, Sclerolaena brachyptera, Sclerolaena divaricata and Sclerolaena stelligera* with the floodplain species *Calotis hispidula* (65% of sites).

2. "Bare soil" characterised by quadrats devoid of vegetation (15% of sites).

3. "Flood responders 1" characterised by the floodplain species *Glinus lotoides, Glycyrrhiza acanthocarpa, Heliotropium europaeum* and *Polygonum plebeium* and the exotic terrestrial annual *Medicago* spp. (8% of sites).

4. "Flood responders 2" characterised by the floodplain species *Dysphania pumilio* and *Sporobolus mitchelli;* amphibious *Cyperus gymnocaulos* and the exotic terrestrial annual *Carrichtera annua* (3.5% of sites).

5. "Open water" sites that were inundated (5% of sites).

6. "Flood responders 3" characterised by the floodplain species *Atriplex suberecta, Dittrichia graveolens, Heliotropium curassavicum, Scleroblitum atriplicinum, Senecio cunninghamii* and *Stemodia florulenta* (3.5% of sites).

There was evidence to suggest that some areas of the Katarapko Floodplain were inundated recently. The vegetation present on the Katarapko Floodplain in 2015 had a higher proportion of floodplain species (38.4% of observations) compared to the Pike (27%) and Chowilla (25%) floodplains in 2015. This may be an artefact of sampling because a larger number of temporary wetlands were surveyed compared to the Pike Floodplain; although, a larger number of temporary wetlands were surveyed on the Chowilla Floodplain and the environmental regulator was operated in spring 2014. In addition to temporary wetlands on the Katarapko Floodplain having large numbers of floodplain species, these species were also present at sites that were dominated by terrestrial species. Species richness on the Katarapko Floodplain in 2015 (52 species) was also higher than the Pike Floodplain (35 species).

The current vegetation survey for the Katarapko Floodplain will provide a baseline that can be used to detect the change in vegetation through time, in response to natural flooding events, drying phases and management actions including managed inundations via the operation of the proposed environmental regulator. The collection of several years of pre-construction data will enable the changes in vegetation through time to be investigated and gain information regarding decline or recovery depending on natural conditions prior to regulator construction.

1. INTRODUCTION

The combination of river regulation and water abstraction has resulted in reduced frequency, duration and magnitude of floodplain inundation in the lower River Murray compared to pre-regulation (e.g. Maheshwari *et al.* 1995). The biota of river systems are adapted to the natural flow regime and alteration of the flow regime typically results in substantial changes to biotic patterns and processes (e.g. Poff *et al.* 1997; Poff and Zimmerman 2010). This includes the spatio-temporal dynamics of floodplain and littoral vegetation communities. In the lower River Murray, reduced floodplain inundation has resulted in rising saline water tables and soil salinisation (e.g. Eldridge *et al.* 1993; Akeroyd *et al.* 2003; Holland *et al.* 2006; Overton *et al.* 2006a) and a reduction in the width of the littoral zone to a narrow band around permanent water bodies (Nicol *et al.* 2010a). This has resulted in species adapted to stable water levels colonising river banks (Blanch and Walker 1997; Blanch *et al.* 1999; 2000), the decline in condition of long-lived species such as river red gums (*Eucalyptus camaldulensis*) and black box (*Eucalyptus largiflorens*) (e.g. Eldridge *et al.* 1993; Murray-Darling Basin Commission 2003; Overton *et al.* 2006a) and reduced opportunities for colonisation of floodplain understorey species (Nicol *et al.* 2010a).

The floodplain understorey plant community of the lower River Murray is dominated by species that are adapted to regular disturbance (Grime's (1979) r-selected species) and physiologically and ecologically more similar to desert annuals than aquatic plants (Nicol 2004). Most species are intolerant of flooding as adult or juvenile plants but require high soil moisture to germinate. In the arid environment of the lower River Murray Floodplain rainfall is generally insufficient and inundation via flooding is required for germination (Nicol 2004; Nicol *et al.* 2010a). Most floodplain species germinate as flood waters recede and have flexible life history strategies that enable them to grow, flower and set seed before conditions become unfavourable during the drying phase (Nicol 2004). Whilst conditions are unfavourable they persist in the seed bank, with most species having long-lived persistent seed banks (e.g. Thompson 1992; Leck and Brock 2000; Brock 2011). Whilst the majority of understorey species are intolerant of flooding and germinate as water levels recede (herein referred to as floodplain species), amphibious species (species that either tolerate or respond to fluctuating water levels as adult or juvenile plants (Brock and Casanova 1997) are also often present on floodplains; particularly in areas close to permanent water or in temporary wetlands (Gehrig *et al.* 2014).

Management actions to deliver environmental water, reinstate water level variability and inundate floodplain in the absence of hydrological flooding have been undertaken throughout the lower River Murray. Management actions that have been implemented include: pumping water to temporary wetlands, weir pool manipulations, injection of freshwater into shallow aquifers and the construction of the Chowilla Environmental Regulator. Pumping temporary wetlands has been successful in improving tree condition (Holland *et al.* 2009; Holland *et al.* 2013) and providing suitable conditions for recruitment of floodplain and amphibious understorey species (Nicol *et al.* 2010b; Nicol 2012). However, the areas influenced are usually small, not hydrologically connected to the main river channel and typically require large pumps to move water from the main channel and the construction of banks or levees to retain water in the wetland basin. Weir pool manipulations maintain the hydrological connection to the main river channel but operational constraints mean the maximum water level is typically only 50 cm above normal operating level. Therefore, the area inundated is usually small and the effect of the weir pool raising diminishes as the distance from the weir increases (Overton *et al.* 2006b). The small area inundated by raising weirs is often occupied by emergent species, and the opportunities for floodplain and amphibious plant recruitment is limited (Gehrig *et al.* 2015). Injection of freshwater into shallow aquifers at the Bookpurnong Floodplain proved effective in creating localised freshwater lenses and improving tree condition but the areas that benefited were small and provided no surface water for the recruitment of floodplain and amphibious taxa (Berens *et al.* 2009a; 2009b; Alaghmand *et al.* 2015).

The Chowilla Environmental Regulator was commissioned in spring 2014. The 3 m head differential between the upper and lower pool levels of Lock and Weir 6 meant that water levels could be raised up to 3 m by the regulator and significant areas of temporary wetlands and floodplain inundated. This significantly increased the littoral zone and provided large areas with conditions suitable for the recruitment of floodplain and amphibious species. Monitoring results showed that there was significant recruitment of floodplain and amphibious species, although not to the extent as expected (Gehrig *et al.* in prep.). Similar to the Chowilla Floodplain, the Katarapko (and Pike) Anabranch systems bypass a weir and there is potential to construct environmental regulators on these systems to inundate temporary wetlands and floodplain in the absence of overbank flows. One of the objectives of the *South Australian Riverland Floodplain Integrated Infrastructure Program* (SARFIIP) is to fund the construction of regulators on the Katarapko and Pike systems to improve floodplain condition.

The collection of data prior to regulator construction is important to (i) provide a baseline to facilitate comparisons of the plant communities before and after the regulator has been operated and (ii) allow iterative improvement of subsequent management actions. In contrast to the Chowilla and Pike floodplains, where there are extensive datasets regarding floodplain plant communities, there is little quantitative vegetation data from Katarapko. Large-scale plant communities have been mapped on the Katarapko Floodplain (Katfish Reach Steering Group 2008); however, vegetation mapping has limited applicability to evaluate management actions. Furthermore, the temporally variable nature of plant communities (particularly understorey vegetation) is not captured in a vegetation map from a specific point in time. Future monitoring will contribute to the understanding of the vegetation dynamics of the Katarapko Floodplain and provide an extensive baseline dataset to evaluate the benefits of regulator operation.

1.1. Objectives

The objective of the study was to quantitatively monitor the understorey plant community of the Katarapko Floodplain in 2015 to provide a baseline to evaluate future changes in the plant community under regulated inundation (and other interventions) and natural flooding.

2. METHODS

2.1. Study site and hydrology

The Katarapko Anabranch and Floodplain located between the townships of Berri and Gerrard in South Australia (Figure 1) is one of three large anabranch-floodplain habitats in the lower Murray. Covering approximately 9,000 ha (Katfish Reach Steering Group 2008) Katarapko consists of a variety of aquatic environments including a series of anabranch creeks, temporary billabongs and permanent backwaters (Katfish Reach Steering Group 2008; Beyer *et al.* 2011) (Figure 2). Water enters the Katarapko system through four inlet creeks upstream of Lock and Weir number 4; the Northern and Southern Arms of Eckert Creek, Sawmill Creek and Katarapko Creek (Katfish Reach Steering Group 2008; Beyer *et al.* 2011) (Figure 2). Water flows through the Northern Arm of Eckert Creek into Eckert Wide Water but the Southern Arm of Eckert Creek Divides into two with one creek flowing into the Northern Arm and the other into the downstream end of Eckert Wide Water (Figure 2). After Eckert Wide Water, Eckert Creek flows into The Splash and is joined by Sawmill Creek (Figure 2). Katarapko Creek branches off the River Murray downstream of Sawmill Creek and is regulated by the Katarapko Weir, The Splash joins Katarapko Creek downstream of Katarapko Weir and flows for 16.2 km before rejoining with the River Murray downstream of Lock and Weir number 4 (Katfish Reach Steering Group 2008) (Figure 2).

The Katarapko Floodplain is characterised by a range of vegetation types including *Eucalyptus largiflorens* (black box) woodlands, *Eucalyptus camaldulensis* var. *camaldulensis* (river red gum) woodlands, *Atriplex* spp. (saltbush) shrublands, *Acacia stenophylla* (river coobah) woodlands, *Duma florulenta* (lignum) shrublands and a range of aquatic and riparian vegetation types associated with the various temporary and permanent wetlands (Katfish Reach Steering Group 2008). However, the Millennium drought (van Dijk *et al.* 2013), river regulation (e.g. Maheshwari *et al.* 1995) and the regulation of the Katarapko Anabranch system through a series of banks and flow-control structures has reduced the occurrence of overbank flooding. Consequently, the water requirements of floodplain flora have not been met and an overall decline in the condition of floodplain vegetation has been observed (Katfish Reach Steering Group 2008).

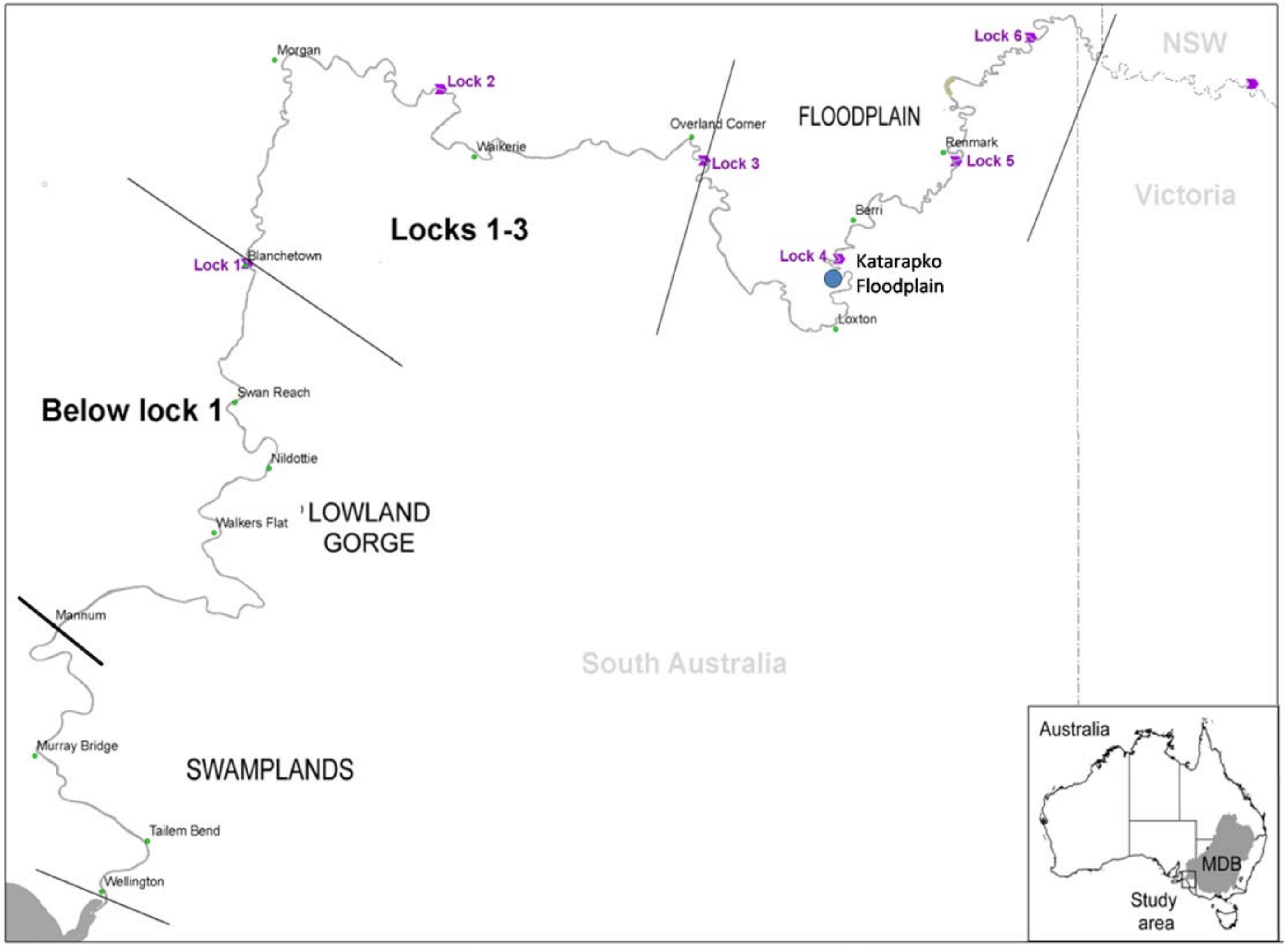

Figure 1: The Lower River Murray and geomorphic regions in South Australia (modified from Holland *et al.* 2013); inset shows extent and position of the Murray-Darling Basin in Australia. The Katarapko Floodplain is represented by the blue circle.

Figure 2: Map of the Katarapko Anabranch and Floodplain system (modified from Beyer *et al.* 2011).

Recent flows to the Katarapko Floodplain

From 1996 to 2010, the Murray-Darling Basin experienced the most severe drought in recorded history (van Dijk *et al.* 2013). Below average stream flows, coupled with upstream water extraction and river regulation, resulted in reduced inflows to South Australia (van Dijk *et al.* 2013), which prior to August 2010 were insufficient to inundate the floodplain (Murray-Darling Basin Authority 2011) (Figure 3). However, from June 2010 to May 2011 total inflow volumes were among the highest on record and the patterns of inflows were atypical compared to historical flows (Murray-Darling Basin Authority 2011) (Figure 3). Until the end of November 2010, inflows were the highest since 2000, but not unusual compared to historical flows. However, inflows during summer 2010-11 were the highest on record (~6,700 GL); more than double the previous highest record of ~2,980 GL in the summer of 1992-93 (Murray-Darling Basin Authority 2011).

The increase in inflows in the spring and summer of 2010-11 resulted in widespread flooding across the Murray-Darling Basin. By the end of May 2011, the total annual flow into South Australia was ~14,000 GL, which was the highest total since 1975-76. During this period, flow into South Australia peaked at 93,000 ML/day, in February 2011 (Figure 3). Flows of this magnitude were estimated to inundate around 70% of the Katarapko Floodplain area (Overton *et al.* 2006b), where the delineation between floodplain and highland is based upon the extent of the 1956 flood (Overton and Doody 2010). Hence, for the first time in ten years, flows not only watered red gum (*Eucalyptus camaldulensis*) woodland and wetland areas, but also reached some black box (*Eucalyptus largiflorens*) woodlands (Murray-Darling Basin Authority 2011).

Large flows with maximums of ~100,000 ML/day typically last for around three months as unregulated events (Sharley and Huggan 1995), but the 2010-11 high flows and floodplain inundation persisted for ~11 months (Figure 3). Flows remained high throughout winter and spring 2011 peaking at 41,000 ML/day in August 2011 and remained above 15,000 ML/day throughout the summer and another two flow pulses peaking at 60,000 ML day^{-1} and 50,000 ML/day (flow into South Australia) occurred in April and October 2012 (Figure 3). Flow declined and from January 2013 flow into South Australia was maintained at entitlement flows until August 2013, when there was a small unregulated flow peaking at 23,500 ML/day in October (Figure 3). Flow then declined and from December 2013 to June 2014 flow to South Australia was at entitlement levels (Figure 3). There was a small flow peaking at 16,000 ML/day in July after which flows decreased to 5,000 ML/day in September 2014 and increased to between 7,000 and 11,000 ML/day between October 2014 and March 2015 after which flows returned to entitlement levels (Figure 3). These flows were confined to the channel and were insufficient to inundate large areas of floodplain; nevertheless, some low lying temporary wetlands were flooded between 2011 and 2015.

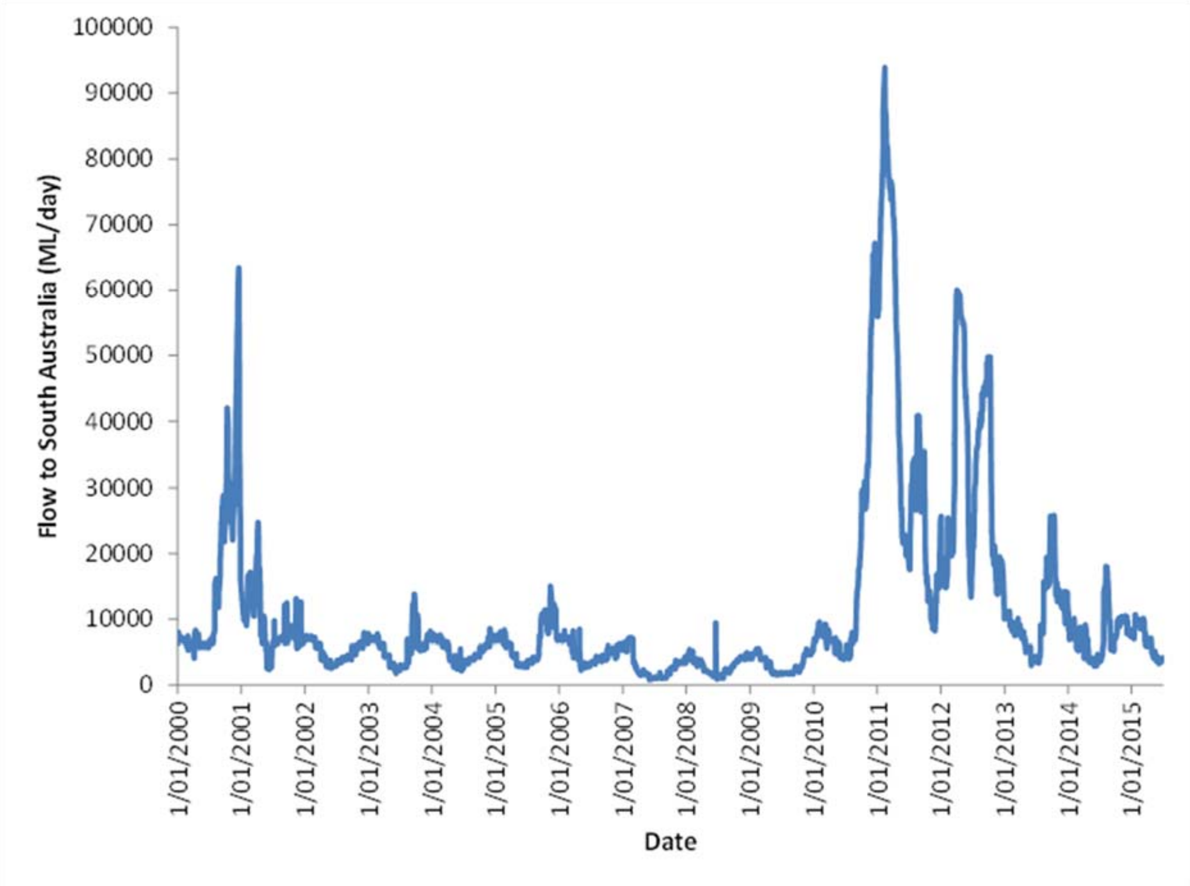

Figure 3: River Murray flow to South Australia from January 2000 to June 2015.

2.2. Vegetation surveying protocol

Vegetation survey methods used in this assessment followed those used for other vegetation monitoring projects in the South Australian River Murray Corridor upstream of Wellington; including the Chowilla condition (Gehrig *et al.* 2014) and intervention (Nicol *et al.* 2010b; Nicol 2012) monitoring programs, Chowilla works and measures understorey vegetation surveys (Zampatti *et al.* 2011), Lock 1 draw down (Nicol 2010) and refill (Nicol *et al.* 2013), Pike Floodplain condition monitoring (Marsland 2010; Holland *et al.* 2013) and weir pool raising monitoring (Gehrig *et al.* 2015). The use of consistent methods and ongoing monitoring will allow comparison of data across studies to enable a greater understanding of vegetation dynamics in the lower River Murray.

In April 2015 the baseline vegetation survey was undertaken and 60 sites located in low-lying open areas across the Katarapko Floodplain were established (Figure 4, Appendix 1). Sites were chosen such that:

- all sites were located in areas that would be inundated by natural overbank flows;
- some sites were located in areas that would be inundated by the proposed regulator and others in areas that would not be inundated to act as reference sites;
- had no direct tree overstorey;
- were accessible by 4WD vehicle during dry conditions or by boat; and
- covered a range of vegetation types.

At each site, three 15 m x 1 m quadrats were surveyed. Quadrats were arranged in a straight line parallel to elevation contours (i.e. quadrats were at the same elevation) 50 m apart. Each quadrat was divided into 15, 1 m x 1 m cells. The presence of each species that had live plants rooted within each cell was recorded to give a total score out of 15 for each quadrat. Cells containing no live plants were recorded as bare ground.

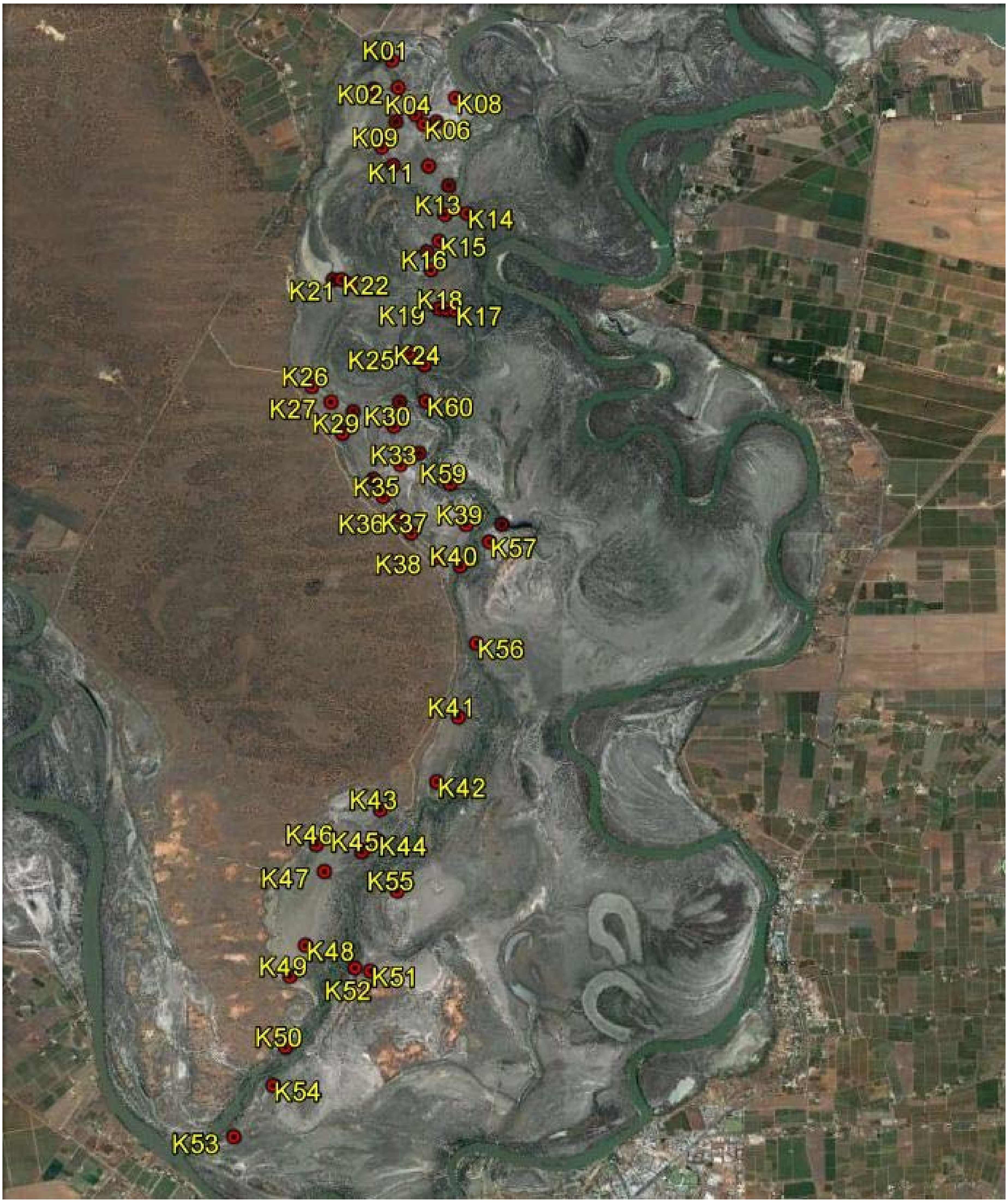

Figure 4: Satellite image of the Katarapko Floodplain showing floodplain vegetation monitoring sites.

2.3. Plant identification and nomenclature

Plants were identified using keys in Jessop and Toelken (1986), Cunningham *et al.* (1992), and Jessop *et al.* (2006). In some cases, due to immature individuals or lack of floral structures, plants were identified to genus only. Nomenclature follows the Centre for Australian National Biodiversity Research and Council of Heads of Australasian Herbaria (2015). A species list, plus their functional classification, life history strategy and conservation status is presented in Appendix 2.

2.4. Data analysis

The plant communities present were compared using Group Average Clustering (McCune *et al.* 2002) performed on pooled data (species scores were averaged from the three quadrats at each site). A cut-off score of 30% similarity was used to determine the cluster groups based on species presence and their abundances. The 30% cutoff produces a manageable number of significantly different groups that characterised floodplain vegetation well in studies from the Chowilla (Gehrig *et al.* 2014) and Pike (Marsland 2010) floodplains. To identify the representative species for each group, Indicator Species Analysis (Dufrene and Legendre 1997) was performed on the unpooled data (n = 180) using the groupings of sites derived from the cluster analysis. All multivariate analyses used Bray-Curtis (1957) distances to construct the similarity matrices and were undertaken using the multivariate statistical package PCOrd 5.12 (McCune and Mefford 2006). Finally, the locations of the quadrats were mapped to allow presentation of the spatial distribution of the vegetation groups.

3. RESULTS

3.1. 2015 plant communities

A total of 52 taxa (including 11 exotics and two species listed as rare in South Australia) from 18 families were observed across the 60 sites. The five most frequently encountered taxa (accounting for 45% of quadrat presences) were *Atriplex* spp., *Calotis hispidula, Sclerolaena stelligera, Sclerolaena divaricata and Disphyma crassifolium* ssp*. clavellatum*. All but *Disphyma crassifolium* ssp*. clavellatum* (Aizoaceae) and *Calotis hispidula* (Asteraceae) are members of the Chenopodiaceae.

Cluster analysis separated the sites into six groups at 30% similarity (Figure 5). This produced a manageable number of groups and reflected the major differences between sites. The spatial distribution of plant communities based on the groups identified by cluster analysis is presented in Figure 6. Indicator Species Analysis produced a list of representative taxa for each grouping (Table 1). These species lists were used to name the five groups according to their characteristic taxa:

1. "Dryland" characterised by the terrestrial taxa *Atriplex* spp*., Bulbine bulbosa, Chenopodium nitrariaceum*, *Disphyma crassifolium, Sclerolaena brachyptera, Sclerolaena divaricata and Sclerolaena stelligera* with the floodplain species *Calotis hispidula* (65% of sites) (Table 1).

2. "Bare soil" characterised by quadrats devoid of vegetation (15% of sites) (Table 1).

3. "Flood responders 1" characterised by the floodplain species *Glinus lotoides, Glycyrrhiza acanthocarpa, Heliotropium europaeum* and *Polygonum plebeium* and the exotic terrestrial annual *Medicago* spp. (8% of sites) (Table 1).

4. "Flood responders 2" characterised by the floodplain species *Dysphania pumilio* and *Sporobolus mitchelli;* amphibious *Cyperus gymnocaulos* and the exotic terrestrial annual *Carrichtera annua* (3.5% of sites) (Table 1).

5. "Open water" sites that were inundated (5% of sites) (Table 1).

6. "Flood responders 3" characterised by the floodplain species *Atriplex suberecta, Dittrichia graveolens, Heliotropium curassavicum, Scleroblitum atriplicinum, Senecio cunninghamii* and *Stemodia florulenta* (3.5% of sites) (Table 1).

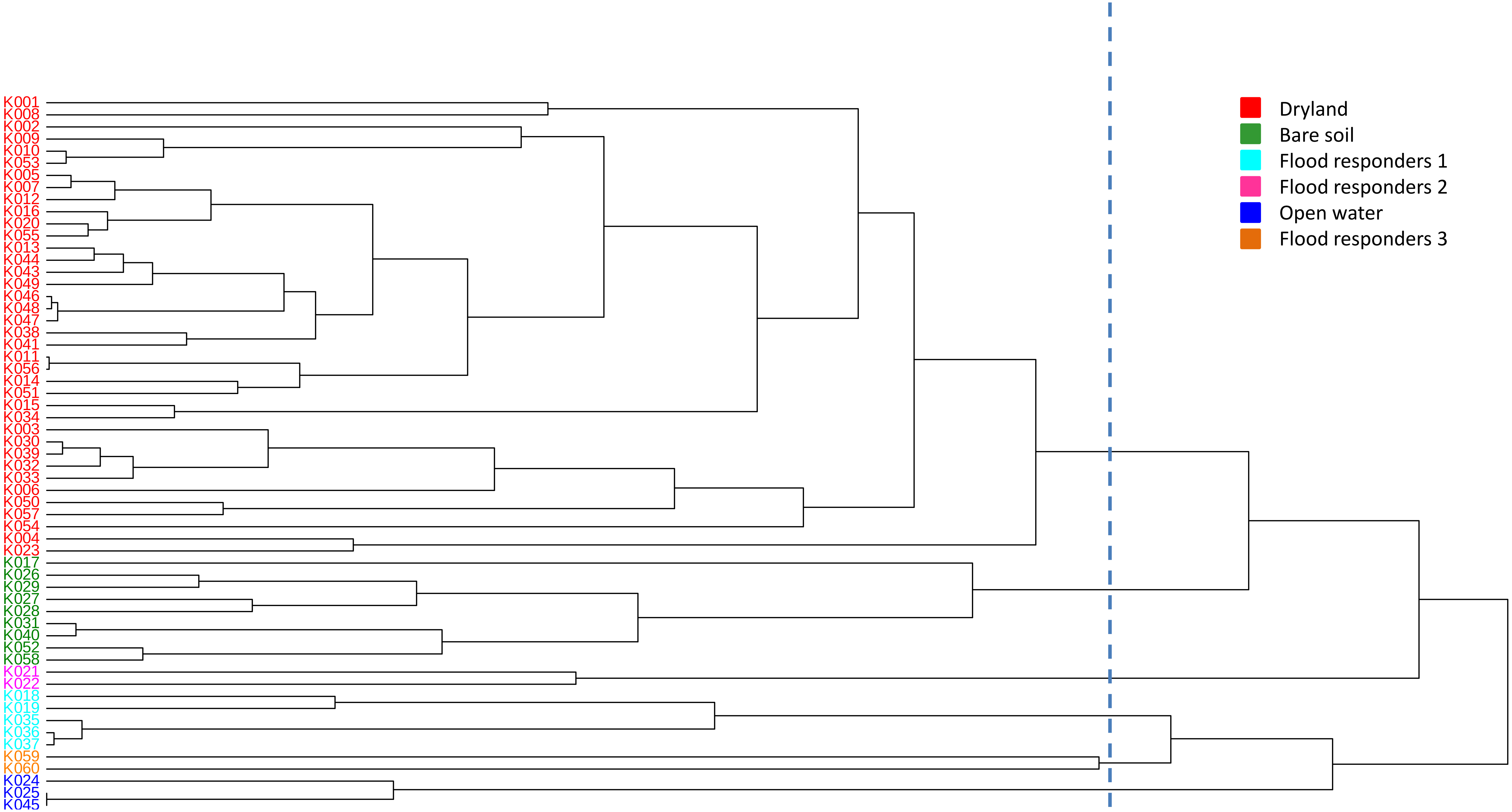

Figure 5: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis similarity from the 2015 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 1: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (n = 180) from the 2015 vegetation survey. Max. Group indicates group in which taxon had highest indicator value. P-value derived from Monte-Carlo test of significance (permutations = 10,000). Significant ($p < 0.05$) taxa are highlighted (*denotes exotic species).

Taxon	Max. Group	*P*-value
Bare soil	Bare Soil	0.0002
*Rorippa palustris**	Bare Soil	0.1652
Isoetopsis graminifolia	Bare Soil	0.2452
Helichrysum luteoalbum	Bare Soil	0.2456
Lachnagrostis filiformis	Bare Soil	0.3681
Maireana spp.	Bare Soil	0.5559
Solanum lacunarium	Bare Soil	0.5833
Duma florulenta	Bare Soil	0.7429
Atriplex spp.	Dryland	0.0002
Sclerolaena divaricata	Dryland	0.0004
Sclerolaena stelligera	Dryland	0.0004
Calotis hispidula	Dryland	0.0014
Chenopodium nitrariaceum	Dryland	0.0118
Sclerolaena brachyptera	Dryland	0.0208
Bulbine bulbosa	Dryland	0.0236
Disphyma crassifolium ssp. *clavellatum*	Dryland	0.0264
*Heliotropium amplexicaule**	Dryland	0.0688
Einadia nutans	Dryland	0.0888
Eremophila scoparia	Dryland	0.2695
Enchylaena tomentosa	Dryland	0.3079
Tecticornia triandra	Dryland	0.3119
Eucalyptus largiflorens	Dryland	0.4067
Tecticornia pergranulata	Dryland	0.4337
Brachyscome dentata	Dryland	0.5027
Chamaesyce drummondii	Dryland	1.0000
Duma horrida	Dryland	1.0000
Frankenia pauciflora var. *gunnii*	Dryland	1.0000
Myoporum parvifolia	Dryland	1.0000
Rhagodia spinescens	Dryland	1.0000
Suaeda australis	Dryland	1.0000
Tetragonia tetragonioides	Dryland	1.0000
Glinus lotoides	Flood Responders 1	0.0002
Glycyrrhiza acanthocarpa	Flood Responders 1	0.0002
*Heliotropium europaeum**	Flood Responders 1	0.0002
Medicago spp.*	Flood Responders 1	0.0002
Polygonum plebeium	Flood Responders 1	0.0006
Cyperus gymnocaulos	Flood Responders 2	0.0002
Dysphania pumilio	Flood Responders 2	0.0002
Sporobolus mitchellii	Flood Responders 2	0.0002
*Carrichtera annua**	Flood Responders 2	0.0006
Centipeda minima	Flood Responders 2	0.0770
*Sonchus oleraceus**	Flood Responders 2	0.1592
*Heliotropium curassavicum**	Flood Responders 3	0.0008
Atriplex suberecta	Flood Responders 3	0.0014
Scleroblitum atriplicinum	Flood Responders 3	0.0026
*Dittrichia graveolens**	Flood Responders 3	0.0028
Senecio cunninghamii	Flood Responders 3	0.0082
Stemodia florulenta	Flood Responders 3	0.0184
*Centaurium tenuiflorum**	Flood Responders 3	0.0650
Senecio runcinifolius	Flood Responders 3	0.0650
*Citrullus lanatus**	Flood Responders 3	0.0704
Open Water	Open water	0.0002

Taxon	**Max. Group**	***P*-value**
*Riechardia tingitana**	Open water	0.1220
Eucalyptus camaldulensis var. *camaldulensis*	Open water	0.4915

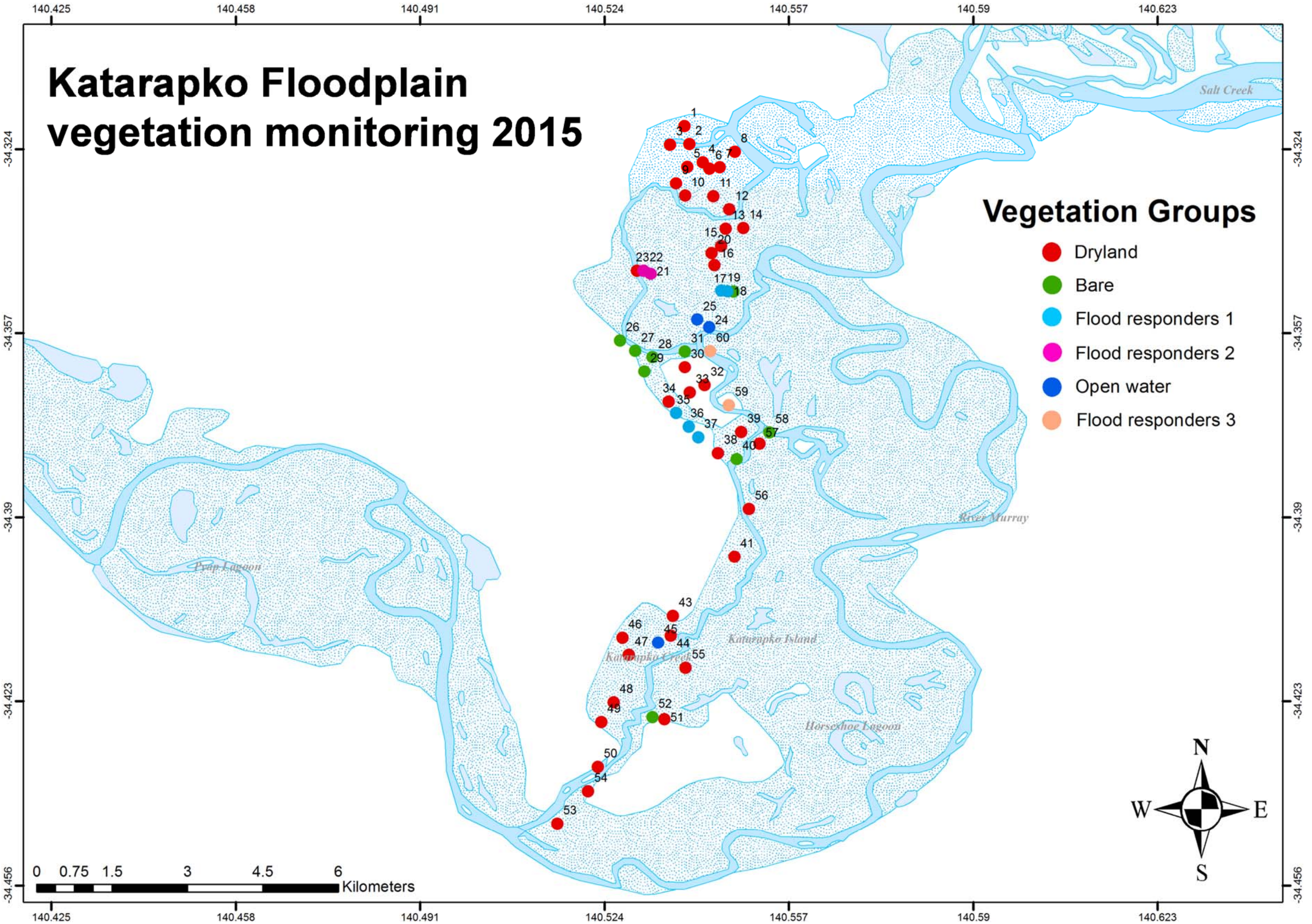

Figure 6: Spatial distribution and vegetation communities of the 60 sites surveyed on the Katarapko Floodplain for the 2015 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings (Figure 5).

Taxa from the floodplain and terrestrial functional groups had the highest number of observations at sites on the Katarapko Floodplain (Figure 7). Salt tolerant species were also abundant, but bare soil was uncommon (Figure 7). Three sites (sites 24, 25 and 48) were inundated (Figure 5, Figure 6) and amphibious species were uncommon (Figure 7).

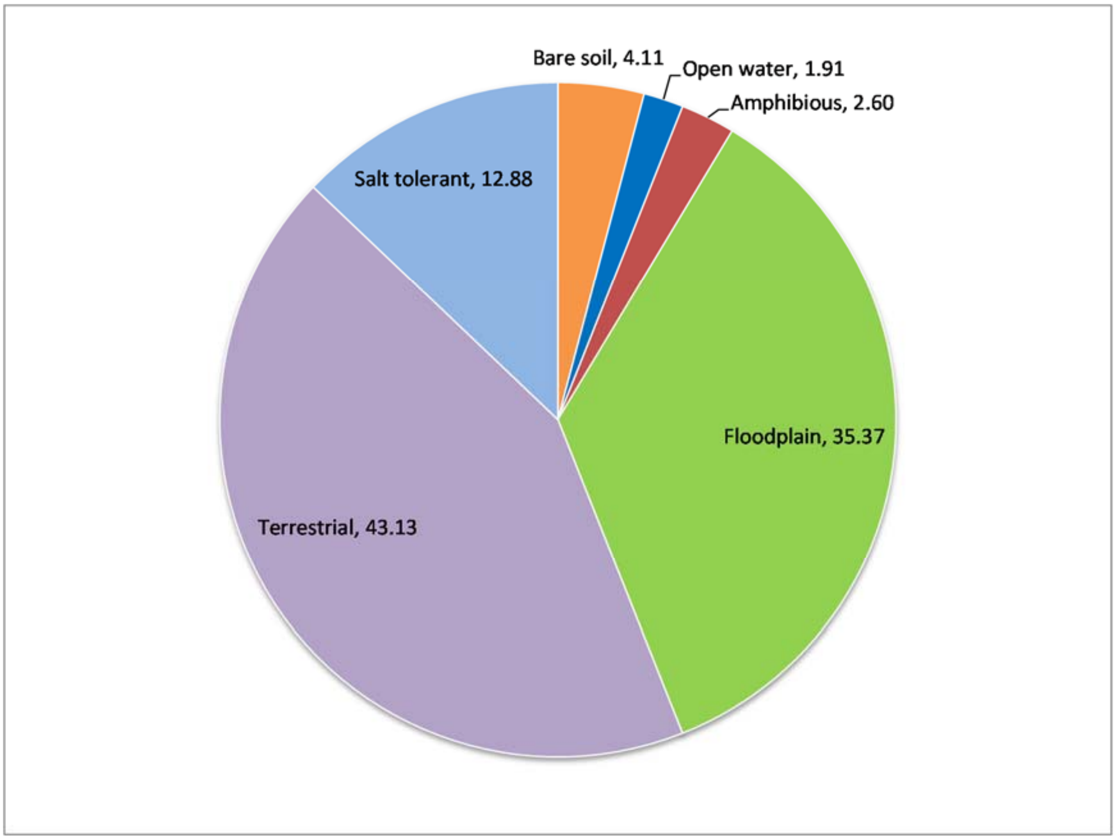

Figure 7: Proportion of observations of vegetation functional groups from the Katarapko Floodplain in 2015.

4. DISCUSSION

The current vegetation survey for the Katarapko Floodplain provides a baseline that can be used to compare the change in vegetation through time, in response to natural flooding and drying cycles and management actions such as managed inundations that utilise the proposed environmental regulator. Sites were selected to provide adequate coverage of floodplain areas and temporary wetlands that will be inundated by regulator operation but also areas that will not be inundated that can serve as reference sites (*sensu* Underwood 1992). The collection of several years of pre-regulator operation data will provide a robust baseline to facilitate assessments of changes in condition driven by management actions relative to condition without management action. Similar vegetation monitoring programs were established for the Chowilla Floodplain in 2006 (Weedon and Nicol 2006) and Pike Floodplain in 2010 (Marsland 2010). Both programs were able to detect changes to the plant community associated with management actions and natural flooding (Holland *et al.* 2013; Gehrig *et al.* 2014). Data from the Katarapko Floodplain, in conjunction with data from the Pike and Chowilla monitoring programs, could provide the basis for the development of a predictive floodplain vegetation model that could inform management decisions.

There was evidence to suggest that some areas of the Katarapko Floodplain were recently inundated. The vegetation present on the Katarapko Floodplain in 2015 had a higher proportion of floodplain species (38.4% of observations) compared to the Pike (27%) (Nicol *et al.* in prep.) and Chowilla (25%) (Gehrig *et al.* in prep.) floodplains in 2015. This may be an artefact of sampling because a larger number of temporary wetlands were able to be surveyed compared to the Pike Floodplain; although, a larger number of temporary wetlands were surveyed on the Chowilla Floodplain and the environmental regulator was operated in spring 2014. In addition to temporary wetlands on the Katarapko Floodplain having large numbers of floodplain species, these species were sometimes present at sites that were dominated by terrestrial species. Species richness at the Katarapko Floodplain in 2015 (52 species) was also higher than the Pike Floodplain (35 species) (Nicol *et al.* in prep.).

Despite the larger proportion of floodplain species compared to the Pike (Nicol *et al.* in prep.) and Chowilla (Gehrig *et al.* in prep.) floodplains, the highest proportion of observations were from the terrestrial functional group. This is due to the lack of overbank flooding in recent years and follows similar patterns to the Chowilla

Floodplain (Gehrig *et al.* 2014) where there is a long-term vegetation monitoring dataset. However, at Chowilla there was a higher proportion of bare soil and salt tolerant species (Gehrig *et al.* in prep.) that suggests the soil salinity at Katarapko is lower than Chowilla because of the higher proportion of drought tolerant species with low to medium salinity tolerance.

4.1. Future studies

Future studies of the vegetation of the Katarapko Floodplain that would contribute to a greater understanding of plant community dynamics and inform management of the system include:

- Continuation of the monitoring program established in 2015 to gain further baseline information to assess the response to interventions.
- Undertake soil sampling at monitoring sites to investigate the relationship between vegetation and soil properties such as texture, water potential, organic matter and salinity.
- Assess soil seed banks across the flooding frequency gradient to gain information regarding species resilience and water requirements to maintain resilience (*sensu* Boulton and Lloyd 1992).
- Investigate regeneration niches of key native and exotic species (*sensu* Nicol and Ganf 2000) to provide data to develop a predictive floodplain vegetation model.
- Investigate inundation tolerances of key native and exotic species to provide data to develop a predictive floodplain vegetation model.

4.2 Conclusions

Data collected in this survey will serve as baseline data to evaluate the effects of interventions and natural flooding on floodplain vegetation. Future surveys before the proposed regulator is constructed and operated will give an indication of the medium-term variability of the system and provide a multi-year baseline to evaluate interventions.

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APPENDICES

Appendix 1: Monitoring site GPS coordinates (map datum WGS 84).

Site	Latitude	Longitude	Site	Latitude	Longitude
K01	-34.31982939	140.5383223	K31	-34.36026487	140.5391792
K02	-34.32308239	140.5391871	K32	-34.36627552	140.5419341
K03	-34.32321213	140.5357171	K33	-34.36760404	140.5392541
K04	-34.32633587	140.541615	K34	-34.36923902	140.5354674
K05	-34.32715216	140.5388424	K35	-34.37131327	140.536799
K06	-34.32749968	140.5427802	K36	-34.37372393	140.5390809
K07	-34.32721503	140.5445887	K37	-34.37560337	140.5407442
K08	-34.32443473	140.5473243	K38	-34.37847873	140.5443273
K09	-34.33014247	140.5368015	K39	-34.37470716	140.5484797
K10	-34.33231143	140.5384408	K40	-34.3795293	140.5476245
K11	-34.33247562	140.5434543	K41	-34.39706059	140.5472484
K12	-34.33481032	140.5463033	K42	-34.40448209	140.5441636
K13	-34.33825933	140.5456963	K43	-34.40764554	140.5362009
K14	-34.33814335	140.5488477	K44	-34.41115986	140.5358285
K15	-34.34136229	140.5448857	K45	-34.41244868	140.5335906
K16	-34.3447409	140.543695	K46	-34.41156752	140.5272132
K17	-34.34955869	140.5470819	K47	-34.41468697	140.5283277
K18	-34.34948297	140.5459772	K48	-34.42315454	140.5256534
K19	-34.34934517	140.5448766	K49	-34.42667923	140.5234436
K20	-34.34258653	140.5431389	K50	-34.43476949	140.5228031
K21	-34.34631286	140.5322551	K51	-34.42617304	140.5347168
K22	-34.34574464	140.5310228	K52	-34.42580168	140.5325684
K23	-34.345735	140.5298041	K53	-34.44494024	140.5155602
K24	-34.35593245	140.5427426	K54	-34.4391331	140.5210691
K25	-34.35454417	140.5405642	K55	-34.41701061	140.5385306
K26	-34.35827717	140.52677	K56	-34.38849986	140.549841
K27	-34.36014613	140.529486	K57	-34.37676253	140.5517466
K28	-34.36128985	140.5326043	K58	-34.37473405	140.5535139
K29	-34.36381886	140.5311003	K59	-34.36986654	140.5462311
K30	-34.36308003	140.5383633	K60	-34.36019688	140.5429231

Appendix 2: Species list, functional classification, life history strategy, conservation status (state conservation status from listings in Barker *et al.* 2005 (*denotes exotic species, **denotes proclaimed pest plant in South Australia, ***denotes weed of national significance, # denotes listed as rare in South Australia, ^ denotes listed as vulnerable in South Australia, ^^denotes listed as endangered in South Australia).

Species	Common name	Family	Status	Life history strategy	Functional group
Atriplex spp.	saltbush	Chenopodiaceae	Native	Perennial	Terrestrial
Atriplex suberecta	lagoon saltbush	Chenopodiaceae	Native	Perennial	Floodplain
Brachyscome dentata	swamp daisy	Asteraceae	Native	Perennial herb	Floodplain
Bulbine bulbosa	bulbine lily	Alliaceae	Native	Perennial herb	Floodplain
Calotis hispidula	bogan flea, hairy burr-daisy, bindyi	Asteraceae	Native	Annual herb	Floodplain
*Carrichtera annua**	Wards weed	Brassicaceae	Exotic, Naturalised	Annual	Terrestrial
Centipeda minima	speading sneezeweed	Asteraceae	Native	Annual herb	Floodplain
*Centaurium tenuiflorum**	branched centaury	Gentianaceae	Exotic, Naturalised	Annual	Terrestrial
Chenopodium nitrariaceum	nitre goosefoot	Chenopodiaceae	Native	Perennial	Terrestrial
Dysphania pumilio	clammy goosefoot, small crumbweed	Chenopodiaceae	Native	Annual/Perennial	Floodplain
*Citrullus lanatus**	bitter melon, wild (or camel) melon	Cucurbitaceae	Exotic, Naturalised	Annual herb	Terrestrial
Cyperus gymnocaulos	spiny flat-sedge, spiny sedge	Cyperaceae	Native	Perennial	Amphibious
Disphyma crassifolium ssp. *clavellatum*	angular pigface	Aizoaceae	Native	Perennial	Salt tolerant
*Dittrichia graveolens**	stinkwort, stink-weed	Asteraceae	Exotic, Naturalised	Annual herb	Floodplain
Duma florulenta	lignum	Polygonaceae	Native	Perennial shrub	Amphibious
Duma horrida#	spiny lignum	Polygonaceae	Native, Rare in South Australia	Perennial shrub	Amphibious
Einadia nutans	climbing saltbush	Chenopodiaceae	Native	Perennial shrub	Terrestrial
Enchylaena tomentosa	ruby saltbush, barrier saltbush	Chenopodiaceae	Native	Perennial shrub	Terrestrial
Eremophila scoparia	broom emubush, silver emubush, scotia bush	Scrophulariaceae	Native	Perennial shrub	Terrestrial
Eucalyptus camaldulensis var. *camaldulensis*	red gum, river red gum	Myrtaceae	Native	Tree	Amphibious
Eucalyptus largiflorens	black box	Myrtaceae	Native	Tree	Amphibious
Chamaesyce drummondii	caustic weed	Euphorbiaceae	Native	Perennial herb	Floodplain

Species	Common name	Family	Status	Life history strategy	Functional group
Frankenia pauciflora var. *gunnii*	common (or southern) sea-heath	Frankeniaceae	Native	Perennial herb	Salt tolerant
Glinus lotoides	hairy carpet-weed	Aizoaceae	Native	Annual/Perennial herb	Floodplain
Glycyrrhiza acanthocarpa	liquorice	Fabaceae	Native	Annual herb	Floodplain
*Heliotropium amplexicaule**	blue heliotrope	Boraginaceae	Exotic, Naturalised	Perennial herb	Floodplain
*Heliotropium curassavicum**	smooth heliotrope	Boraginaceae	Exotic, Naturalised	Annual/Perennial herb	Floodplain
*Heliotropium europaeum**	potato weed, heliotrope, common heliotrope	Boraginaceae	Exotic, Naturalised	Annual herb	Floodplain
Helichrysum luteoalbum	jersey cudweed	Asteraceae	Native	Annual	Floodplain
Isoetopsis graminifolia	grass cushions, grass buttons	Asteraceae	Native	Annual herb	Floodplain
Lachnagrostis filiformis	blown grass, fairy grass	Poaceae	Native	Perennial	Floodplain
Maireana spp.	bluebush	Chenopodiaceae	Native	Perennial shrub	Terrestrial
Medicago spp.*	burr-medic	Fabaceae	Exotic, Naturalised	Annual herb	Terrestrial
Myoporum parvifolium#	creeping boobiella	Myoporaceae	Native, Rare in South Australia	Perennial	Terrestrial
Polygonum plebeium	small knotweed	Polygonaceae	Native	Annual	Floodplain
*Riechardia tingitana**	false sow thistle	Asteraceae	Exotic, Naturalised	Annual herb	Terrestrial
Rhagodia spinescens	spiny saltbush, berry saltbush	Chenopodiaceae	Native	Perennial shrub	Terrestrial
*Rorippa palustris**	yellow cress, marsh watercress	Brassicaceae	Exotic, Naturalised	Annual/Biennial herb	Floodplain
Sclerolaena brachyptera	short-winged copperburr, hairy bassia,	Chenopodiaceae	Native	Annual	Salt tolerant
Sclerolaena divaricata	tangled copperburr, pale poverty bush	Chenopodiaceae	Native	Perennial	Terrestrial
Sclerolaena stelligera	star-fruit bassia, star copperburr, starred bluebush	Chenopodiaceae	Native	Perennial	Salt tolerant
Scleroblitum atriplicinum	purple (or starry or purple-leaved) goosefoot,	Chenopodiaceae	Native	Annual	Floodplain
Senecio cunninghamii	bushy groundsel	Asteraceae	Native	Perennial shrub	Floodplain
Senecio runcinifolius	tall groundsel	Asteraceae	Native	Perennial herb	Floodplain
Solanum lacunarium	lagoon Nightshade	Solanaceae	Native	Perennial herb	Floodplain
*Sonchus oleraceus**	sow thistle	Asteraceae	Exotic, Naturalised	Annual herb	Terrestrial
Sporobolus mitchellii	rats-tail couch, short rats-tail grass	Poaceae	Native	Perennial	Floodplain

Species	Common name	Family	Status	Life history strategy	Functional group
Stemodia florulenta	blue-rod	Scrophulariaceae	Native	Perennial herb	Floodplain
Suaeda australis	Austral seablight	Chenopodiaceae	Native	Perennial	Salt tolerant
Tecticornia pergranulata	N/A	Chenopodiaceae	Native	Perennial herb/shrub	Amphibious
Tecticornia triandra	desert glasswort	Chenopodiaceae	Native	Perennial shrub	Salt tolerant
Tetragonia tetragonioides	New Zealand spinach, Warragul cabbage	Aizoaceae	Native	Annual/Perennial herb	Floodplain