Chowilla Icon Site – Floodplain Vegetation Monitoring

2011 Interim Report

Susan Gehrig, Kelly Marsland, Jason Nicol, and James Weedon

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Executive Summary

The Chowilla Floodplain is the largest remaining area of undeveloped floodplain habitat in the lower Murray-Darling system. It was designated as one of The Living Murray (TLM) initiative's icon sites and management actions are being undertaken to attain the following resource condition targets: improve the area and diversity of grass and herblands (Target 5), improve the area and diversity of flood dependent understorey vegetation (Target 6), maintain or improve the area and diversity of grazing sensitive plant species (Target 8) and limit the extent of invasive (increaser) species, including weeds (Target 9). The aim of this study was to monitor and assess vegetation condition (across a range of open habitats subjected to a wide range of flood frequencies) against the TLM resource condition targes used for the Chowilla Living Murray (CLW) icon site. A network of vegetation survey sites were established in areas of herbland and grassland in 2006. These sites were used to provide baseline vegetation data in 2006, and were re-surveyed in 2007, 2008, 2009, 2010 and 2011. This quadrat network has been used to monitor medium-term vegetation changes and to assess the aforementioned resource condition targets.

The overbank flood in 2010/11 resulted in a third watering of the Gum Flat and Coppermine Complex areas and extensive inundation of more than 60% of the floodplain. Overall, higher species richness was recorded in 2011 compared to previous survey years, with a total of 66 species from 28 families recorded across the 67 sites surveyed. The five most frequently encountered species were *Atriplex* spp., *Sclerolaena stelligera, Ammannia multiflora*, *Carpobrotus* sp. and *Sporobolus mitchellii.* Cluster analysis distinguished seven significantly different groups:

1. "Carpobrotus" sites were characterised by salt tolerant and desiccation tolerant species: *Carpobrotus* sp. and *Pachycornia triandra* (32.84% of sites),
2. "Ammannia" sites were characterised by amphibious species: *Ammannia multiflora* and *Mimulus repens* (25.37%),
3. "Tetragonia/Centipeda" sites were characterised by floodplain species: *Tetragonia tetragonioides*, *Centipeda minima*, *Senecio runcinifolius*, *Plantago cunninghamii*, *Sporobolus mitchellii*, *Rorippa palustris** and *Psuedognaphalium luteo-album* (20.9%),
4. "Marsilea/Eleocharis" sites were characterised by amphibious and floodplain species: *Marsilea angustifolia*, *Eleocharis acuta*, *Spergularia marina* and *Calotis scapigera* (10.45%),
5. "Bare soil" sites were predominantly characterised by bare soil (7.46 % of sites),
6. "Craspedia/Salsola" sites were characterised by terrestrial, salt tolerant or floodplain species: *Craspedia chrysantha*, *Salsola kali, Scleroblitum atriplicinum* and *Enchylaena tomentosa* (1.49%),
7. "Sclerolaena brachyptera" were characterised by *Sclerolaena brachyptera*, *Brachyscome basaltica* and *Taraxacum officinale* (1.49% of sites).

Significant differences were observed in areas that were flooded compared to sites that were previously watered. Watered sites were dominated by amphibious and floodplain taxa, whilst the sites that were flooded were generally dominated by floodplain taxa. Unflooded (and unwatered) sites in 2011 remained dominated by salt tolerant and terrestrial taxa.

Prior to 2010, the Asset Environmental Management Plan (AEMP) targets 5, 6 and 8 were not met without management intervention (namely watering). Whilst watering did result in the aforementioned targets being met, the spatial extent was limited and significant increases in the abundance of pest plants resulted in target 9 not being met. The overbank flood in 2010/11 resulted in increased recruitment of flood dependent and amphibious species (including grazing sensitive species) and minimal weed recruitment. Therefore, all of the TLM targets for the Chowilla icon site were met in 2011.

1. Introduction

The Chowilla Floodplain, located on the lower River Murray at the borders of South Australia, New South Wales and Victoria, is the largest remaining undeveloped area of floodplain habitat in the lower Murray-Darling system. It is unique both for its large area of contiguous floodplain habitat and for the wide variety of aquatic environments including fast and slow flowing anabranches, temporary billabongs and permanent backwaters (O'Malley and Sheldon 1990). The area supports a large range of species across many taxonomic groups and has been recognised as a wetland of international significance under the RAMSAR convention (O'Malley and Sheldon 1990).

Vegetation on the Chowilla Floodplain includes a range of vegetation types including *Eucalyptus largiflorens* (black box) woodlands, *Eucalyptus camaldulensis* var. *camaldulensis* (river red gum) woodlands, *Atriplex* spp. (saltbush) shrublands and a range of aquatic and riparian vegetation types associated with the various temporary and permanent wetlands (O'Malley and Sheldon 1990). The majority of previous vegetation studies of the Chowilla Anabranch system have focussed on the *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* overstorey communities with an emphasis on the impact of groundwater depth and salinity on tree condition (Jolly *et al.* 1993; Jolly, *et al.* 1994; McEwan *et al.* 1995; Walker *et al.* 1996; Akeroyd *et al.* 1998; Doble *et al.* 2004; Overton and Jolly 2004). In the last 20 years there have been sporadic investigations of the understorey vegetation of the system; O'Malley (1990) undertook an extensive vegetation survey of the floodplain and Roberts and Ludwig (1990) of the permanently inundated wetlands in 1988 and there has been a series of monitoring and scientific investigations in Pilby Creek (e.g. Stone 2001; Siebentritt 2003). Currently there are several projects underway to quantify the spatial and temporal dynamics of understorey, aquatic and riparian plant communities in a range of locations across the Chowilla system (Zampatti *et al.* 2011; Nicol *et al.* 2010).

The Asset Environmental Management Plan (AEMP) for the Chowilla Floodplain (DWLBC 2006) identified a number of targets for management of the various components of the Chowilla Floodplain ecosystem that were later revised (Murray Darling Freshwater Research Centre 2010). Four targets were identified for understorey vegetation, namely, "improve the area and diversity of grass and herblands" (Target 5), "improve the area and diversity of flood dependent understorey vegetation" (Target 6), "maintain or improve the *area* and diversity of grazing sensitive plant species" (Target 8) and "limit the extent of invasive (increaser) species, including weeds" (Target 9). Evaluation of the progress towards achieving these targets requires both baseline data and ongoing monitoring, particularly after large flood events or interventions.

In February 2006, a series of sites were established in areas of herbland and grassland across the Chowilla Floodplain, which provided baseline data for the study. These sites were re-surveyed in February 2007, 2008, 2009, 2010 and July 2011 to monitor the condition of floodplain understorey vegetation with reference to the targets outlined in the AEMP. This interim report describes the methods used to establish the monitoring sites, including survey quadrat design, results from six years of surveys, plus the quantitative and qualitative comparisons of the changes in floristic composition between the 2006 and 2011 surveys.

Flows to the Chowilla Floodplain

From 1996 to 2010, the Murray-Darling Basin (MDB) experienced the most severe drought in recorded history (Bond *et al.* 2008). Below average stream flows, coupled with upstream extraction and river regulation, resulted in reduced inflows to South Australia (Timbal and Jones 2008), which prior to August 2010 were insufficient to inundate the floodplain without managed interventions (MDBA 2011) (Figure 1).

In early 2010, inflows into the River Murray were anticipated to be very low and the drought in the southern MDB was expected to continue. 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 (MDBA 2011). 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 (MDBA 2011).

The dramatic increase in inflows in the summer of 2010-11 resulted in widespread flooding across the MDB. In the River Murray system, the extent of flooding varied considerably due to the pattern of rainfall and the nature of the floodplain. 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^{-1}, in February 2011. Flows of a magnitude between 90,000 to 100,000 ML day^{-1} (in combination with increased local rainfall) are estimated to inundate between 62.7–74.6% (11,100 – 13,200 ha) of the floodplain area (Sharley and Huggan 1995, cited in Cale 2009; see Figure 2), where the delineation between floodplain and highland is based upon the extent of the 1956 flood (Overton et al. 2006; Overton and Doody 2006). Large flows of ~100, 000 ML day^{-1} typically last for about three months (Sharley and Huggan 1995), but the 2010/11 overbank flood persisted for ~11 months. 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*) communities (MDBA 2011).

The monitoring survey undertaken in 2011 builds upon data collected from 2006 to 2010 and provides information regarding the change in plant communities across that time. The survey period includes a period of record low inflows, targeted environmental watering and an unregulated River Murray flow. Therefore, this monitoring program collected information regarding the change in floodplain understorey vegetation communities in response to desiccation, targeted environmental watering and increased water levels due to natural flooding. This study also provides an insight into the recovery of floodplain systems under hydrological restoration.

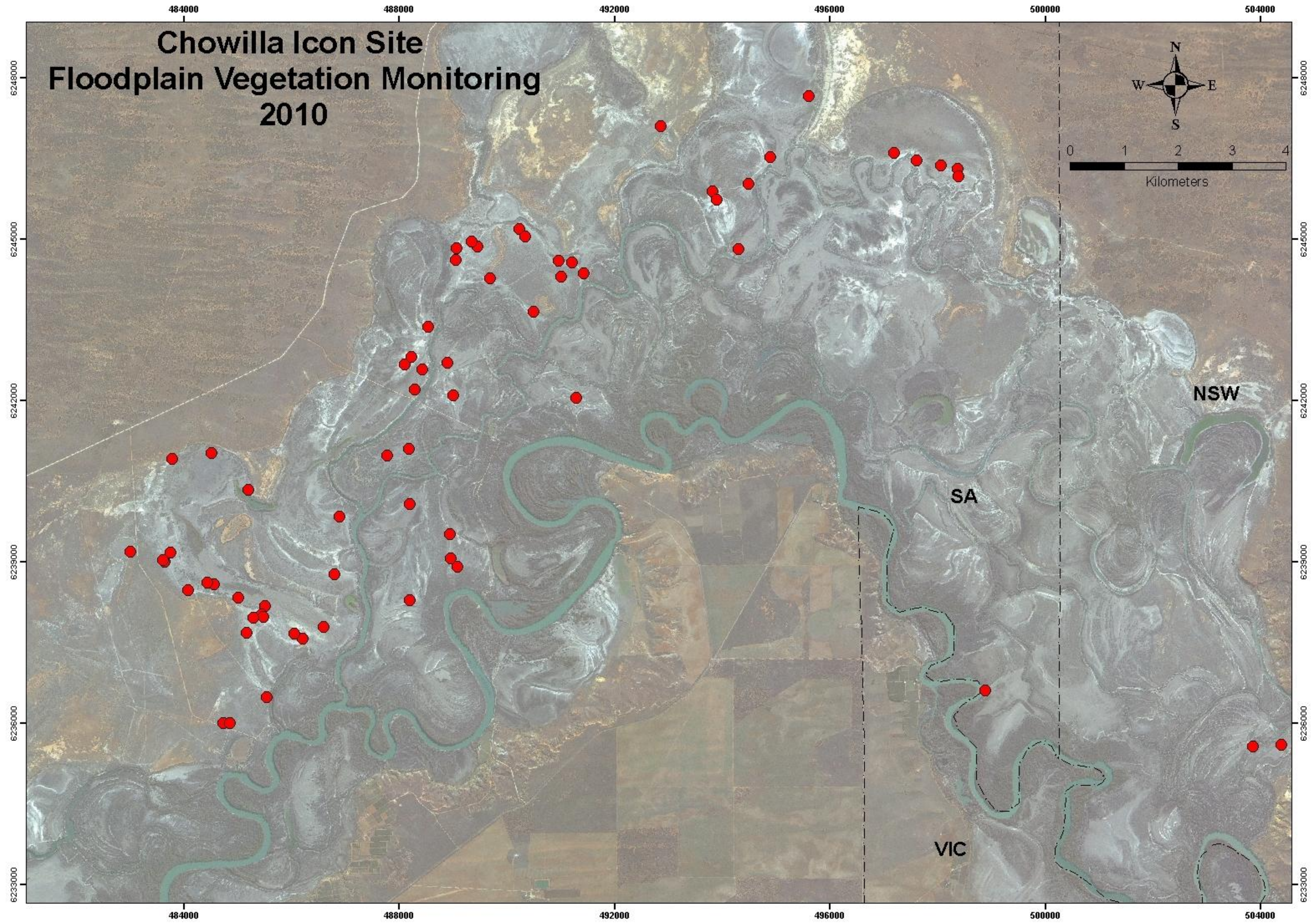

Figure 1: Aerial photograph of the Chowilla Floodplain in February 2010, during drought conditions. Red dots indicate floodplain vegetation monitoring sites. Map sourced from ArcGIS version 9.3.1 (Department of Heritage server: http://imagemapsa.deh.sa.gov.au).

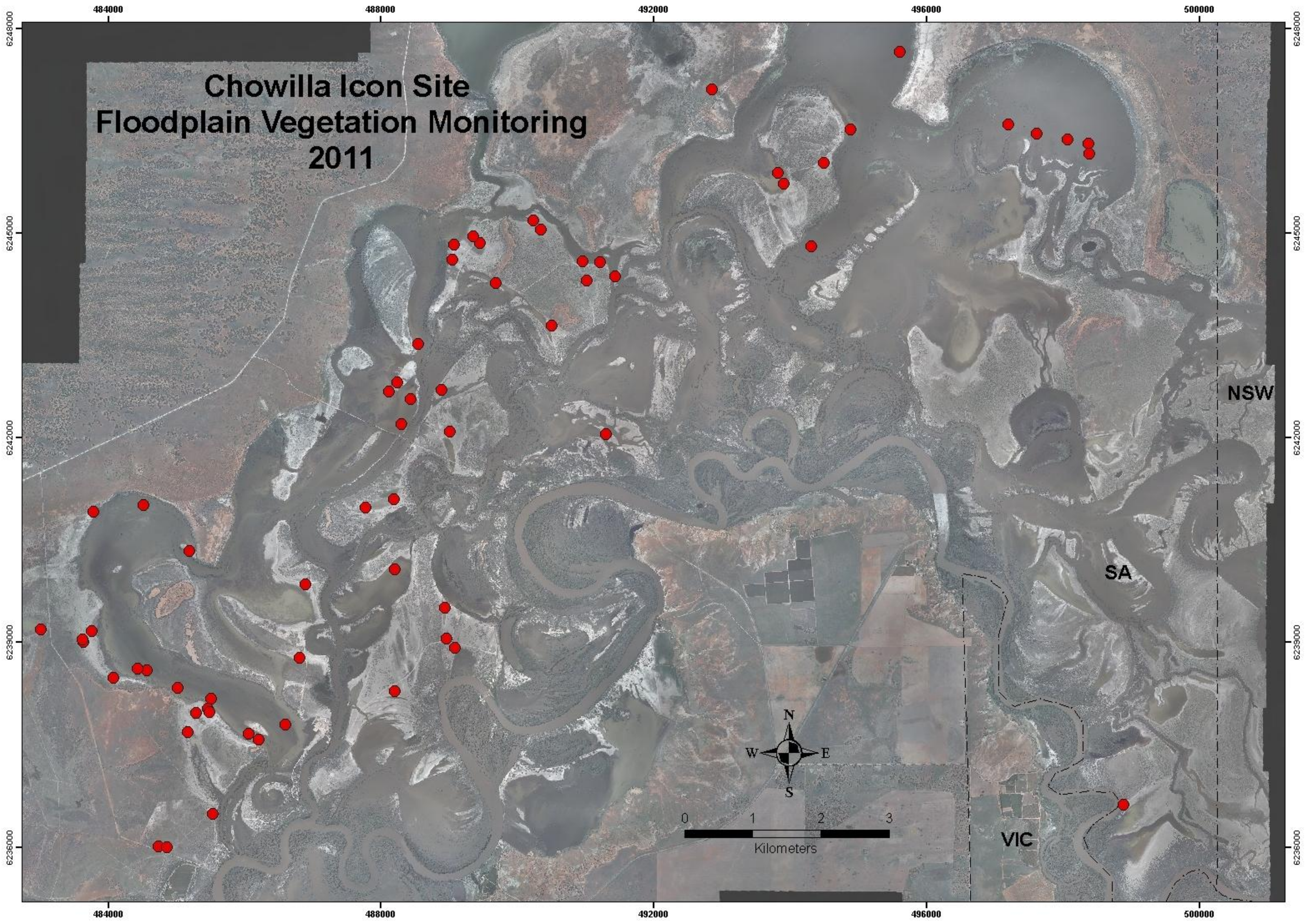

Figure 2: Aerial photograph of the Chowilla Floodplain showing inundation during unregulated flow conditions of 2010/11. Map sourced from ArcGIS version 9.3.1 (Department of Heritage server: http://imagemapsa.deh.sa.gov.au). Please note that date when photograph was taken has not been verified and therefore may not represent full extent of flooding. Red dots indicate floodplain vegetation monitoring sites (excluding sites 83 and 84, which are located in New South Wales).

2. Methods

Vegetation survey methods were the same as those used for other vegetation monitoring projects in the Chowilla icon site, namely Environmental Watering and Chowilla Aquatic Macrophyte Works and Measures understorey vegetation surveys (Zampatti *et al.* 2006a; Zampatti *et al.* 2006b; Nicol *et al.* 2010). The maintenance of consistent methods and ongoing monitoring will facilitate comparison of data across studies to enable a greater understanding of vegetation dynamics.

The February 2006 "baseline" survey involved quantitative vegetation surveys at 79 sites located in open areas across the Chowilla Floodplain. Sites were chosen such that they:

- were located in areas that would be inundated by overbank flows
- had no tree overstorey
- were accessible by 4WD vehicle during dry conditions
- covered a range of vegetation types and grazing histories.

Sites were re-surveyed in February 2007, 2008, 2009 and 2010. Due to the 2010/11 overbank flood, access to the Chowilla Floodplain was not possible to July 2011. In 2008 three additional sites on the outer islands and New South Wales section of the floodplain were added. Two sites established in 2006 (53 and 54) were excluded from 2009 onwards as the construction of a fence made them inaccessible. In 2010 and 2011, sites on Punkah Island were inaccessible due to high water levels in Punkah Creek and in 2011 a total of 16 sites (including the sites on Punkah Island) were inaccessible due to high river levels.

At each site three 15m x 1m quadrats were surveyed. Quadrats were arranged in a straight line parallel to elevation 50m apart. Each quadrat was divided into 15, 1m x 1m 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 given a bare ground score of one.

Plants were identified using keys in Cunningham *et al.* (1981), Jessop and Toelken (1986) and Jessop *et al.* (2006). In some cases, due to immature individuals or lack of floral structures, plants were identified to genus only. Nomenclature used follows Barker *et al.* (2005).

For each survey the vegetation communities present (a snapshot for each year) 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 and each year (except 2011 when there were seven groups) five distinct groups were produced based on species presence and their abundances. To identify the representative species for each group, Indicator Species Analysis (Dufrene and Legendre 1997) was performed on the unpooled data using the groupings of sites derived from the cluster analysis. All multivariate analyses used Bray-Curtis (1957) similarities to construct the similarity matrices and were undertaken using the 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, as well as their distribution in relation to environmental variables such as elevation/inundation frequency.

Maps of flood inundation for October flood events modelled to simulate flood return frequencies of between three and 13 years (the maximum permitted by the model) under regulated conditions were generated using the GIS model FIM III (Overton *et. al.* 2004). This allowed the "natural" flood return frequency for each site to be determined. Sites were assigned to one of three flood types based on their flood return frequency: "Often", for sites flooded at least one in five years; "Sometimes", for sites flooded between one in five and one in 13 years; and "Rarely" for sites not flooded under the highest flow permitted by the model (102, 000 ML day^{-1}). The cut off points for the groups were chosen to reflect the tri-modal nature of the flood frequency distribution (Figure 5). A Fisher's Exact Test for Count Data was performed on the vegetation group vs. flood frequency contingency table using R (R Development Core Team 2006).

The change in floristic composition from 2006 to 2011 was analysed using NMS ordination, two-factor PERMANOVA (Anderson 2001; Anderson and Ter Braak 2003) and Indicator Species Analysis (Dufrene and Legendre 1997). Sites were categorised on the basis of inundation history (watered, watered + flooded, flooded and unflooded) and year. In addition, plants were classified into functional groups based on the framework developed by Nicol *et al.* (2010) and the proportion of broad functional groups (terrestrial, salt tolerant, floodplain, amphibious and bare soil) present each year plotted.

3. Results

3.1. 2006 Survey

Figure 3 shows the spatial distribution and vegetation communities (based on groupings identified from cluster analysis) of the 79 survey sites across the Chowilla Floodplain in 2006.

Twenty-eight taxa from 13 families were observed across the 79 sites. The five most frequently encountered taxa (accounting for 73% of quadrat presences) were *Atriplex* spp., *Sclerolaena brachyptera*, *Sclerolaena divaricata*, *Carpobrotus* sp. and *Maireana* spp. All but *Carpobrotus* sp. (Aizoaceae) are members of the Chenopodiaceae.

Cluster analysis separated the sites into 5 groups at 30% similarity (Figure 4). This produced a manageable number of groups and reflected the major differences between sites.

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. "Bare soil" characterised by empty cells (14% of sites)
2. "Atriplex" sites characterised by high abundances of *Atriplex* spp. and *Sclerolaena brachyptera* (65%)
3. "Salt Tolerant" sites characterised by salt tolerant species such as *Carpobrotus* sp., *Halosarcia pergranulata* ssp. *pergranulata*, and *Pachycornia triandra* (9%)
4. "Flood responders" sites characterised by taxa that typically establish in response to flood events such as *Alternanthera denticulata, Cyperus gymnocaulos, Eragrostis australasica, Euphorbia drummondii, Glinus lotoides, Heliotropium europaeum* and *Sporobolus mitchellii* (3%)
5. "Sclerolaena" characterised by the shrub *Sclerolaena divaricata* (10%).

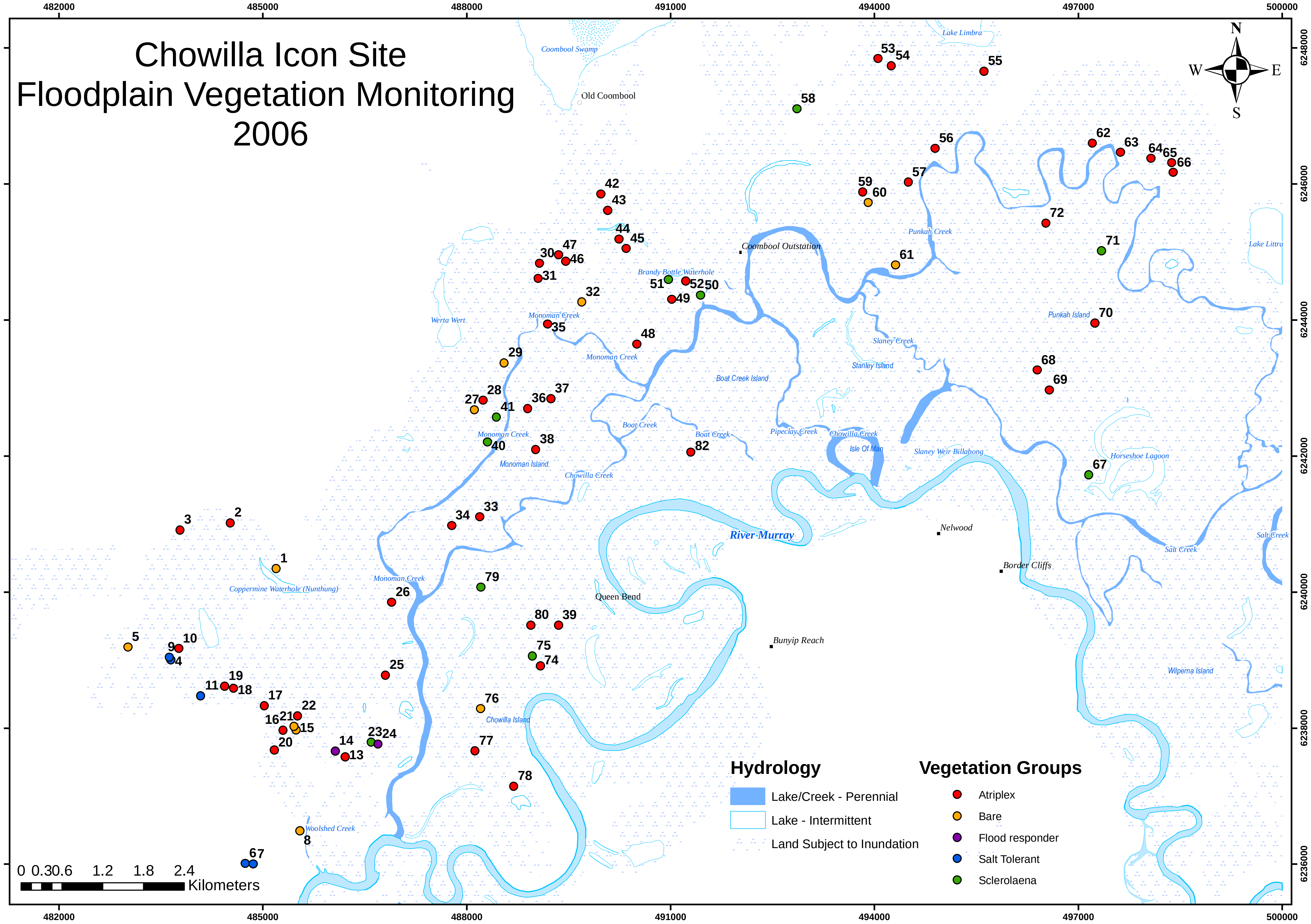

Figure 3: Spatial distribution and vegetation communities of the 79 survey sites across the Chowilla Floodplain for the 2006 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

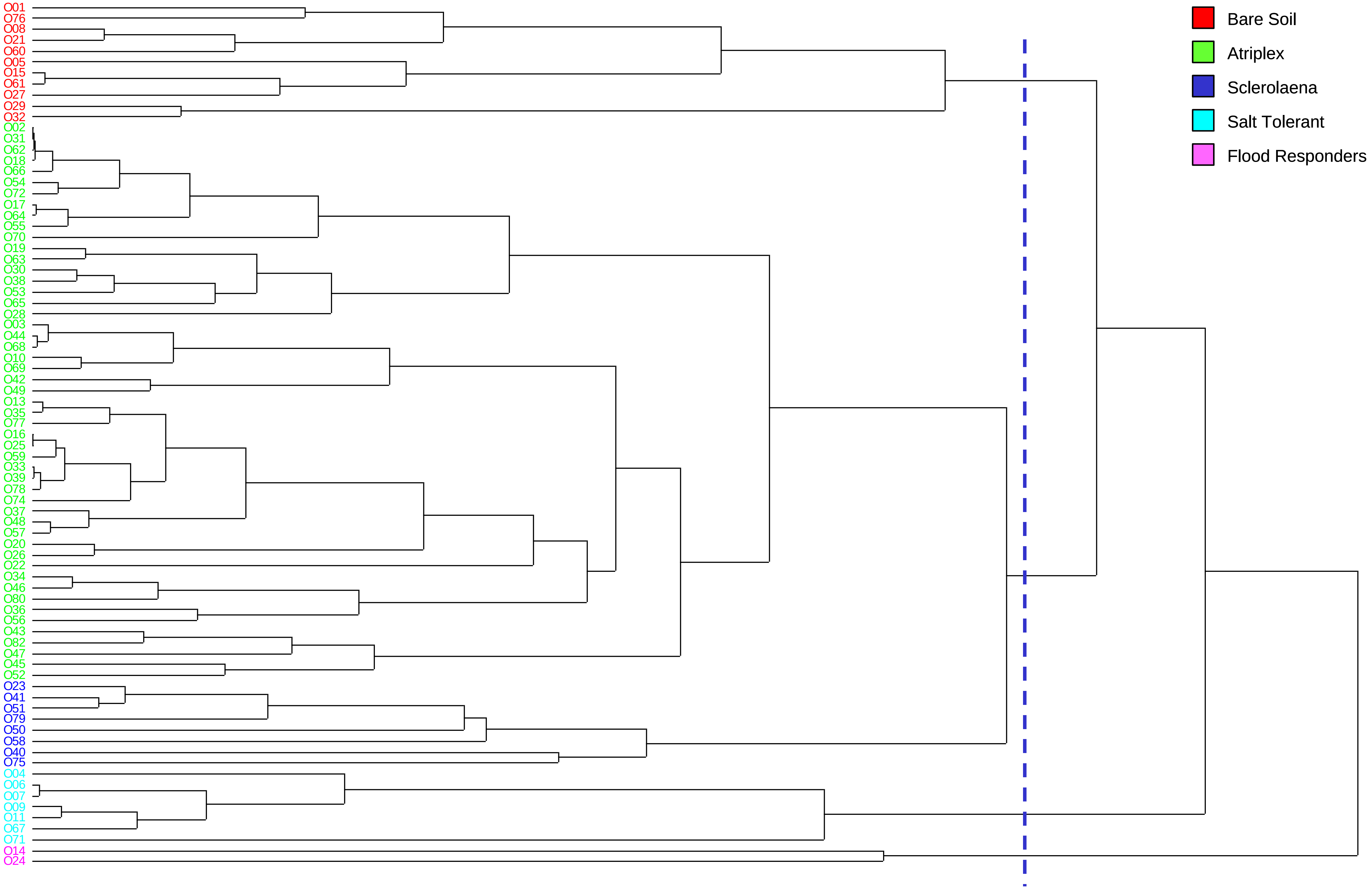

Figure 4: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2006 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 1: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=237) from the 2006 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
Alternanthera denticulata	Flood Responders	0.0252
Atriplex spp.	Atriplex	0.0001
Bare soil	Bare Soil	0.0001
Brachyscome basaltica	Atriplex	1.0000
Calotis hispidula	Atriplex	1.0000
Carpobrotus sp.	Salt Tolerant	0.0001
Centaurea sp.*	Sclerolaena	0.2781
Centipeda minima	Flood Responders	0.0004
Chenopodium nitrariaceum	Atriplex	1.0000
Craspedia chrysantha	Sclerolaena	0.1105
Cyperus gymnocaulos	Flood Responders	0.0007
Enchylaena tomentosa	Sclerolaena	0.3048
Eragrostis australasica	Flood Responders	0.0001
Euphorbia drummondii	Flood Responders	0.0001
Glinus lotoides	Flood Responders	0.0007
Halosarcia pergranulata ssp. *pergranulata*	Salt Tolerant	0.0585
*Heliotropium europaeum**	Flood Responders	0.0001
Maireana sp.	Atriplex	0.2817
Morgania floribunda	Sclerolaena	0.2144
Muehlenbeckia florulenta	Flood Responders	0.0835
Sclerolaena brachyptera	Atriplex	0.0001
Pachycornia triandra	Salt Tolerant	0.0001
Plantago turrifera	Sclerolaena	0.0672
*Polygonum aviculare**	Sclerolaena	0.2153
Sclerolaena divaricata	Sclerolaena	0.0001
*Solanum nigrum**	Sclerolaena	0.2173
Sporobolus mitchellii i	Flood Responders	0.0001
Tetragonia tetragonioides	Sclerolaena	0.0687
Unknown daisy	Bare Soil	0.0788

The distribution of sites across the flood frequency gradient is shown in Figure 5. The distribution forms three easily identifiable modes, which justifies the classification of sites into three flood frequency classes.

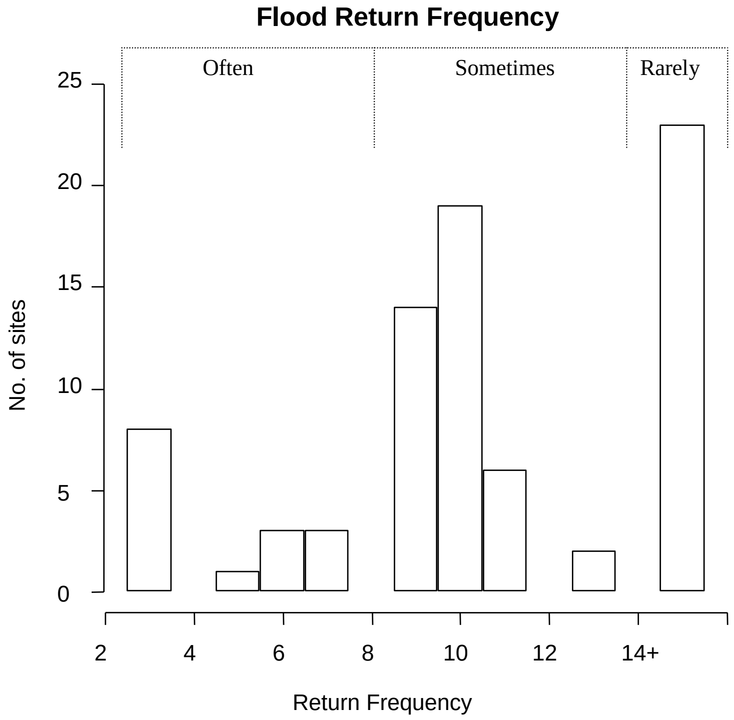

Figure 5: Distribution of all vegetation survey sites according to flood return frequency. Groupings show division into flood frequency classes used for contingency analysis.

The distribution of the sites according to their vegetation group and flood frequency class is summarised in Table 2. The Fisher's Exact Test for Count Data performed on this contingency table returned a P-value of 0.0237 allowing rejection of the null hypothesis of no relationship between flood frequency and vegetation type. The contingency plot (Figure 6) graphically summarises the results of this test. The positive association of "Salt Tolerant" sites with rarely flooded areas is the source of the deviation from the null hypothesis.

Table 2: Vegetation group distribution according to flood return frequency. Values indicate number of sites (*n*=79).

Vegetation Group	**Flood Frequency**		
	Often (1 in ≤ 5 years)	**Sometimes (between 1 in 5 and 1 in 13 years)**	**Rarely (less often than 1 in 13 years)**
Atriplex	7	35	9
Bare soil	1	5	5
Flood Responders	0	2	0
Salt Tolerant	0	1	6
Sclerolaena	1	4	3

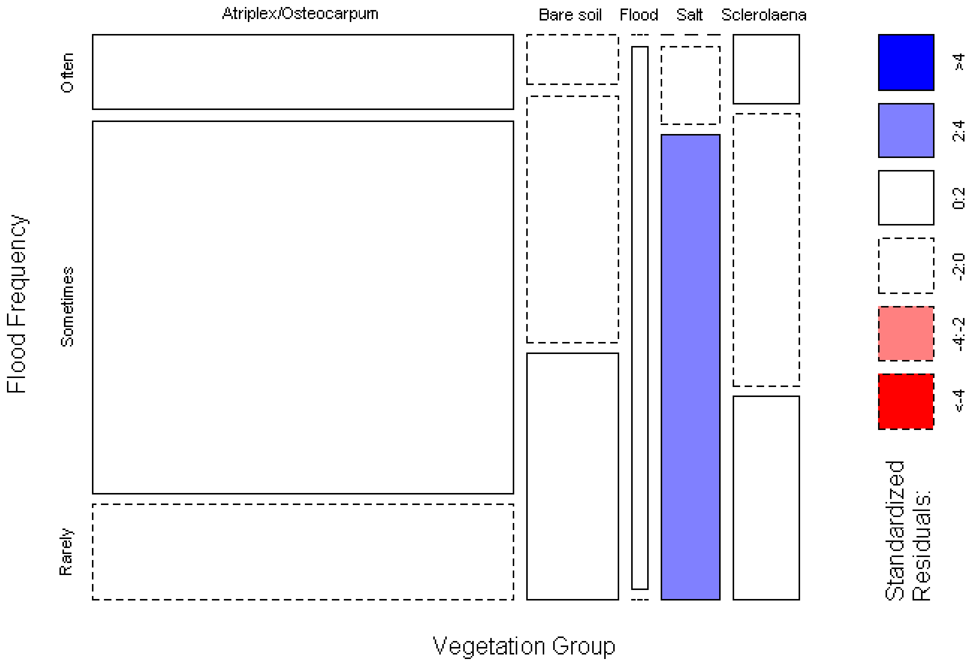

Figure 6: Contingency plot for Vegetation Group by Flood Frequency. Width of columns is proportional to group size, box size represents proportion of dendrogram group within each flood frequency class. Box outline and colour indicates standardised residuals from chi-squared style test. Residuals indicate the difference between observed values and those expected under H_0.

3.2. 2007 Survey

Figure 7 shows the spatial distribution and vegetation communities (based on groupings identified from cluster analysis) of the 79 survey sites across the Chowilla Floodplain in 2007.

In 2007 a total of 48 taxa from 20 families were recorded across the 79 sites. The five most encountered taxa (accounting for 59% of all quadrat presences) were *Sclerolaena brachyptera*, *Atriplex* spp., *Carpobrotus* sp., *Sclerolaena divaricata* and *Craspedia chrysantha.* All but *Carpobrotus* sp. (Aizoaceae) and *Craspedia chrysantha* (Asteraceae) are members of the Chenopodiaceae.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 8). This produced a manageable number of groups and reflected the major differences between sites. Indicator species analysis (Table 3) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (14% of sites).

2. "Sclerolaena brachyptera" sites characterised by high abundances of *Sclerolaena brachyptera, Carpobrotus* sp. and *Pachycornia triandra* (64%).

3. "Heliotropium" sites characterised by *Heliotropium curassavicum*, and *Solanum esuriale* (4%).

4. "Flood responders" characterised by taxa that establish in response to flood events, including *Alternanthera denticulata, Ammannia multiflora, Atriplex* spp., *Centipeda minima, Cyperus gymnocaulos, Eleocharis acuta, Epaltes australis, Euphorbia drummondii, Goodenia gracilis, Heliotropium europaeum, Isolepis hookeriana, Marsilea angustifolia, Mimulus repens Phyllanthus lacunaris* and *Sporobolus mitchellii* (10%). These sites were all inundated by pumping in spring 2006.

5. "Sclerolaena" sites characterised by the shrubs *Sclerolaena divaricata* and *Salsola kali* var. *kali* (7%).

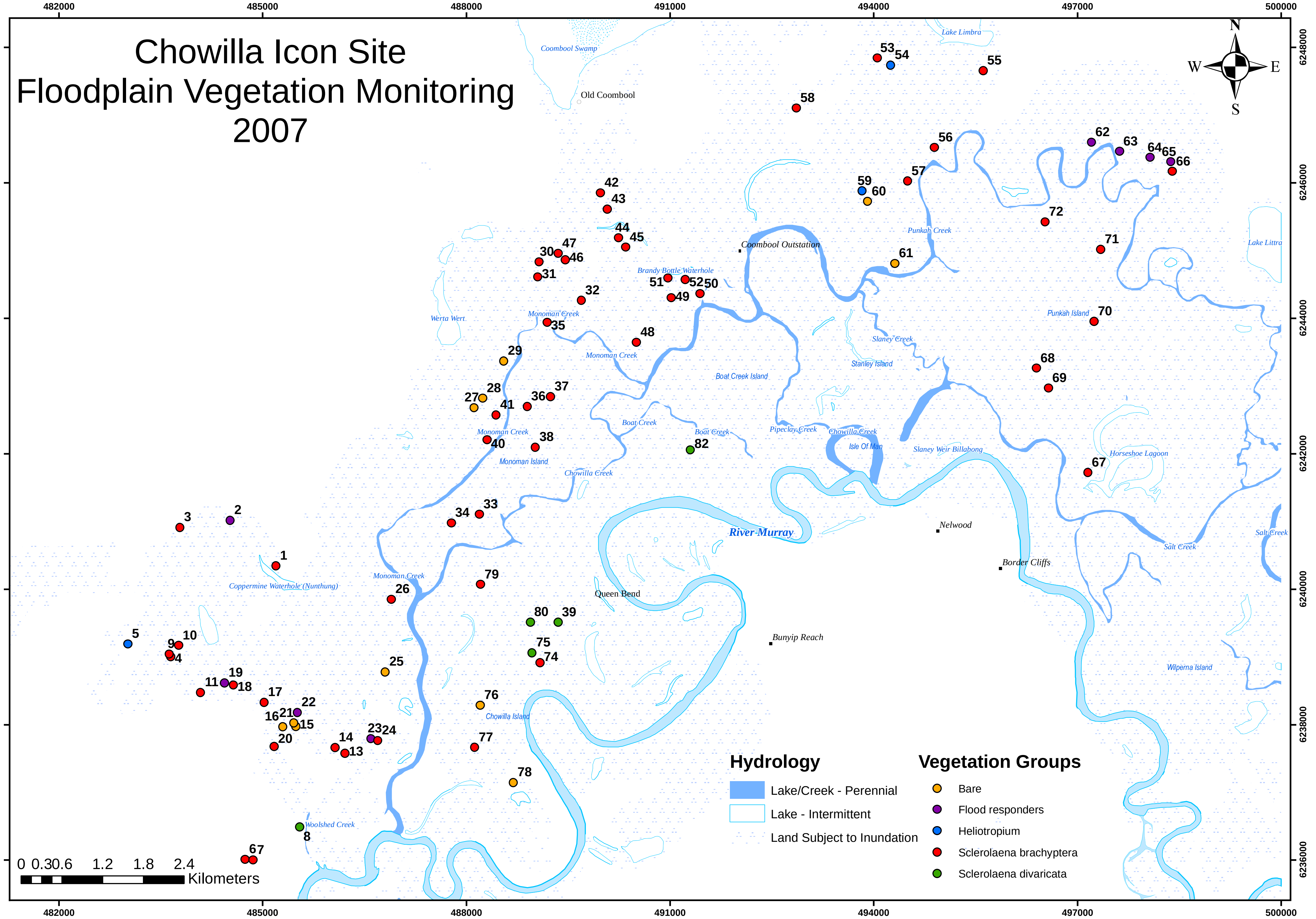

Figure 7: Spatial distribution and vegetation communities of the 79 survey sites across the Chowilla Floodplain for the 2007 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

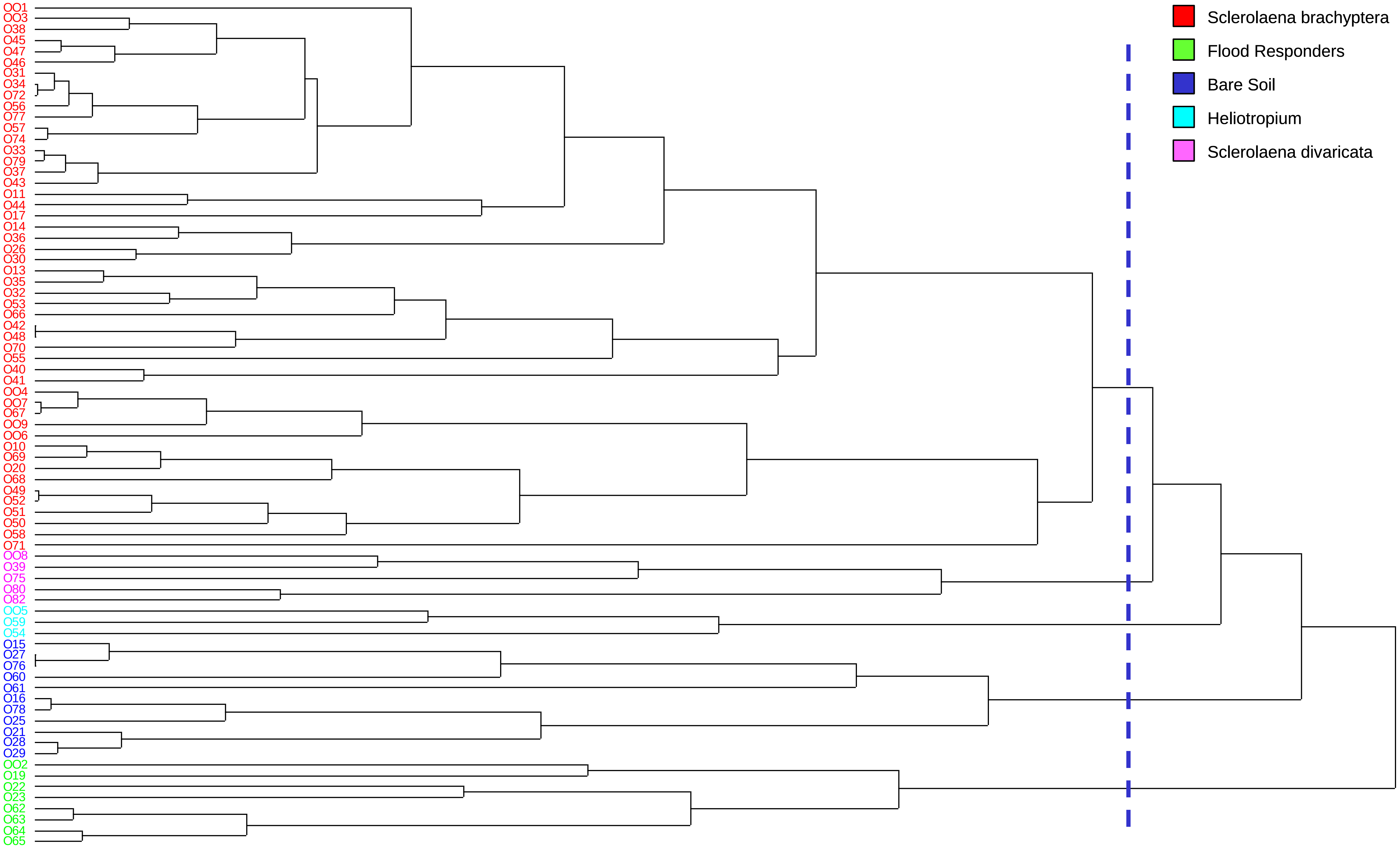

Figure 8: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2007 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 3: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=237) from the 2007 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
Agrostis avenacea	Sclerolaena divaricata	0.2114
Alternanthera denticulata	Flood Responder	0.0002
Ammannia multiflora	Flood Responder	0.0002
Atriplex spp.	Flood Responder	0.0002
Bare soil	Bare Soil	0.0002
Brachyscome basaltica	Flood Responder	0.4585
Calotis hispidula	Flood Responder	0.2501
Carpobrotus sp.	Sclerolaena brachyptera	0.0008
Centipeda minima	Flood Responder	0.0002
Chenopodium nitrariaceum	Sclerolaena brachyptera	1
Chenopodium pumilio	Flood Responder	0.2142
*Citrullus lanatus**	Flood Responder	0.2094
Craspedia chrysantha	Sclerolaena brachyptera	0.2725
Cyperus gymnocaulos	Flood Responder	0.0002
Eleocharis acuta	Flood Responder	0.0108
Epaltes australis	Flood Responder	0.009
Eremophila scoparia	Flood Responder	0.8726
Euphorbia drummondii	Flood Responder	0.0244
Glinus lotoides	Flood Responder	0.1256
Goodenia gracilis	Flood Responder	0.004
Grass 1	Sclerolaena brachyptera	1
Haloragis aspera	Heliotropium	0.0564
Halosarcia pergranulata ssp. *pergranulata*	Sclerolaena brachyptera	0.7111
*Heliotropium amplexicaule**	Heliotropium	0.0682
*Heliotropium curassavicum**	Heliotropium	0.0372
*Heliotropium europaeum**	Flood Responder	0.0112
Isolepis hookeriana	Flood Responder	0.0004
Ixiolaena brevicompta	Sclerolaena brachyptera	1
Maireana sp.	Sclerolaena divaricata	0.1304
*Malva parviflora**	Sclerolaena brachyptera	1
Marsilea angustifolia	Flood Responder	0.0038
Mimulus repens	Flood Responder	0.009
Mollugo cerviana	Flood Responder	0.0076
Muehlenbeckia florulenta	Heliotropium	0.1514
Pachycornia triandra	Sclerolaena brachyptera	0.0516
Phyllanthus lacunaris	Flood Responder	0.0178
Plantago turrifera	Flood Responder	0.2022
*Polygonum aviculare**	Flood Responder	0.1998
Salsola kali var. *kali*	Sclerolaena divaricata	0.0032
Scleroblitum atriplicinum	Bare Soil	0.1898
Sclerolaena brachyptera	Sclerolaena brachyptera	0.0002

Taxon	Max. Group	P-value
Sclerolaena divaricata	Sclerolaena divaricata	0.0002
Solanum esuriale	Heliotropium	0.0384
Solanum oligacanthum	Flood Responder	0.811
Sporobolus mitchellii	Flood Responder	0.0002
Tetragonia tetragonioides	Sclerolaena brachyptera	0.9136
Unknown Brassicaceae	Sclerolaena brachyptera	1
Unknown daisy	Sclerolaena divaricata	0.5247
*Xanthium occidentale**	Flood Responder	0.1976

3.3. 2008 Survey

Figure 9 shows the spatial distribution and vegetation communities (based on groupings identified from cluster analysis) of the 82 survey sites across the Chowilla Floodplain in 2008.

A total of 21 taxa from eight families were recorded across the 82 sites. The five most frequently encountered taxa (accounting for 73% of all quadrat presences) were *Sclerolaena brachyptera*, *Atriplex* spp., bare soil, *Sclerolaena stelligera* and *Carpobrotus* sp. All but *Carpobrotus* sp. (Aizoaceae) and bare soil are members of the Chenopodiaceae.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 10), which reflected the major differences between sites. Indicator Species Analysis (Table 4) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. “Bare soil” characterised by empty cells (24% of sites).
2. “Sclerolaena brachyptera” sites characterised by high abundances of *Sclerolaena brachyptera* and *Sclerolaena stelligera* (35%).
3. “Atriplex” sites characterised by *Atriplex* spp. and *Sporobolus mitchellii* (16%).
4. “Salt Tolerant” sites characterised by the salt tolerant taxa *Carpobrotus* sp. and *Pachycornia triandra* (24%).
5. “Sclerolaena” sites characterised by the shrubs *Sclerolaena divaricata* and *Enchylaena tomentosa* (3%).

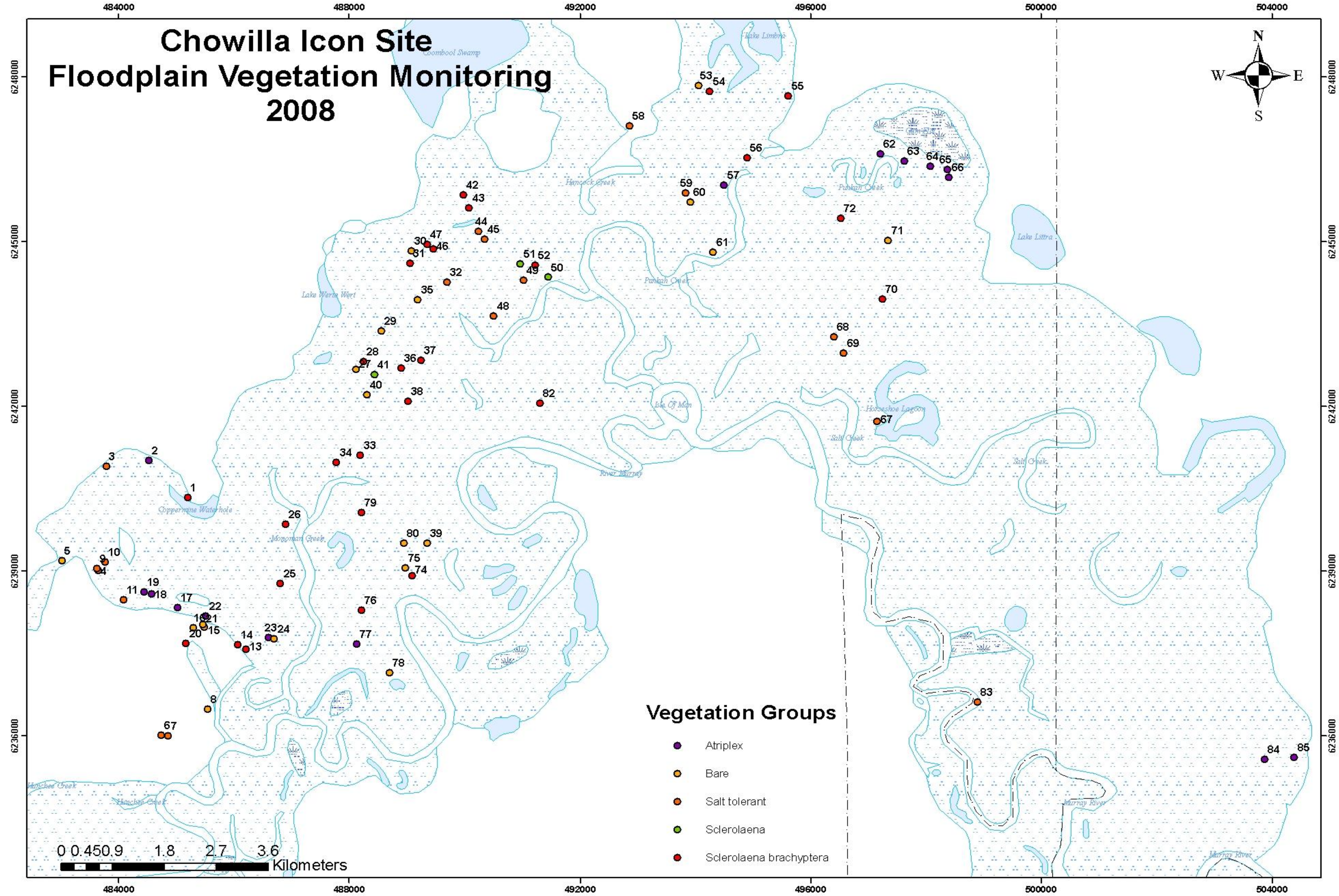

Figure 9: Spatial distribution and vegetation communities of the 82 survey sites across the Chowilla Floodplain for the 2008 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

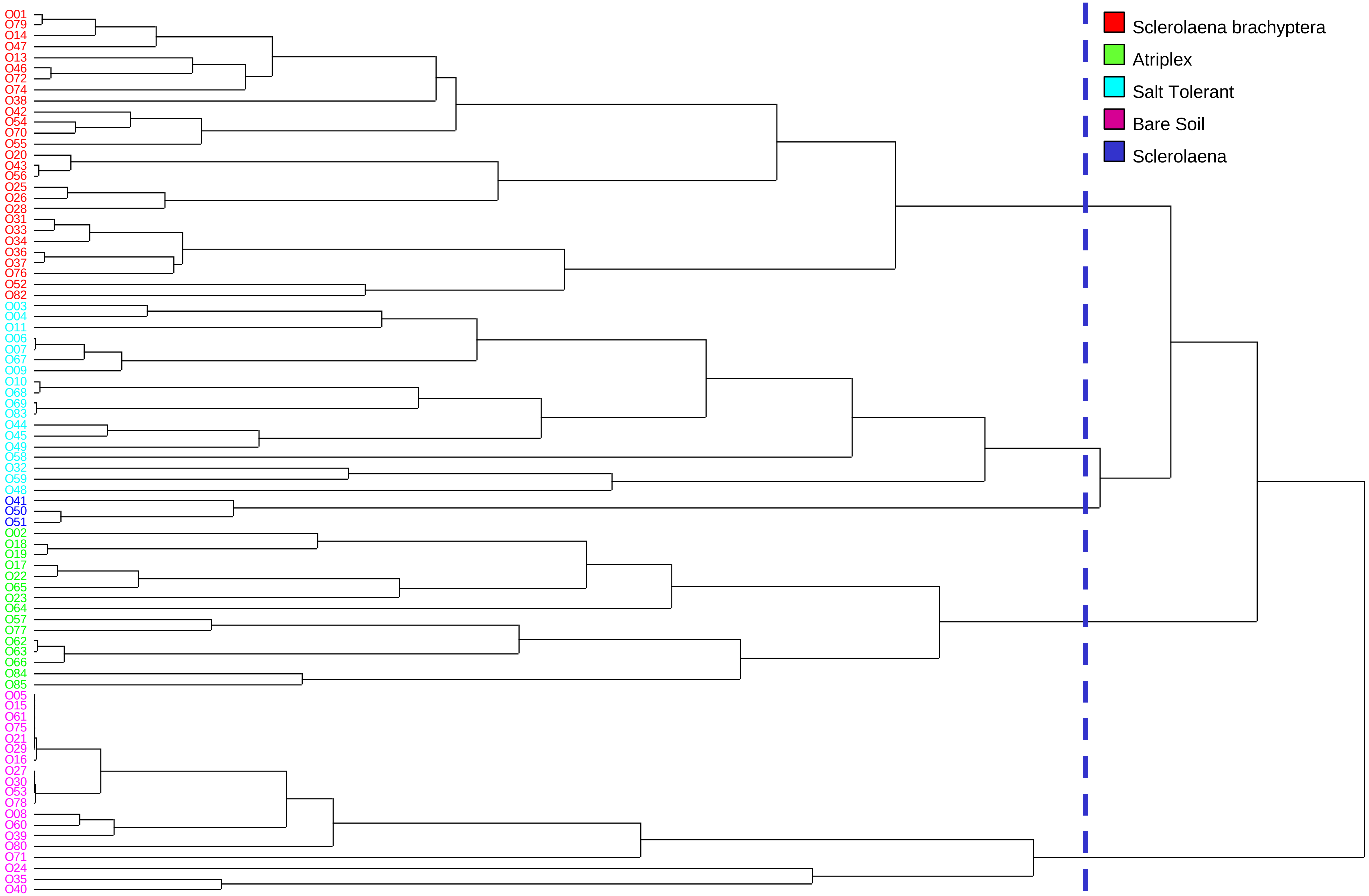

Figure 10: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2008 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 4: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=246) from the 2008 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
Atriplex spp.	Atriplex	0.0002
Bare soil	Bare Soil	0.0002
Brachyscome basaltica	Atriplex	0.0728
Carpobrotus sp.	Salt Tolerant	0.0002
Chenopodium nitrariaceum	Salt Tolerant	0.1598
Craspedia chrysantha	Sclerolaena brachyptera	0.2374
Enchylaena tomentosa	Sclerolaena	0.0332
Eragrostis australasica	Atriplex	0.223
Frankenia pauciflora	Sclerolaena brachyptera	0.5351
Halosarcia pergranulata	Salt Tolerant	0.6833
Maireana sp.	Atriplex	0.0934
Muehlenbeckia florulenta	Atriplex	0.1576
Pachycornia triandra	Salt Tolerant	0.0004
Rhagodia sp.	Sclerolaena brachyptera	1
Salsola kali var. *kali*	Salt Tolerant	0.9212
Sclerolaena brachyptera	Sclerolaena brachyptera	0.0004
Sclerolaena divaricata	Sclerolaena	0.0002
Sclerolaena stelligera	Sclerolaena brachyptera	0.0002
Solanum oligacanthum	Sclerolaena brachyptera	1
Sporobolus mitchellii	Atriplex	0.0002
Unknown Dicot 1	Salt Tolerant	0.1514
Wahlenbergia fluminalis	Salt Tolerant	0.7383

3.4. 2009 Survey

Figure 11 shows the spatial distribution and vegetation communities (based on groupings identified from cluster analysis) of the 80 survey sites across the Chowilla Floodplain in 2009.

A total of 17 taxa from six families were recorded across the 80 sites. The most frequently encountered species was *Sclerolaena brachyptera,* which accounted for 22.5% of all quadrat presences. Also abundant were *Sclerolaena stelligera, Atriplex* spp. and *Carpobrotus* sp. which cumulatively accounted for 49% of all quadrat presences. All species but *Carpobrotus* sp. (Aizoaceae) are members of the Chenopodiaceae. Of the 3,600 1 x 1 m cells surveyed, approximately 15% were found to be devoid of vegetation and classified as bare soil.

Cluster analysis separated sites into 5 groups at 30% similarity (Figure 12), which reflected the major differences between sites. Indicator Species Analysis (Table 5) produced a list of representative taxa for each group, which were used to name the five groups according to their characteristic taxa:

1. "Bare soil" characterised by empty cells (27.5% of sites).
2. "Sclerolaena brachyptera" sites characterised by high abundances of *Sclerolaena brachyptera* (51.5%).
3. "Atriplex" sites characterised by *Atriplex* spp., and *Sclerolaena divaricata* (6.25%).
4. "Salt Tolerant" sites characterised by the salt tolerant taxa *Carpobrotus* sp. and *Pachycornia triandra* (13.75%).
5. "Maireana/Salsola kali" site characterised by the shrubs *Maireana* sp. and *Salsola kali* var. *kali* (1%).

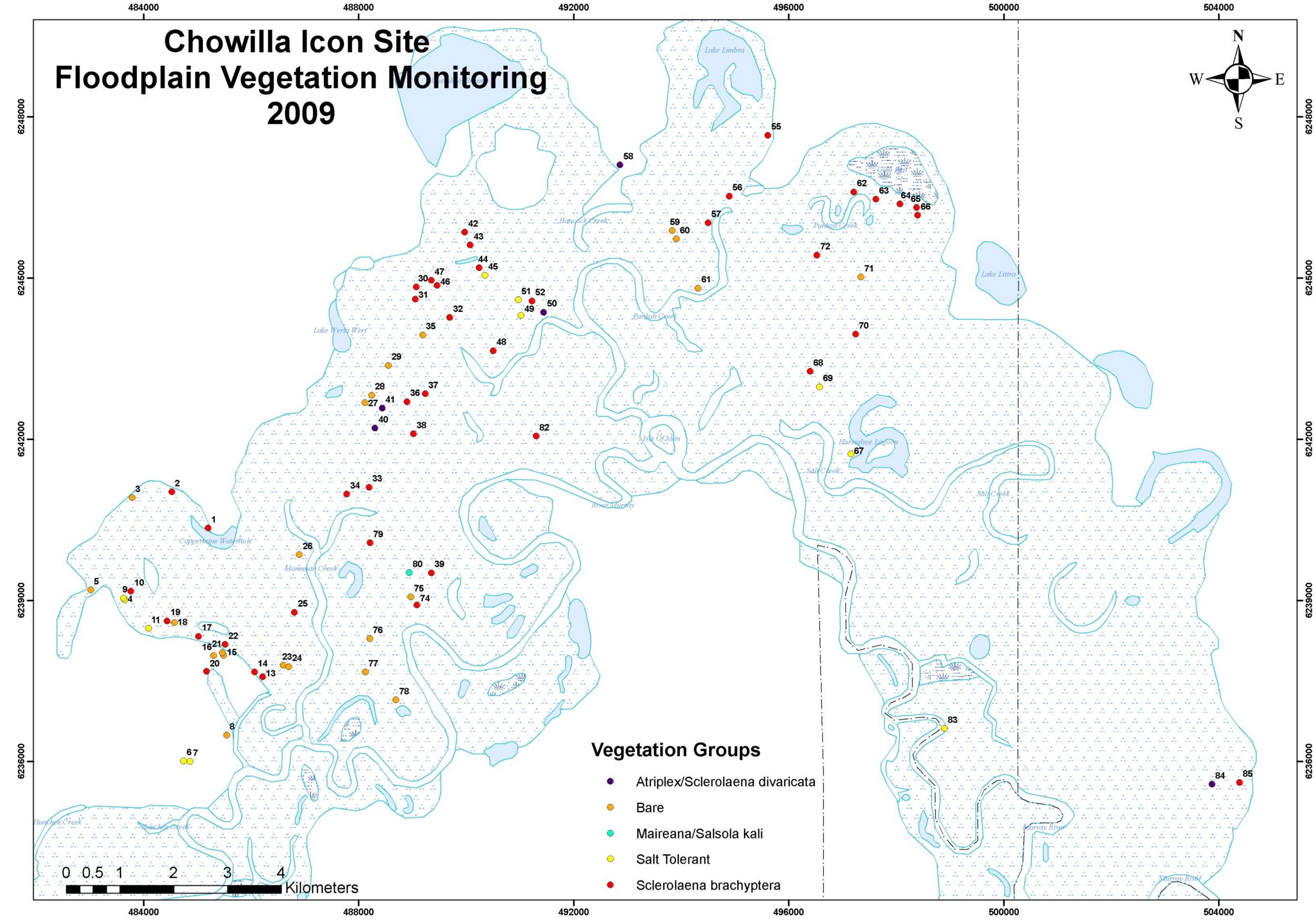

Figure 11: Spatial distribution and vegetation communities of the 80 survey sites across the Chowilla Floodplain for the 2009 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

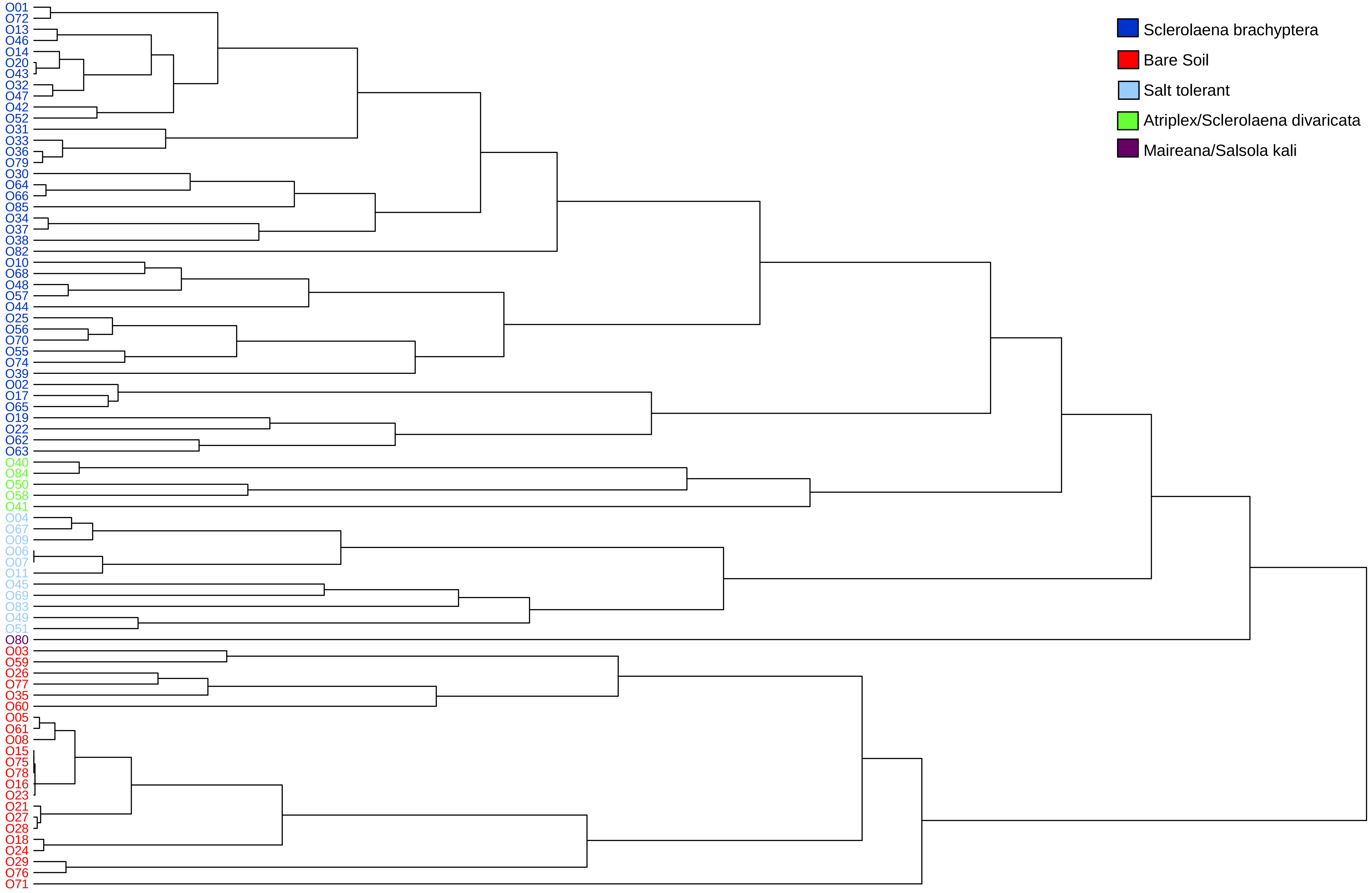

Figure 12: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2009 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 5: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=240) from the 2009 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
Atriplex spp.	Atriplex/Sclerolaena divaricata	0.0256
Bare soil	Bare Soil	0.0002
Carpobrotus sp.	Salt Tolerant	0.0002
Chenopodium nitrariaceum	Salt Tolerant	0.2206
Frankenia pauciflora	Maireana/Salsola	0.0782
Halosarcia pergranulata	Bare	0.2004
*Heliotropium europaeum**	Bare	0.4859
Maireana sp.	Maireana/Salsola	0.0024
Muehlenbeckia florulenta	Sclerolaena brachyptera	1.000
Pachycornia triandra	Salt Tolerant	0.0056
Rhagodia sp.	Atriplex/Sclerolaena divaricata	0.0694
Salsola kali var. *kali*	Maireana/Salsola	0.0002
Sclerolaena brachyptera	Sclerolaena brachyptera	0.0002
Sclerolaena divaricata	Atriplex/Sclerolaena divaricata	0.0002
Sclerolaena stelligera	Maireana/Salsola	0.1102
Sporobolus mitchellii	Sclerolaena brachyptera	0.1606
Unknown	Atriplex/Sclerolaena divaricata	0.7025

3.5. 2010 Survey

Figure 13 shows the spatial distribution and vegetation communities (based on groupings identified from cluster analysis) of the 74 survey sites across the Chowilla Floodplain in 2010.

Following re-watering of the Coppermine Complex and Gum Flat areas, in spring 2009, the total number of species recorded more than doubled (compared to the 2009 survey); with a total of 42 species from 19 families across the 74 sites surveyed. The five most frequently encountered species did not differ from 2008 and 2009: *Sclerolaena brachyptera*, *Atriplex* spp., *Sclerolaena stelligera, Carpobrotus* spp. and bare soil, which accounted for 64% of all quadrat presences. Of the 2,115, 1 x 1 m cells surveyed, approximately 6% were found to be devoid of vegetation and classified as bare soil, less than half the number of bare cells recorded in 2009.

Cluster analysis produced five significantly different groups (at 30% similarity, Figure 14), although one group included a single site only. These groups reflected major differences between sites, and Indicator Species Analysis (Table 6) produced a list of representative taxa for each group:

1. "Sclerolaena brachyptera" sites were characterised by high abundances of *Sclerolaena brachyptera* and *Sclerolaena stelligera* (47.19% of sites).

2. "Gum Flat" sites were characterised by taxa: *Atriplex* spp., *Sporobolus mitchellii* and *Craspedia chrysantha* (22.54%).

3. "Coppermine Complex" sites were characterised by the flood responder taxa: *Cyperus difformis, Marsilea angustifolia, Eleocharis acuta* and *Ammannia multiflora* (18.60 %).

4. "Bare soil" sites were predominantly characterised by empty cells and occasional occurrences of *Muehlenbeckia horrida* and *Brachyscome dentata* (6.22%).

5. "Sclerolaena divaricata" site was characterised by *Sclerolaena divaricata* and *Phyllanthus lacunaris* (5.39%).

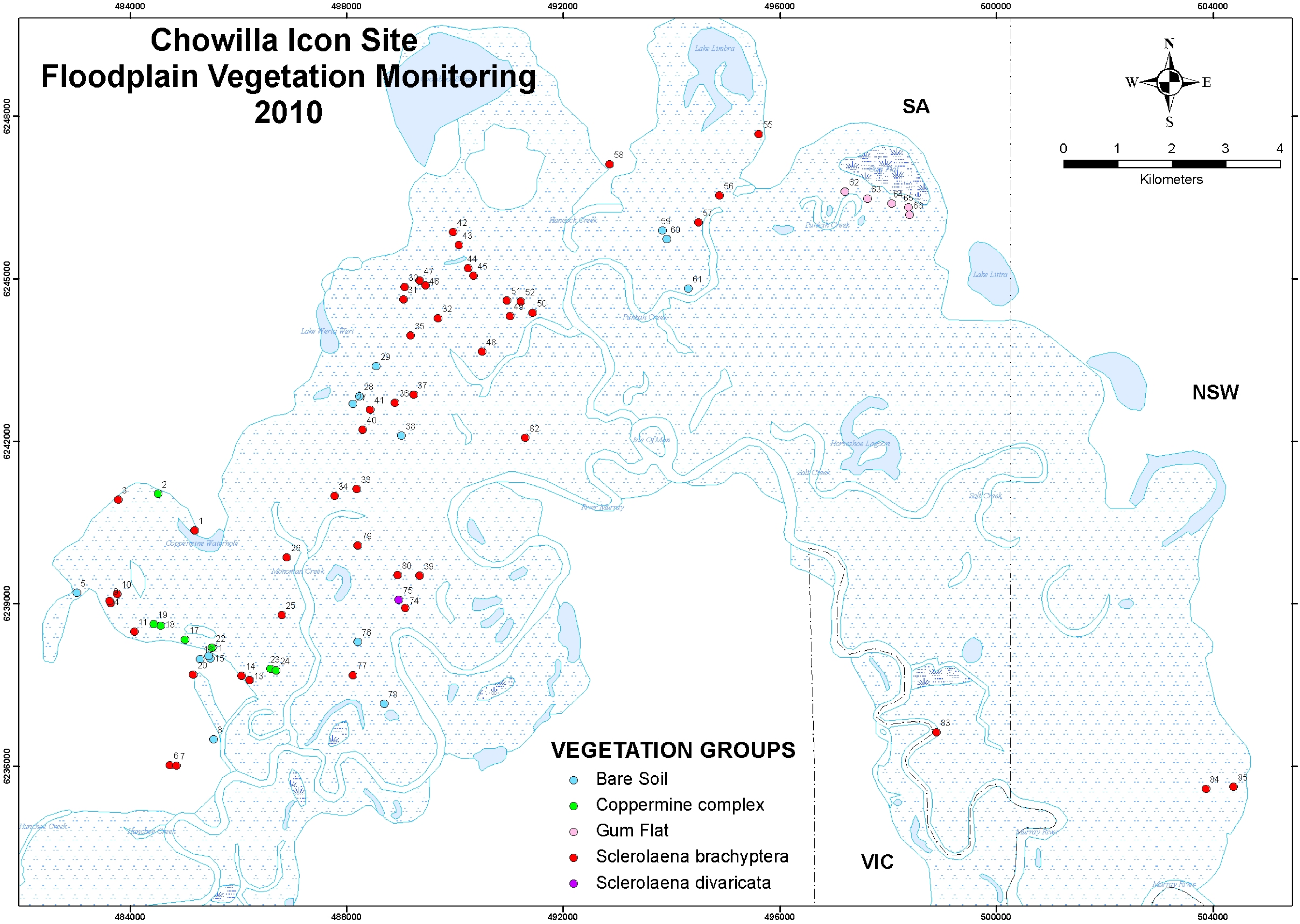

Figure 13: Spatial distribution and vegetation communities of the 74 survey sites across the Chowilla Floodplain for the 2010 survey. Numbers refer to site IDs. Legend colours reflect dendrogram groupings.

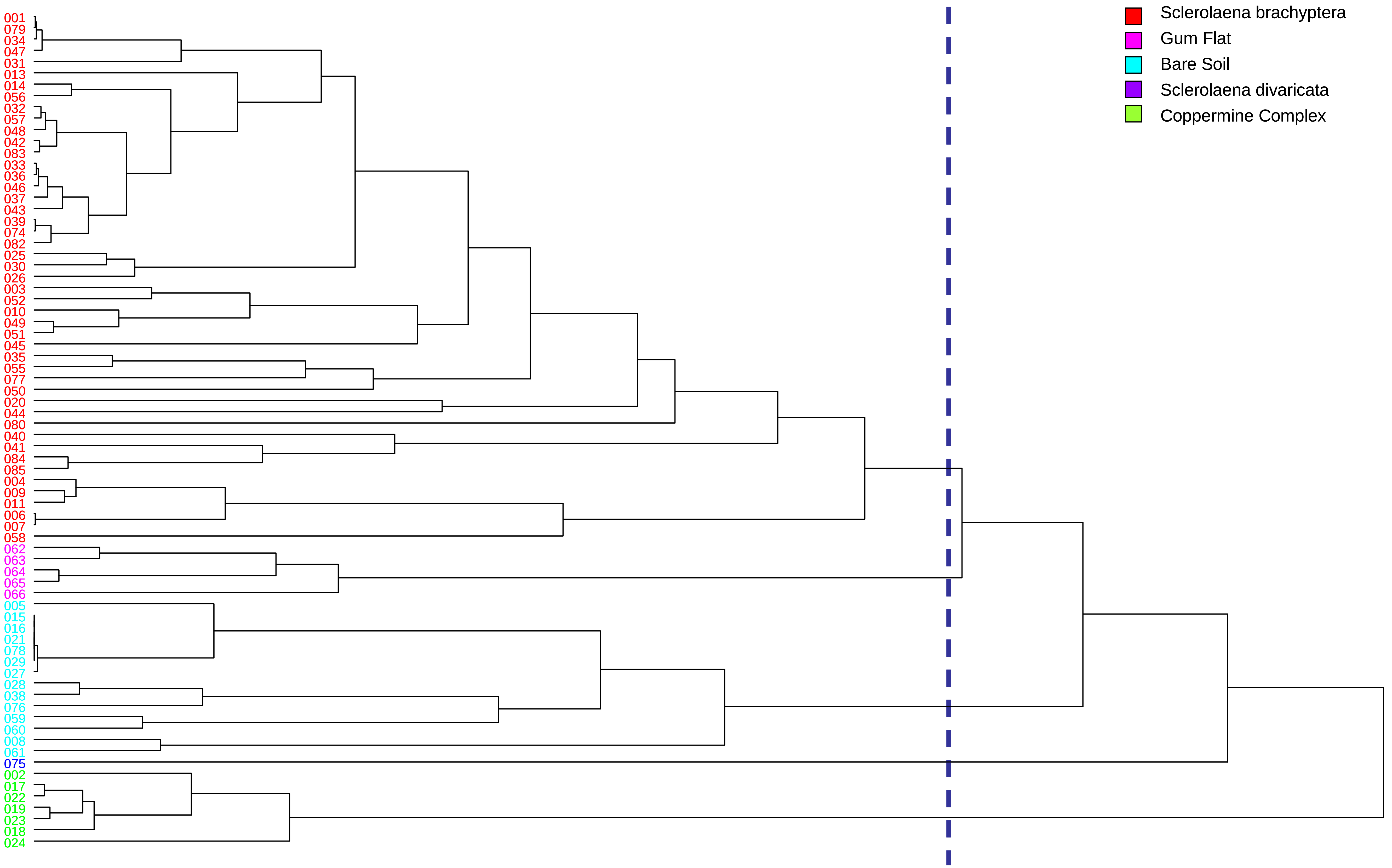

Figure 14: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2010 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 6: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (n=222) from the 2010 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
Alternanthera denticulata	Gum Flat	0.1075
Ammannia multiflora	Coppermine Complex	0.0001
Atriplex spp.	Gum Flat	0.0001
Bare Soil	Bare Soil	0.0001
Brachyscome basaltica	Gum Flat	0.0415
Brachyscome dentata	Bare Soil	0.9305
Calotis scapigera	Gum Flat	0.1268
Carpobrotus rossii	Sclerolaena brachyptera	0.0234
Centipeda minima	Coppermine Complex	0.0500
*Centaurium tenuiflorum**	Sclerolaena brachyptera	1.0000
Chenopodium nitrariaceum	Sclerolaena brachyptera	1.0000
*Conyza bonariensis**	Gum Flat	0.0785
Craspedia chrysantha	Gum Flat	0.0001
Cyperus difformis	Coppermine Complex	0.0001
Eleocharis acuta	Coppermine Complex	0.0001
Enchylaena tomentosa var. *tomentosa*	Gum Flat	0.1443
Eragrostis australasica	Coppermine Complex	0.0855
Frankenia pauciflora	Sclerolaena brachyptera	0.4562
Goodenia gracilis	Gum Flat	0.5078
*Heliotropium europaeum**	Coppermine Complex	0.0412
Isolepis hookeriana	Coppermine Complex	0.0289
Maireana microcarpa	Sclerolaena brachyptera	0.2596
Marsilea angustifolia	Coppermine Complex	0.0001
Mimulus repens	Coppermine Complex	0.0001
Muehlenbeckia florulenta	Sclerolaena brachyptera	1.0000
Muehlenbeckia horrida	Bare Soil	0.1751
Osteocarpum acropterum ssp. *acropterum*	Gum Flat	0.0319
Pachycornia triandra	Sclerolaena brachyptera	0.2031
*Phyla canescens**	Sclerolaena brachyptera	1.0000
Phyllanthus lacunaris	Sclerolaena divaricata	0.0006
*Polypogon monspeliensis**	Coppermine Complex	0.0490
Polygonum plebeium	Gum Flat	0.0309
Rhagodia spinescens	Sclerolaena brachyptera	1.0000
Salsola kali var. *kali*	Sclerolaena brachyptera	0.6349
Sclerolaena divaricata	Sclerolaena divaricata	0.0002
Sclerolaena stelligera	Sclerolaena brachyptera	0.0001
Sclerolaena brachyptera	Sclerolaena brachyptera	0.0001
Senecio runcinifolius	Gum Flat	0.0800
Sida ammophila	Sclerolaena brachyptera	1.0000
Solanum esuriale	Coppermine Complex	0.2340
Sporobolus mitchellii	Gum Flat	0.0007
Tetragonia tetragonioides	Sclerolaena brachyptera	1.0000
Typha domingensis	Coppermine Complex	0.0500

3.6. 2011 Survey

Figure 15 shows the spatial distribution and vegetation community (based on groupings identified from cluster analysis) of the 67 survey sites across the Chowilla Floodplain in 2011.

Following flooding in 2010/11, the total number of species recorded increased by more than 50% (compared to the 2010 survey); with a total of 66 species, from 28 families, across the 67 sites surveyed. The five most frequently encountered species were *Atriplex* spp., *Sclerolaena stelligera, Ammannia multiflora*, *Carpobrotus rossii* and *Sporobolus mitchellii*, accounting for 42.5% of all quadrats surveyed. Of the 3,015, 1 x 1 m cells surveyed, approximately 1.5% were found to be devoid of vegetation, the lowest number recorded since surveys began in 2006.

Cluster analysis produced seven significantly different groups (at 30% similarity, Figure 16), although two groups included a single site. These groups reflected major differences between sites, and Indicator Species Analysis (Table 7) produced a list of representative taxa for each group:

1. "Carpobrotus" sites were characterised by salt tolerant and desiccation tolerant species: *Carpobrotus* sp. and *Pachycornia triandra* (32.8% of sites),

2. "Ammannia" sites were characterised by amphibious species: *Ammannia multiflora* and *Mimulus repens* (25.4%),

3. "Tetragonia/Centipeda" sites were characterised by floodplain species: *Tetragonia tetragonioides*, *Centipeda minima*, *Senecio runcinifolius*, *Plantago cunninghamii*, *Sporobolus mitchellii*, *Rorippa palustris** and *Psuedognaphalium luteo-album* (20.9%),

4. "Marsilea/Eleocharis" sites were characterised by amphibious, floodplain or salt tolerant species: *Marsilea angustifolia*, *Eleocharis acuta*, *Spergularia marina* and *Calotis scapigera* (10.5%),

5. "Bare soil" sites were predominantly characterised by empty cells (7.5 % of sites),

6. "Craspedia/Salsola" sites were characterised by terrestrial, salt tolerant or floodplain species: *Craspedia chrysantha*, *Salsola kali, Scleroblitum atriplicinum* and *Enchylaena tomentosa* (1.5%),

7. "Sclerolaena brachyptera" were characterised by *Sclerolaena brachyptera*, *Brachyscome basaltica* and *Taraxacum officinale* (1.5% of sites).

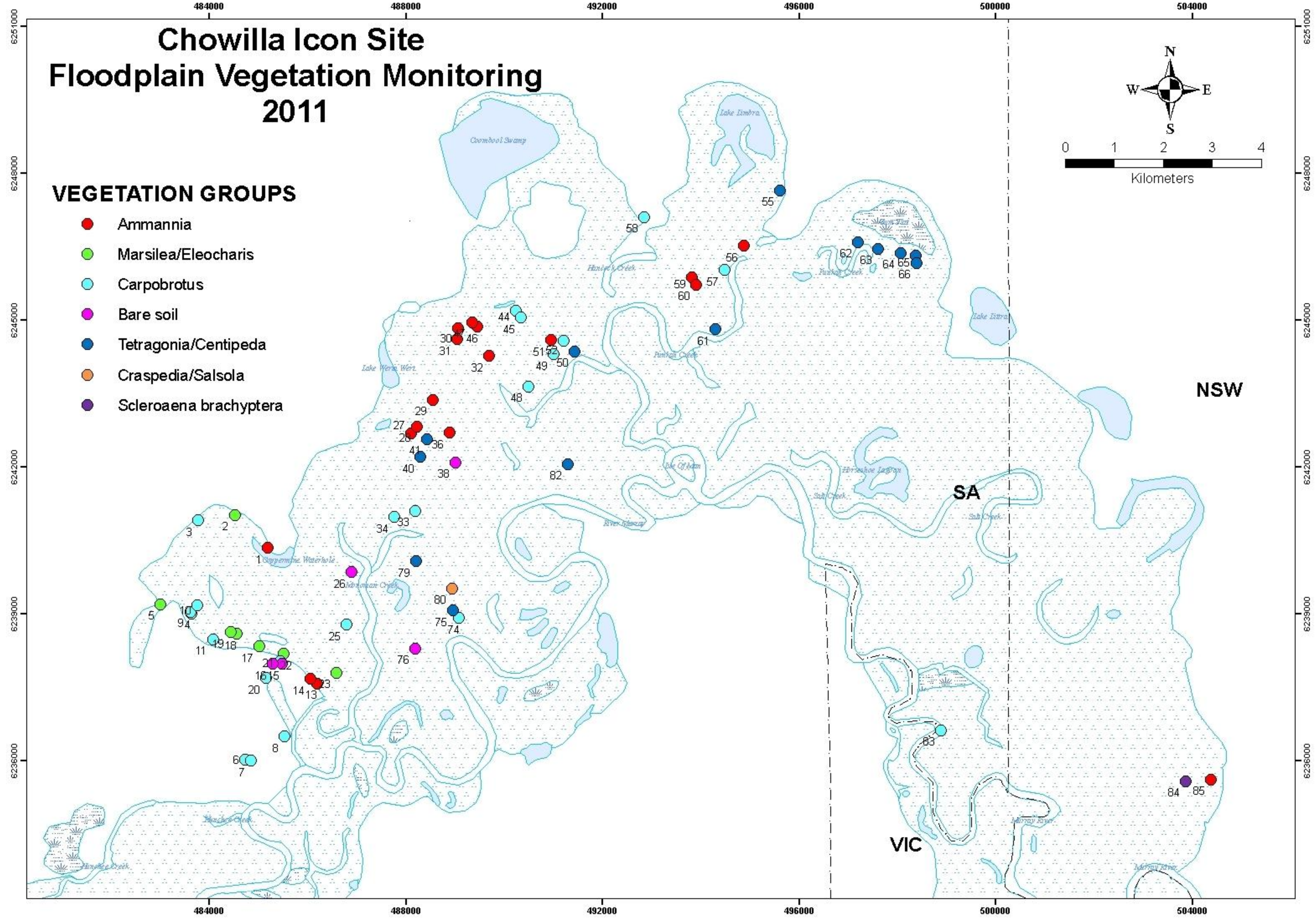

Figure 15: Spatial distribution and vegetation communities of the 67 survey sites across the Chowilla Floodplain for the 2011 survey. Colours refer to 2011 dendrogram groupings.

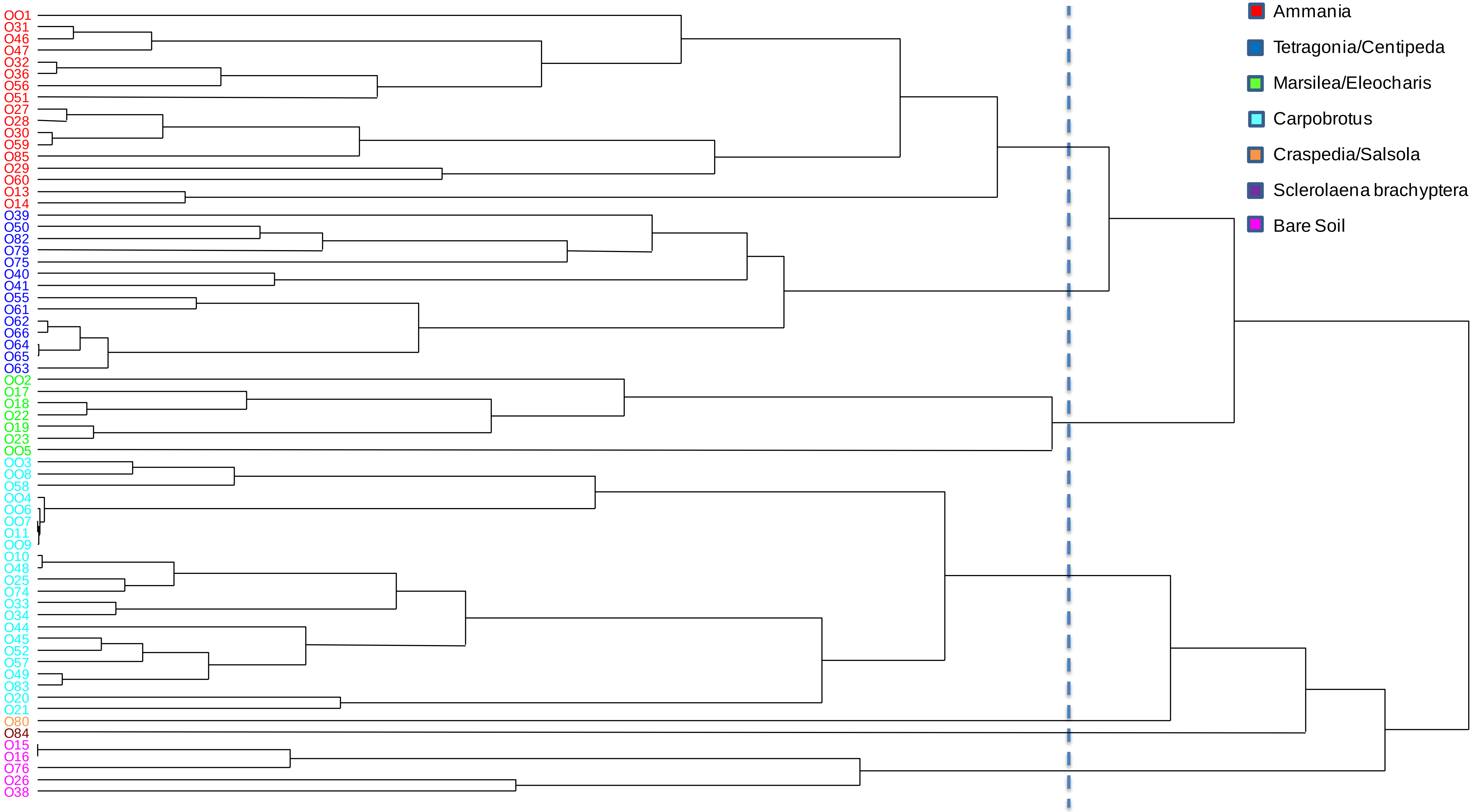

Figure 16: Dendrogram showing clustering of vegetation survey sites using Bray-Curtis distance measure from the 2011 survey. Dashed line shows division of sites into vegetation groups at 30% similarity.

Table 7: Indicator Species Analysis (Dufrene and Legendre 1997) based on unpooled data (*n*=201) from the 2011 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 taxon; #denotes listed as rare in South Australia; ## denotes listed as endangered in South Australia).

Species	Max. Group	P-value
Alternanthera denticulata	Marsilea/Eleocharis	0.3472
Ammannia multiflora	Ammannia	0.0006
*Asphodelus fistulosus**	Tetragonia/Centipeda	0.4859
Atriplex spp.	Tetragonia/Centipeda	0.0552
Atriplex suberecta	Tetragonia/Centipeda	0.2932
Bare Soil	Bare soil	0.0001
Brachyscome basaltica	Sclerolaena brachyptera	0.0044
Calotis hispidula	Ammannia	0.2781
Calotis scapigera	Marsilea/Eleocharis	0.0305
Carpobrotus rossii	Carpobrotus	0.0001
Centipeda minima	Tetragonia/Centipeda	0.001
Chenopodium nitrariaceum	Marsilea/Eleocharis	0.4238
Chenopodium pumilio	Tetragonia/Centipeda	0.1347
*Conyza bonariensis**	Tetragonia/Centipeda	0.1347
Cotula australis	Marsilea/Eleocharis	0.2035
Craspedia chrysantha	Craspedia/Salsola	0.0004
Crassula helmsii	Marsilea/Eleocharis	0.2101
Crassula sieberiana ##	Tetragonia/Centipeda	0.2426
Cyperus difformis	Ammannia	0.0929
Eleocharis acuta	Marsilea/Eleocharis	0.0005
Enchylaena tomentosa	Craspedia/Salsola	0.0007
Enneapogon nigricans	Ammannia	0.2212
Epaltes australis	Marsilea/Eleocharis	0.567
Eragrostis australasica	Tetragonia/Centipeda	0.726
*Erodium cicutarium**	Tetragonia/Centipeda	0.1716
Euphorbia drummondii	Tetragonia/Centipeda	0.1131
Frankenia pauciflora	Carpobrotus	0.3205
Glinus lotoides	Marsilea/Eleocharis	0.1166
Goodenia gracilis	Ammannia	0.4242
*Heliotropium amplexicaule **	Marsilea/Eleocharis	0.3022
*Heliotropium europaeum**	Tetragonia/Centipeda	0.4205
*Hypochaeris glabra **	Carpobrotus	1
Iseotopsis graminifolia	Ammannia	0.1507
Isolepis hookeriana	Ammannia	0.16
Limosella australis	Tetragonia/Centipeda	0.4205
Maireana spp.	Craspedia/Salsola	0.1016
Marsilea angustifolia	Marsilea/Eleocharis	0.0001
Medicago spp.*	Ammannia	0.5966
Mentha australis	Tetragonia/Centipeda	0.4174
Mimulus repens	Ammannia	0.0295
Mollugo cerviana	Ammannia	0.2247
Muehlenbeckia florulenta	Craspedia/Salsola	0.1584
Muehlenbeckia horrida#	Craspedia/Salsola	1
Myosurus minima	Tetragonia/Centipeda	0.1397
Neogunnia septifraga	Bare soil	0.3973
*Nothoscordum borbonicum**	Tetragonia/Centipeda	0.1935
Pachycornia triandra	Carpobrotus	0.0458
*Phyla canescens**	Tetragonia/Centipeda	0.4114
Picris angustifolia	Carpobrotus	1
Plantago cunninghamii	Tetragonia/Centipeda	0.0087
Psuedognaphalium luteo-album	Tetragonia/Centipeda	0.0492

Species	**Max. Group**	**P-value**
*Rorippa palustris**	Tetragonia/Centipeda	0.0258
Rumex bidens	Marsilea/Eleocharis	0.3205
Salsola kali var. *kali*	Craspedia/Salsola	0.0004
Scleroblitum atriplicinum	Craspedia/Salsola	0.0471
Sclerolaena brachyptera	Sclerolaena brachyptera	0.0001
Sclerolaena divaricata	Carpobrotus	0.1477
Sclerolaena stelligera	Marsilea/Eleocharis	0.188
Senecio cunninghamii	Ammannia	0.5085
Senecio runcinifolius	Tetragonia/Centipeda	0.0039
Solanum lacunarium	Ammannia	0.6725
*Spergularia marina**	Marsilea/Eleocharis	0.0129
Sporobolus mitchellii	Tetragonia/Centipeda	0.0114
*Taraxacum officinale**	Sclerolaena brachyptera	0.029
Tetragonia tetragonioides	Tetragonia/Centipeda	0.0005
Trachymene cyanopetula	Tetragonia/Centipeda	0.1061
Wahlenbergia fluminalis	Tetragonia/Centipeda	0.2758

3.7. Change in Floristic Composition between 2006 and 2011

In spring 2006, two large areas of floodplain (Coppermine Complex and Gum Flat) were watered by pumping; resulting in sites 2, 19, 22, 23 (Coppermine Complex) and sites 62, 63, 64, and 65 (Gum Flat) being inundated. Surveys in 2007 indicated that the vegetation at these sites changed from a community dominated by desiccation tolerant terrestrial species in 2006, to one dominated by flood dependent herbs and grasses, then back to a drought tolerant terrestrial community in 2008. By 2009, all sites (with the exception of one bare site), were classified as salt tolerant communities. In spring 2009 these two areas were watered for a second time, resulting in sites 2, 17, 18, 19, 22, 23 and 24 (Coppermine Complex) and sites 62, 63, 64, 65 and 66 (Gum Flat) being inundated, and communities were dominated by amphibious and floodplain species in 2010. As a result of flooding from August 2010 to May 2011, over 65% of sites surveyed in 2011 had been inundated. Table 8 summarises inundation history of the aforementioned sites.

Table 8: List of sites (surveyed in 2011) and inundation history (*Unflooded* = sites that remained dry throughout survey period (2006-2011); *Flooded* = sites flooded in 2010/11; *1 Water* + *Flooding* = sites watered in spring 2009 and flooded in 2010/11; *2 water* + *Flooding* = sites watered in spring 2006, re-watered in spring 2009 and flooded in 2010/11. CC = Coppermine Complex; GF = Gum Flat).

	Unflooded	***Flooded***	***1 x Watering + Flooding***	***2 x Watering + Flooding***
Site #	4, 5, 6, 7, 8, 9, 11, 15, 16, 21, 25, 26, 38, 45, 52, 57, 58, 74, 76, 80, 82, 83, 84	1, 3, 10, 13, 14, 20, 27, 28, 29, 30, 31, 32, 33, 34, 36, 39, 40, 41, 44, 46, 47, 48, 49, 50, 51, 55, 56, 59, 60, 61, 75, 79, 85	CC: 17, 18 GF: 66	CC: 2, 19, 22, 23 GF: 62, 63, 64, 65
Total	**23**	**33**	**3**	**8**

Between 2006 and 2009, species richness generally declined across the Chowilla Floodplain (Figure 17) despite a rise in species richness in 2007. This peak in species richness followed the first watering of Coppermine Complex and Gum Flat in spring 2006, but in subsequent years species richness steadily declined, such that by 2009, a total of only 17 taxa were recorded (Figure 17). Re-watering of the same areas in spring 2009 resulted in higher species richness in the 2010 survey similar to the numbers recorded in the 2007 survey (42 and 48 taxa, respectively) (Figure 17). In 2011, following overbank flooding; species richness increased by more than 50% compared to 2010 (66 and 42 taxa respectively) (Figure 17).

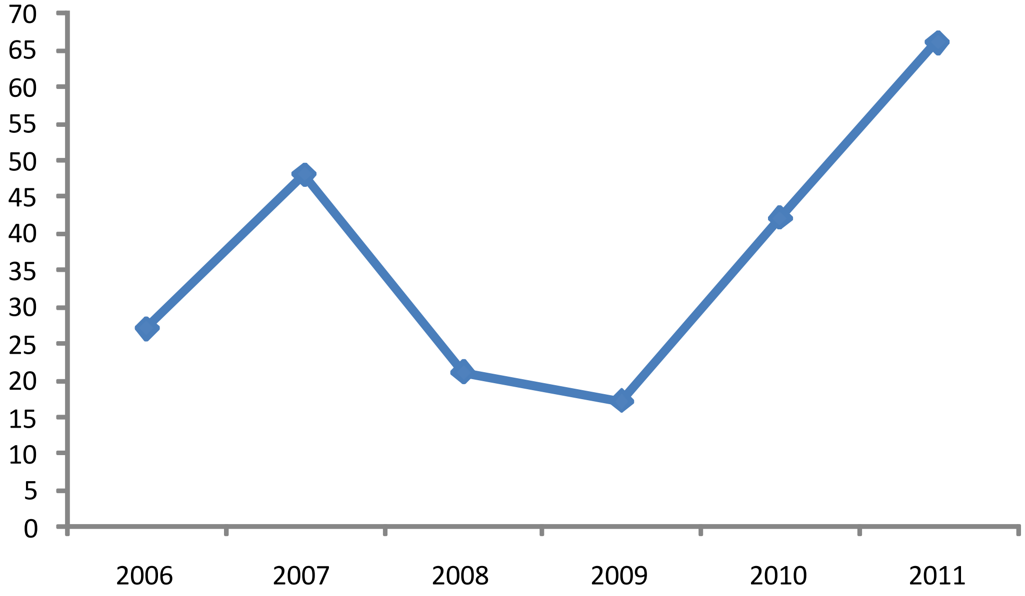

Figure 17: Changes through time in species richness (number of taxa) of the Chowilla Floodplain from 2006 to 2011.

In 2006, the floodplain understorey was mostly comprised of taxa from salt tolerant and terrestrial functional groups (Figure 18); however, following the first watering of the Coppermine Complex and Gum Flat (spring 2006) there was an increase in amphibious, floodplain and salt tolerant taxa and a concomitant decrease in terrestrial taxa and bare soil (Figure 18). In 2008 and 2009, the number of observations of bare soil, terrestrial and salt tolerant taxa increased, while floodplain taxa decreased and amphibious taxa were not observed (Figure 18). Re-watering of the Coppermine Complex and Gum Flat (spring 2009) resulted in an increase in floodplain and amphibious taxa in 2010 (Figure 18). Overbank flooding in 2010/11 resulted in a further decline in bare soil, terrestrial and salt tolerant taxa, a moderate increase in amphibious taxa and a large increase of floodplain taxa (Figure 18).

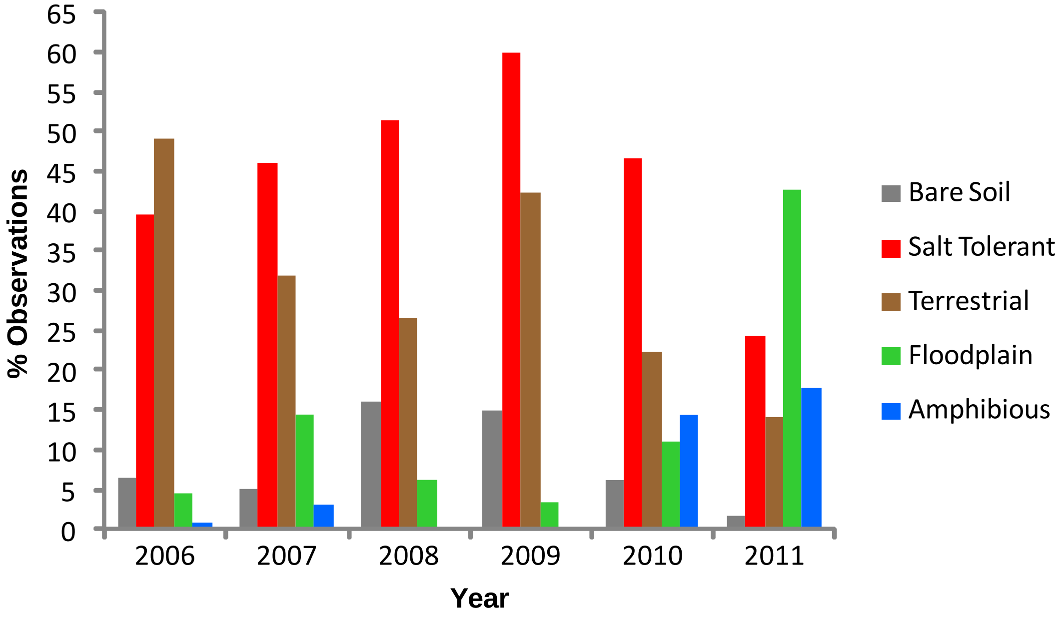

Figure 18: Changes in the percentage of observation of vegetation functional groups of the Chowilla Floodplain from 2006 to 2011.

The change in floristic composition over the Chowilla Floodplain between 2006 and 2011 were strongly related to site inundation history. Two factor PERMANOVA results (Table 9) showed the floristic composition was significantly different between years and inundation history: *unflooded* (sites remained dry since 2006); *flooded* (sites flooded in 2010/11); *watered* (sites were watered in spring 2006 and rewatered in spring 2009, then flooded in 2010/11). There was a significant interaction between year and inundation history (Table 9), which indicated that change through time was not consistent between sites.

Table 9: PERMANOVA *pseudo-F*-statistic results comparing years and watering (or flow conditions: Unflooded; Flooded and 2 watering + Flooded).

Factor	*df*	*Pseudo-F*	*P*
Year	5, 353	9.03	<0.001
Inundation History	2, 353	26.05	<0.001
Year x Inundation History	10, 353	2.78	<0.001

NMS ordination (Figure 19) showed that the plant communities in unflooded sites (years 2006–2011) and flooded sites (years 2006–2010) were similar, but they were significantly different to *i*) sites that were watered in years 2006, 2008 and 2009 (i.e. Coppermine Complex and Gum Flat sites that were surveyed: prior to watering (spring 2006); and in the intervening years before re-watering (spring 2009)); *ii*) watered sites in year 2007 (i.e. Coppermine Complex and Gum Flat sites that were watered once in spring 2006; surveyed in 2007); *iii*) watered sites in year 2010 (i.e. Coppermine Complex and Gum Flat sites that were watered twice) and watered sites in year 2011 (i.e. Coppermine Complex and Gum Flat sites that were watered twice and then flooded) and *iv*) sites that were flooded in year 2011 (i.e. sites flooded but not watered).

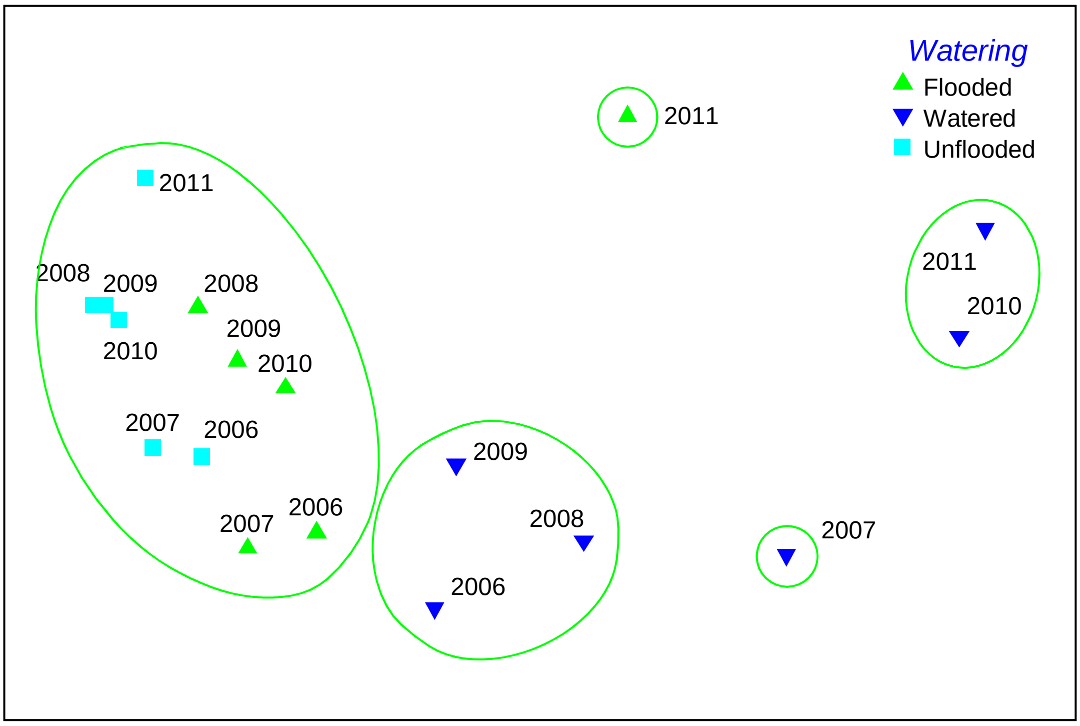

Figure 19: NMS ordination comparing sites and inundation history across the survey period. Light blue squares: unflooded sites that remained dry. Green triangles: flooded sites were flooded in 2010/11. Blue triangles: a) sites that were watered in spring 2006 (i.e. surveyed 2007), and again in spring 2009 (surveyed 2010) and then flooded in 2010/11 (surveyed 2011). Stress = 6%.

In the unflooded areas of the floodplain, changes in floristic composition were driven by changes in abundance of salt tolerant taxa such as, *Carpobrotus rossii, Pachycornia triandra* and *Frankenia pauciflora* and bare soil (Table 10). Conversely, the differences in floristic composition of sites that were watered were largely driven by increases (post watering) in abundance of amphibious (*Cotula australis* and *Marsilea angustifolia*), floodplain (*Ammannia multiflora, Centipeda minima*, *Chenopodium pumilio*, *Euphorbia drummondii*, *Plantago cunninghamii*, *Sporobolus mitchellii,* and *Senecio runcinifolius*) and salt tolerant (*Spergularia marina*) taxa (Table 10). In areas that were flooded, differences in floristic composition were due to increased abundances of floodplain (*Alternanthera denticulata*, *Calotis scapigera, Goodenia gracilis, Iseotopsis graminifolia, Nothoscordum borbonicum*, Rorippa palustris*, Psuedognaphalium luteo-album, Tetragonia tetragonioides),* amphibious (*Cyperus difformis* and *Mimulus repens*) salt tolerant (*Sclerolaena stelligra*) and terrestrial (*Atriplex* spp.) taxa (Table 10).

Table 10: Indicator Species Analysis (Dufrene and Legendre 1997) results and functional group list (Nicol _et al._ 2010) based on unpooled data (n=253) from the 2006 – 2011 vegetation surveys of sites that were watered in spring 2006, re-watered in spring 2009 and then flooded in 2010/11. Inundation History indicates the group in which taxon had the highest indicator value. P-value derived from Monte-Carlo test of significance (permutations=10,000). Significant (p<0.05) taxa are highlighted (*denotes exotic taxon; # denotes taxon listed as rare in South Australia; ## denotes taxon listed as endangered in South Australia; § denotes species not recorded in Chowilla Floodplain system since 1989, see Nicol 2009).

Taxon	Functional Group	Inundation History	p-value
Alternanthera denticulata	Floodplain	Flooded	0.0486
Ammannia multiflora	Floodplain	Watered	0.0001
_Asphodelus fistulosus_*	Terrestrial	Flooded	0.2471
Atriplex spp.	Terrestrial	Flooded	0.0041
Atriplex suberecta	Floodplain	Flooded	0.248
Bare Soil	Bare Soil	Unflooded	0.0013
Brachyscome basaltica	Floodplain	Unflooded	0.5209
Calotis hispidula	Floodplain	Flooded	0.168
Calotis scapigera	Floodplain	Flooded	0.0738
Carpobrotus rossii	Salt Tolerant	Unflooded	0.0001
Centipeda minima	Floodplain	Watered	0.0001
Chenopodium nitrariaceum	Terrestrial	Unflooded	0.4727
Chenopodium pumilio	Floodplain	Watered	0.0036
_Conyza bonariensis_*	Terrestrial	Flooded	0.2272
Cotula australis	Amphibious	Watered	0.0107
Crassula helmsii	Amphibious	Watered	0.1386
Crassula sieberiana##	Amphibious	Flooded	0.6422
Craspedia chrysantha	Floodplain	Unflooded	0.4504
Cyperus difformis	Amphibious	Flooded	0.0383
Eleocharis acuta	Amphibious	Watered	0.0001
Enchylaena tomentosa	Terrestrial	Unflooded	0.0886
Enneapogon nigricans	Floodplain	Flooded	0.3695
Epaltes australis	Floodplain	Watered	0.3612
Eragrostis australasica	Floodplain	Flooded	0.1186
_Erodium cicutarium_*	Floodplain	Watered	0.0942
Euphorbia drummondii	Floodplain	Watered	0.0001
Frankenia pauciflora	Salt Tolerant	Unflooded	0.0219
Glinus lotoides	Floodplain	Watered	0.1775
Goodenia gracilis	Floodplain	Flooded	0.0223
_Heliotropium amplexicaule_*	Floodplain	Watered	0.1172
_Heliotropium europaeum_*	Floodplain	Flooded	1
Iseotopsis graminifolia	Floodplain	Flooded	0.0001
Isolepis hookeriana	Amphibious	Flooded	0.2002
Limosella australis	Amphibious	Flooded	1
Maireana spp.	Terrestrial	Unflooded	0.0613
Marsilea angustifolia	Amphibious	Watered	0.0001
Medicago spp.*	Terrestrial	Flooded	0.1344
Mentha australis	Amphibious	Watered	0.1287
Mimulus repens	Amphibious	Flooded	0.0096
Mollugo cerviana	Floodplain	Flooded	0.1301
Muehlenbeckia florulenta	Amphibious	Flooded	0.0576
Myosurus minima	Floodplain	Flooded	0.2108
Neogunnia septifraga	Floodplain	Flooded	0.4226
_Nothoscordum borbonicum_*	Floodplain	Flooded	0.0487
Pachycornia triandra	Salt Tolerant	Unflooded	0.0001
_Phyla canescens_*	Terrestrial	Flooded	1
Picris angustifolia	Terrestrial	Unflooded	0.4759
Plantago cunninghamii	Floodplain	Watered	0.0002
Psuedognaphalium luteo-album	Floodplain	Flooded	0.0001
_Rorippa palustris_*	Floodplain	Flooded	0.0039

Taxon	Functional Group	Inundation History	p-value
Rumex bidens	Amphibious	Watered	0.3015
Salsola kali var. *kali*	Salt Tolerant	Unflooded	0.1335
Sclerolaena brachyptera	Salt Tolerant	Unflooded	0.1733
Sclerolaena divaricata	Terrestrial	Flooded	0.0183
Sclerolaena stelligera	Salt Tolerant	Flooded	0.0408
Scleroblitum atriplicinum	Floodplain	Watered	0.4254
Senecio cunninghamii	Floodplain	Flooded	0.3319
Senecio runcinifolius	Floodplain	Watered	0.0045
Solanum lacunarium§	Floodplain	Flooded	0.0522
*Spergularia marina**	Floodplain	Watered	0.0026
Sporobolus mitchellii	Floodplain	Watered	0.0001
Tetragonia tetragonioides	Floodplain	Flooded	0.0001
Trachymene cyanopetula	Floodplain	Flooded	0.1859
Wahlenbergia fluminalis	Floodplain	Flooded	0.255

4. Discussion

The floodplain vegetation condition monitoring program for the Chowilla Living Murray Icon Site has provided comprehensive spatial coverage of open habitats with a broad range of flood frequencies across the floodplain (Figure 3). The extensive sampling provided good baseline information, and follow up surveys provided further information regarding medium-term vegetation dynamics of the system and the impacts of watering and natural flooding. In order to monitor medium to long-term vegetation changes these sites should continue to be consistently re-surveyed on an annual basis.

The clearest pattern observed in the 2006 survey was the statistically significant, positive association of the "Salt Tolerant" vegetation type with rarely flooded sites. This association was strong in one direction only, i.e. "Salt Tolerant" vegetation was most likely to be encountered on rarely flooded sites, but rarely flooded sites also hosted other vegetation types. The reason for this association is unclear; the relationships between flood frequency and soil and groundwater salinity are complex and may be overridden by local-scale soil, groundwater and topographic conditions. The association is particularly interesting given that the regularly flooded lagoon, Lake Limbra, is currently dominated by the halophyte *Halosarcia pergranulata* ssp. *pergranulata* (Zampatti *et al.* 2006b). It may be that the plant assemblages in these two differing environments are convergent due to high salinity, regardless of the mechanism by which the salinity is generated.

Also interesting is the fact that the two sites identified as having a "Flood Responder" vegetation type in 2006 were located in areas that fell within the "Sometimes" flood frequency class, having flood return frequencies of 1 in 10 and 1 in 11 years. Given that the vegetation at these sites was characterised by species that are typical of recently inundated areas it is possible either that the spatial resolution of the flood model may be too coarse to identify small localised areas of higher flood frequencies (i.e. narrow flood runners) or that the vegetation at these sites established in response to water from a source other than flooding (e.g. runoff from tracks).

Data from the 2007 survey showed that when areas were watered, the floristic composition changed from a terrestrial dryland plant community to a community dominated by flood dependent species. This indicated that these species form a long-lived seed bank or propagules disperse into these areas by hydrochory, which enables them to colonise areas rapidly in response to inundation. In addition to the flood dependent species that recruited at these sites large numbers of *Atriplex* spp. seedlings were present (Table 3). This is in contrast to the remainder of the floodplain where this taxon was present in significantly lower numbers in 2007 compared with 2006.

Watering areas of floodplain increased the species richness of the Chowilla system; in 2006 28 species from 13 families were recorded, in 2007 (after watering) 48 species from 20 families were recorded. The increase in species richness was primarily due to the colonisation of native flood dependent herbs and grasses in the areas that were watered. However, the number of species decreased to 21 (from eight families) in 2008 and 17 (from six families) in 2009 with *Sporobolus mitchellii* (a drought tolerant, perennial floodplain species (Nicol 2004) being the only flood dependent species present.

In 2010 species richness increased (42 taxa from 19 families) in response to rewatering of Gum Flat and Coppermine Complex; however, the plant communities present in Coppermine Complex and Gum Flat were significantly different (Figure 14). Gum Flat was dominated by native flood dependent and terrestrial species whereas Coppermine Complex was dominated by amphibious species (Table 6). The differences in plant communities between the two sites were probably the result of differences in timing and duration of watering; Gum Flat was watered earlier than Coppermine Complex and inundated for a shorter period. Furthermore, surface water was present in parts of Coppermine Complex when surveyed in February 2010 whereas Gum Flat was completely dry (and had been for several months) and the majority of desiccation sensitive species present at Coppermine were absent at Gum Flat.

In 2011, species richness for the Chowilla Floodplain was the highest recorded over the study period (66 taxa from 28 families). This response was almost undoubtedly due to overbank flooding, which inundated more than 60% (>10,000 ha) of the floodplain from August 2010 to May 2011. During this period, flow in South Australia peaked at 93,000 ML day^{-1}, which was the highest flow into the state since 1993 (MDBA 2011). As expected, there were distinct differences between those areas of the floodplain that were flooded versus those areas that remained unflooded (Figure 19). Unflooded sites continued to be dominated by terrestrial and salt tolerant taxa, whereas areas that were inundated were dominated by flood responders. The significant increase in the abundance of flood responders between 2010 and 2011 indicates that the plant community is resilient and able to recolonise after an extended absence of inundation. However, whether recolonisation has resulted from the resident seed bank or from propagules brought in by floodwaters (hydrochory) is unknown. Strandlines (organic matter deposited by receding floodwaters) were observed in numerous areas throughout the floodplain. Species richness was generally higher at sites where strandlines were present within quadrats (pers. obs.). Furthermore, *Muehlenbeckia florulenta* seedlings were only observed in quadrats that contained strandlines (pers. obs.). Nevertheless, many floodplain species (especially annual herbs and grasses) form long-lived (>10 years) seed banks (Leck and Brock 2000) and resident seed banks may be important sources of regeneration.

There were also distinct differences between the areas that were watered in spring 2006, and again in spring 2009, versus areas that were only flooded. The watered areas were dominated by a mix of floodplain and amphibious taxa, whereas the flooded areas were predominantly floodplain taxa. These results provide evidence that emergency watering of areas of floodplain during extended drought may be important in ensuring persistence of amphibious species outside of the littoral zone.

Results from this study, and environmental watering monitoring during the recent drought (Nicol *et al.* 2010), show that watering may be important for the persistence of amphibious taxa; however, it is not a substitute for flooding. Watering involves the construction of banks, pumping, and is limited to water retaining areas of the floodplain. In contrast, flooding has no infrastructure requirements, is hydraulically complex and inundates much larger areas including water-shedding areas, increasing connectivity between permanent and ephemeral habitats. Flooding is also important for regeneration of the two most abundant taxa in 2011 *Atriplex* spp. and *Sclerolaena stelligera* (terrestrial taxa), evidenced by large numbers of seedlings in areas that were flooded.

Surprisingly, all of the exotic species identified by Nicol (2007) of high or extreme invasion risk due to the operation of the regulator were not significant indicators of flooding or watering (Table 10). Furthermore, *Heliotropium amplexicaule, Heliotropium europaeum, Hypochaeris glabra, Medicago* spp. and *Phyla canescens* were the only taxa present in 2011 (Table 7) of the 29 that were identified as being a high or extreme invasion risk (Nicol 2007). Furthermore these species were also present in very low numbers. The declared noxious weed *Xanthium* spp., which recruits in large numbers on the River Murray Floodplain after inundation, was not observed in 2011, despite being abundant in Werta Wert Wetland and Twin Creeks after watering (Nicol *et al.* 2010), and on the banks of the River Murray and Monoman Creek after increased discharge into SA in 2005 (Zampatti *et al.* 2011). In addition, the floodplain weeds *Abutilon theophrasti* and *Heliotropium curassivicum,* which were abundant in areas watered during the drought (Nicol *et al.* 2010), were not recorded in the 2011 survey.

4.1. TLM Targets

Prior to 2010, AEMP Target 5 (improve the area and diversity of grass and herblands), Target 6 (improve the area and diversity of flood dependent understorey vegetation), and Target 8 (maintain or improve the area and diversity of grazing sensitive plant species) were not met without management intervention (watering) (Nicol *et al.* 2010). Whilst watering did result in the aforementioned targets being met, the spatial extent was limited and there were often significant increases in abundance of pest plants hence Target 9 (limit the extent of invasive (increaser) species, including weeds) was not being met.

The overbank flow in 2010/11 resulted in over 60% of the floodplain being inundated (MDBA 2011), and provided significant recruitment of flood dependent and amphibious species (including grazing sensitive species) with minimal weed recruitment. Therefore, all of the AEMP TLM targets for the Chowilla Icon Site were met in 2011.Whilst overbank flow provided the greatest spatial extent of target species recruitment, watering has been an important management tool to maintain amphibious species on floodplain habitats during extended periods of low flow.

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6. Appendices

Appendix 1: Site GPS coordinates (UTM format, map datum WGS 84).

Site Identifier	Easting	Northing	Site Identifier	Easting	Northing
001	485198	6240345	**043**	490075	6245613
002	484523	6241019	**044**	490242	6245188
003	483784	6240912	**045**	490345	6245049
004	483645	6239006	**046**	489458	6244864
005	483016	6239192	**047**	489351	6244956
006	484742	6236011	**048**	490503	6243645
007	484859	6236000	**049**	491017	6244303
008	485543	6236491	**050**	491442	6244363
009	483624	6239042	**051**	490966	6244592
010	483764	6239169	**052**	491223	6244572
011	484087	6238477	**053**	494051	6247841
013	486211	6237577	**054**	494249	6247739
014	486064	6237665	**055**	495612	6247657
015	485487	6237975	**056**	494893	6246522
016	485298	6237971	**057**	494499	6246028
017	485021	6238331	**058**	492860	6247105
018	484572	6238585	**059**	493830	6245882
019	484438	6238618	**060**	493910	6245725
020	485169	6237680	**061**	494310	6244810
021	485459	6238026	**062**	497206	6246599
022	485513	6238180	**063**	497618	6246464
023	486597	6237792	**064**	498069	6246375
024	486698	6237764	**065**	498376	6246311
025	486805	6238779	**066**	498394	6246168
026	486896	6239849	**067**	497154	6241724
027	488116	6242678	**068**	496397	6243263
028	488241	6242818	**069**	496572	6242971
029	488551	6243371	**070**	497243	6243954
030	489071	6244832	**071**	497342	6245017
031	489052	6244608	**072**	496523	6245423
032	489693	6244265	**074**	489083	6238916
033	488193	6241105	**075**	488969	6239062
034	487778	6240977	**076**	488205	6238287
035	489188	6243939	**077**	488122	6237666
036	488897	6242699	**078**	488692	6237147
037	489238	6242844	**079**	488209	6240070
038	489017	6242097	**080**	488942	6239515
039	489350	6239512	**082**	491300	6242057
040	488303	6242207	**083**	498893	6236615
041	488438	6242575	**084**	503870	6235576
042	489973	6245851	**085**	504385	6235609