APPENDIX K
TERRESTRIAL BIOLOGICAL ASSESSMENT

WESFARMERS LIMITED
MARUBENI CORPORATION
WATER CORPORATION OF WESTERN AUSTRALIA

ORD RIVER STAGE 11
M2 DEVELOPMENT AREA

TERRESTRIAL BIOLOGICAL ASSESSMENT

ADDENDUM A: REGIONAL BIODIVERSITY AND REPRESENTATION

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ENVIRONMENTAL CONSULTANTS

1.0 INTRODUCTION

Interest in the further development of the Ord River Irrigation Area has recently been renewed since Wesfarmers Limited, Marubeni Corporation and the Water Corporation of Western Australia announced that they will undertake a study into the feasability of establishing a raw sugar industry based on the development of the Weaber, Keep River and Knox Creek Plains (M2 Development Area). Biological diversity issues, particularly the maintenance of species and ecosystem diversity, are highly relevant in the context of the proposed development. The National Strategy for the Conservation of Australia's Biological Diversity maintains that ecologically sustainable management of all Australia's terrestrial and marine environments is essential for the conservation of biological diversity. The primary issues examined in this document, therefore, relate to the protection of biological communities and hence protection of biological diversity.

Representation of areas supporting unique vegetation communities or suites of animal species are important within the general reserves framework, and are highly relevant to issues relating to retention of biodiversity within Australian ecosystems. The M2 Development would encompass large areas of cracking clay environments in the North-East Kimberley and adjacent areas of the Northern Territory. Within this sub-region, the areas associated with the alluvial, cracking clay floodplains of the Ord and Dunham Rivers comprise the majority of land with high pastoral potential (WA Department of Agriculture, 1985).

ecologia Environmental Consultants undertook a biological assessment survey in 1996-97 of the Riverside and M2 Development Areas. Based on an analysis of the floristic data obtained during the survey, it has been the contention that the conservation significance of the proposed development area is high, and therefore suitable areas should be protected as part of any future development.

1.1 SCOPE OF THIS REVIEW

The purpose of this review is to examine and synthesise information pertinent to the M2 Development Area for use by Kinhill Pty Ltd in preparing an Environmental Review and Management Programme for the proposed project. In particular, it updates the ecologia (1997a) report by examining floristic composition in a regional context by taking into consideration the results of subsequent field surveys in the region. The bioregional level is taken to be, for the purposes of this document, the Victoria-Bonaparte bioregion as defined by Thackway and Cresswell (1995) and discussed in Connors et al. (1996). The majority of information discussed refers to sites within this bioregion, although some sites are slightly outside the defined region. Within the bioregion, the vegetation has been examined at four levels: between Land Systems; within the Ivanhoe Land System; within the Ord Basin; and within the M2 Development Area.

Comparisons of the floristic composition of sites within the M2 Development Area, as described in ecologia (1997a), have been made with regional data sets obtained from Agriculture Western Australia. This data relates to the vegetation of rangeland areas in the East Kimberley on Land Systems similar to the Ivanhoe Land System, which is represented in the M2 area. Secondly, a review is given of a vegetation survey undertaken by staff of the Parks and Wildlife Commission of the Northern Territory (PWCNT) (Brocklehurst et al., 1998), and the comparison of these areas of the Ivanhoe Land System with the vegetation detailed in the M2 report (ecologia, 1997a). At a finer level, an analysis has been made of the relationship between the vegetation communities of the M2 area and the Riverside area (incorporating the Mantinea Flats, Carlton Plain and Ivanhoe West areas). Finally, the floristic composition of sites within the three plains of the M2, i.e. the Keep, Knox and Weaber, have been compared.

1.1.1 Regional Approach

A regional approach has been adopted in the preparation of this document, based on the bioregions defined by Thackway and Cresswell (1995). These bioregions provide a nationally acknowledged series of defined areas that represent relatively homogeneous areas in terms of their underlying geology, surface landform and vegetation expression, fauna, and climatic regime. These bioregions represent defined areas that can be examined and utilised in an assessment of representation of biotic components of the landscape within the existing conservation reserves framework. In this instance, floristic communities are to be used as the primary means of determining representation, since the large size of the M2 Development Area precludes a fine scale investigation of the biota.

At the broadest scale, comparisons have been made between the vegetation of similar Land Systems. The Land Systems of the region were described and mapped by a surveying party from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), who investigated the Ord-Victoria Area in 1949 and 1952. The geology, geomorphology, soils and vegetation of the area are described, primarily in the context of pastoral productivity, and a series of 50 Land Systems are indicated. Systems are defined as 'an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation' (Stewart et al., 1970). The Ord-Victoria Area, as defined by Stewart et al. (1970), extends from longitude 127°30'E to 132°E and from latitude 13°20'S to 19°S, and is therefore slightly larger than the Victoria-Bonaparte bioregion, incorporating portions of the adjacent Ord-Victoria Plains bioregion. Although relatively old, the Land System categorisation of Stewart et al. (1970) is still used at present as the primary classification of landforms in the region, and has been updated only in areas such as the Ord Irrigation Area, where detailed soil mapping has been undertaken.

A series of Western Australian Rangeland Monitoring System (WARMS) sites from ten of these Land Systems within the East Kimberley are compared with sites from the Riverside and M2 Development Areas in Section 2. These Land Systems consist of several (generally 3 to 6), smaller scale, Land Units. The similarity of the Land Units in which the WARMS sites are located in comparison to Land Units of the Ivanhoe Land System, within which the M2 Development Area lies, are also discussed in Section 2.

The great majority of the M2 Development Area, and the Ord Stage II Area in general, lies within the Ivanhoe Land System of Stewart et al. (1970), hence it is the primary Land System of interest. The major portion of this Land System represents those areas of cracking clay that are considered suitable for irrigated agriculture. The M2 Development Area is surrounded by upland areas of other Land Systems, notably the Cockatoo, Weaber, Pinkerton and Dinnabung Land Systems, that are unsuitable for irrigated agriculture.

Within the Ord-Victoria Area, only a few Land Systems include substantial areas of cracking clays. In addition to the Ivanhoe System, these areas include the Inverway, Wave Hill, Argyle, Hawk, Willeroo, Dillinya and Legune Land Systems. The Ivanhoe Land System, as well as incorporating the major portion of the Ord Stage II Area, includes areas along the Dunham River to the south of the M2 Development Area, a relatively large area in the Victoria River and West Baines River area of the Northern Territory, and scattered locations to the south-east of the M2 Development Area in the vicinity of the WA/NT border, and another series of scattered locations in the western NT.

Ivanhoe Land System areas are therefore widely spread throughout the region, and the underlying geology and climatic conditions of these areas shows some variation, hence we may expect variation in the vegetation and fauna of these areas. It is interesting to note also, that since these areas generally have high stock carrying capacity, they are in the main utilised by pastoralists, and few areas are protected in

reserves. Section 3 of this review examines the composition of the vegetation of the M2 Development Area with vegetation from areas within the Ivanhoe Land System in the Northern Territory on Auvergne and Spirit Hills stations. The information from these areas, collected during a survey by personnel from the PWCNT, pertains to the largest portions of the Ivanhoe Land System within the Northern Territory.

At a finer scale the M2 Development Area and Riverside Areas of the Ord Basin are compared in Section 4. The Ord Basin comprises one of the two main geological formations of the north-east Kimberley, the Ord River originating upstream of the Bungle Bungle Ranges and passing through the Ord Valley, where it is joined by the Dunham River. Aldrick and Moody (1977) have suggested that, possibly in the Tertiary period, the Ord River passed through the Keep River and Weaber Plains, having only relatively recently fallen into its present course. As a result, the M2 Development Area and Riverside Areas are thought to have had relatively similar geological histories, although within different time frames. The underlying geology of the two areas is similar, with both areas incorporating Cainozoic 'black soil', however a greater proportion of the Riverside Area consists of Quaternary alluvium deposited by the (current) Ord River (Geological Survey of WA, 1970).

Within the M2 Development Area, the vegetation of the Keep, Weaber and Knox plains is compared, and the distinctiveness of these areas is assessed (Section 5). The plains of the M2 Development Area occupy different portions of a contiguous drainage system, including the lower reaches of the Keep River (Keep River Plain), an area between Knox Creek, a tributary of the Keep, and the middle portion of the Keep River (Knox Creek Plain), and an area with a seasonally inundated relatively undifferentiated drainage system that lies to the west and slightly upland of the Keep River (Weaber Plain). These areas are, therefore, relatively similar, and lie in close proximity to one another, and the boundaries between them are somewhat arbitrary.

1.1.2 Data Sets

Comparison of data from ecologia (1997a) has been made in the first instance with WARMS data obtained from Natural Resource Management Services, Agriculture Western Australia. Due to the sensitivity of the data, it has been supplied without station or site identifiers. The data relates to WARMS sites in the East Kimberley, and includes Land System and Land Unit information for each site in addition to a species list. This data set applies to cracking clay country on pastoral stations, generally pertaining to grasslands. Additional information supplied includes a map and accompanying list of the sites within three regions from north to south, and the WARMS for Grasslands field manual (Strutt et al., 1995) which details the methodology used.

The second data set examined as part of the review process is detailed in Brocklehurst et al. (1998), 'Reconnaissance Land Resource Survey of Auvergne Station and Sections of Spirit Hills Station, Northern Territory'. This survey was undertaken in 1998, and involved personnel from the PWCNT and the Department of Lands, Planning and Environment (DLPE). A copy of the document, stamped DRAFT, was obtained from Wesfarmers Limited. Information from this document is reviewed, and relevant data examined in Section 3.

The data sets from survey areas in the Ord Stage II Area are detailed in Appendix B of ecologia (1997a). Presence absence data were used in all cases where comparisons were made, since this serves to minimise the effects of between-survey differences in methodology. Site descriptions, including vegetation structure and dominance information, are given in Appendix C of ecologia (1997a). Several assumptions have necessarily been made in these analyses between surveys, the primary one being that species identifications are accurate and comparable. In the case of comparisons within the Ord Stage II Area, consistency has

been maintained since taxonomy is based on Wheeler et al. (1992), and identification of plant material was undertaken by ecologia staff. Comparisons with WARMS data should also be valid, since they also used Wheeler et al. (1992). It is less certain if the Auvergne data is comparable, since it is not clear from their report what nomenclature was used. In an attempt to standardise the various data sets, species lists were examined for nomenclature, species without a specific name were removed where they were present at only one or two sites, and subspecies and varieties were amalgamated into single full species. More detailed descriptions of the data sets, assumptions made, and limitations of the data are given in the following sections.

2.0 WARMS SITE DATA

2.1 INTRODUCTION

A comparison of plant data from Rangeland monitoring sites spread throughout the East Kimberley has been undertaken along with a further comparison with selected sites from the M2 Development Area. The details of these analyses and their findings are the subject of this section.

2.2 WARMS METHODOLOGY

Agriculture Western Australia (AGWest) have established and initiated surveys of a series of Western Australian Rangeland Monitoring System (WARMS) sites in the East Kimberley. A portion of the data relating to the vegetation of WARMS Grassland sites from Land Systems and Land Units (based on Stewart et al., 1970) similar to black soil plain areas has been made available to ecologia Environmental Consultants for independent analysis. All sites are on cracking clay soils in areas north of Halls Creek.

The methodology for surveying WARMS Grassland sites is detailed in Strutt et al. (1995), and will only be summarised here. WARMS sites are aimed at long-term monitoring of rangeland condition and have been established on pastoral leases, in paddocks, ideally near the centre of a relatively large area of a given vegetation type. Sites are marked out and a photo taken from a fixed location. Frequency of perennial species within 100 quadrats (70 cm x 70 cm) are assessed. Quadrat placements are at 2.5 metre intervals along five parallel transects, spaced 6.5 metres apart. Species are recorded as present within a given quadrat, and the frequency score is simply the number of quadrats in which a given species is present. Tree and Shrub crown cover is assessed at six locations along the transect, and is based on the Bitterlich Gauge % crown cover estimate, as described in Strutt et al. (1995).

Sites were surveyed during the dry season, and are located throughout the East Kimberley, from Carlton Hill station in the north to Gordon Downs in the south. The data supplied by AGWest also included Land System and Land Unit information, but due to the 'sensitivity' of the data, it has been coded so that individual sites can not be identified. Species nomenclature used by AGWest follows Wheeler et al. (1992), and longevity information has also been obtained from this source.

2.2.1 Data

Rangeland monitoring data supplied by AGWest is from 37 WARMS sites located within ten of the Land Systems identified for the Ord-Victoria area by Stewart et al. (1970):

Land System	No. of sites
Antrim	5
Argyle	3
Cowendyne	1
Frayne	3
Gordon	1
Inverway	15
Ivanhoe	1
Pinkerton	1
Wave Hill	6
Willeroo	1

These Land Systems include areas described as anything from hilly or rugged stony country to nearly treeless black soil plains, however, only WARMS sites located on land units described as having gentle slopes or on plains have been included in the data set (Table 1). The soils of these areas, as described by Stewart et al. (1970), are predominantly grey and brown cracking clays of the Kununurra, Argyle and Barkly soil families.

Table 1: Land System and Land Unit Information for WARMS monitoring sites.

Descriptions from Lands of the Ord-Victoria Area, WA and NT (CSIRO Land Research Series No. 28)

SITE CODE	LANDSYSTEM (Number) Description	LAND UNIT	LAND UNIT DESCRIPTION	SOILS AND VEGETATION
WARMS 01 - 05	**Antrim (10)**	4	Gentle lower slopes and flat ar	Cununurra, Argyle, Barkly-grey and brown cracking heavy clays
	Hilly country associated with igneous rocks			Mitchell and other mid-height grasses *Astrebla*
				pectinata, Aristida latifolia.
WARMS 06 - 08	**Argyle (43)**	1	Very gentle slopes	Argyle, Cununurra - brown and grey cracking clays.
	Medium & small areas of gently undulating			Mitchell and other mid-height grasses *Astrebla pectinata,*
	black soil plain			*Aristida latifolia.*
WARMS 09	**Cowendyne (-)**	2	cracking clay plains	Not listed
WARMS 10, 12	**Frayne (35)**	3	Gentle slopes	Cununurra and Barkly - grey & brown cracking heavy clays
WARMS 11	Many small patches scattered	3	plain close to channel	Sparse low woodland *Terminalia arostrata, T. volucris* or trees
	undulating to low hilly basalt country			absent *Dichanthium* spp., *Astrebla squarrosa,* or mid-height
				grasses *A. pectinata, D. fecundum, Panicum* spp., *Aristida latifolia.*
WARMS 13	**Gordon (38)**	3	Gentle lower slopes	Cununurra, Barkly, Argyle - grey and brown cracking clays
	Low hilly to undulating limestone country			Barley Mitchell mid-height grass *Astrebla pectinata*
WARMS 14 - 28	**Inverway (41)**	1	Nearly flat broad plains	Cununurra - grey cracking clays; and Argyle - brown ccs
	Nearly treeless high-level black soil plains			Barley Mitchell mid-height grass *Astrebla pectinata*
WARMS 29	**Ivanhoe (47)**	1	Nearly flat plains	Cununurra-grey ccs with small areas of Argyle-brown ccs
	Gently sloping alluvial black soil			Grasses *Dichanthium* spp., *Astrebla squarrosa, Sorghum*
	plains with some timbered red soil			*stipoideum, Ophiuros exaltatus, Aristida latifolia,* with
				fringing forest and tall grasses near stream lines.
WARMS 30	**Pinkerton (1)**	7	Gentle slopes adjacent to	Elliott and miscellaneous alluvial soils
	Rugged stony country on sedimentary r		streamlines	Euc. woodland with *Themeda australis, Sehima nervosum,*
				Chrysopogon fallax, or *Sorghum stipoideum.*
WARMS 31, 33-3	**Wave Hill (42)**	3	Moderate to gentle slopes,	Cununurra, Barkly, Argyle - grey and brown cracking clays
WARMS 32	Gently undulating basalt blacl	3	may be stoney	Mitchell and other mid-height grasses *Astrebla pectinata,*
	soil country			*Dichanthium fecundum, Panicum* spp.
WARMS 37	**Willeroo (45)**	3	Moderate to gentle slopes	Cununurra and Argyle - grey & brown cracking clays
	Numerous small areas of basalt black			Blue grass tall grass *Dichanthium* spp., *Sorghum* spp.,
	soil plains with tall pastures			*Eulalia fulva, Ophiuros exaltatus.*

Data supplied by AGWest includes a list of perennial species and significant semi-perennials and annuals. Species lists for individual sites are relatively short, with from six to 23 species, and most sites having between nine and 13 species recorded, including usually multiple species of (perennial) grass, a few shrubs, and one or two tree species. The low number of species recorded is presumably a reflection of the nature of the sites (i.e. grasslands) and the timing of the surveys in the dry season when perennial species are often the only (identifiable) plant species present. These surveys are relevant in the context of rangeland monitoring, since tropical pastures consist chiefly of summer-growing perennial grasses, and stocking rate is determined by the carrying capacity in the dry season (Bryan, 1970). However, it does not provide a full floristic assessment of the plant species present (particularly annuals), since a large number of flora species occur only during the wet season.

2.2.2 Analysis

Analysis of the relationships between WARMS survey sites was conducted using the cluster analysis component of the computer program Systat. Systat is a statistical analysis software package that performs cluster analysis operations to produce a quantitative index of dissimilarity for each site relative to every other site, ultimately constructing a hierarchical ordering of sites in the form of a dendrogram that shows the relative similarities between sites. The analysis detects natural groupings of data and summarises the hierarchical relationships within the dataset by quantifying the degree of similarity of sites in terms of species composition.

Species presence/absence data were used in the cluster analyses of the WARMS sites (Appendix A1). Frequency data obtained from AGWest was converted to presence absence data and cluster analysis was performed on this data for the complete species list. A second analysis of the presence absence data was undertaken concentrating on unequivocal (adequately identified) and purely perennial species, thus reducing the size of the dataset. Dendrograms were constructed using the Pearson correlation complete linkage method (Wilkinson, 1989).

2.3 RESULTS OF ANALYSES

Analysis of the complete dataset and the refined presence absence data resulted in dendrograms illustrating the relationship of the WARMS sites (Figures 1 and 2). In both instances the broad relationships and clustering of sites within the hierarchy are similar, hence the two datasets will be discussed together.

The first and most obvious feature of the hierarchy is the clear separation of Site W29 from the remainder of the sites. Although Site W29 is located at the base of the dendrogram in the refined dataset (Figure 1) and at the apex in the complete dataset (Figure 2), the relationship with all other sites is identical. This site is from the Ivanhoe Land System, and is clearly distinct from all other WARMS sites in the analysis, indicating that the composition of the vegetation at this site is noticeably at variance with the other sites.

Further relationships evident within the dendrogram include the broad clustering of the Inverway sites. In the complete dataset these sites form a distinct subset of the data, intermixed with several Wave Hill sites, with Site W28 the only site separated from the main cluster. A similar, although slightly less clear-cut relationship is evident in the dendrogram based on the refined dataset.

The three Argyle sites are also very closely clustered in the two dendrograms, indicating close similarity between these sites. The single site from the Gordon Land System, Site W13, is also associated with these Argyle sites.

Finally, the single Cowendyne site clusters with the Antrim sites W2 and W9, although this relationship is more clearly demarcated in the refined dataset analysis (Figure 1).

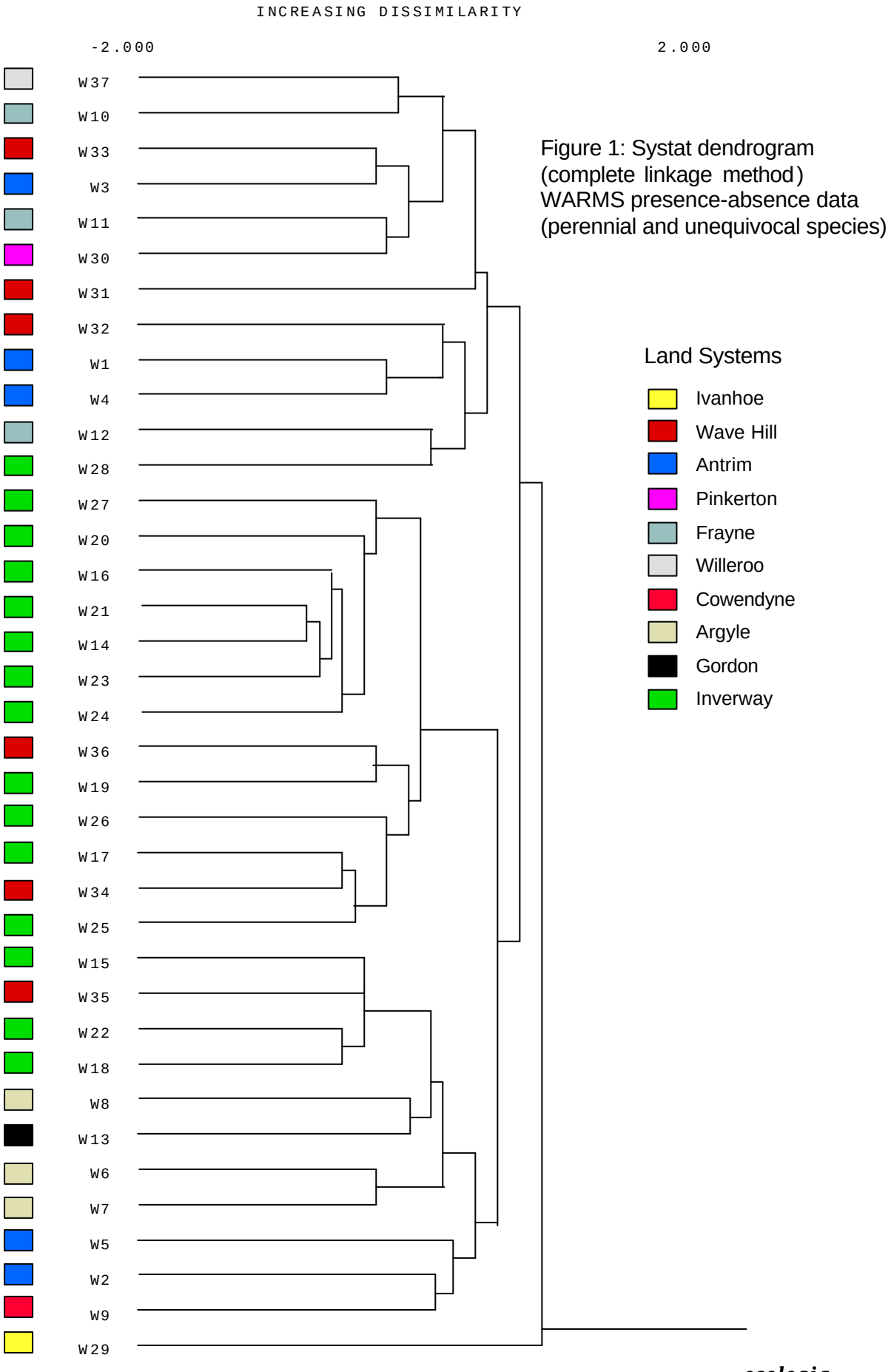


Figure 1: Systat dendrogram (complete linkage method) WARMS presence-absence data (perennial and unequivocal species)

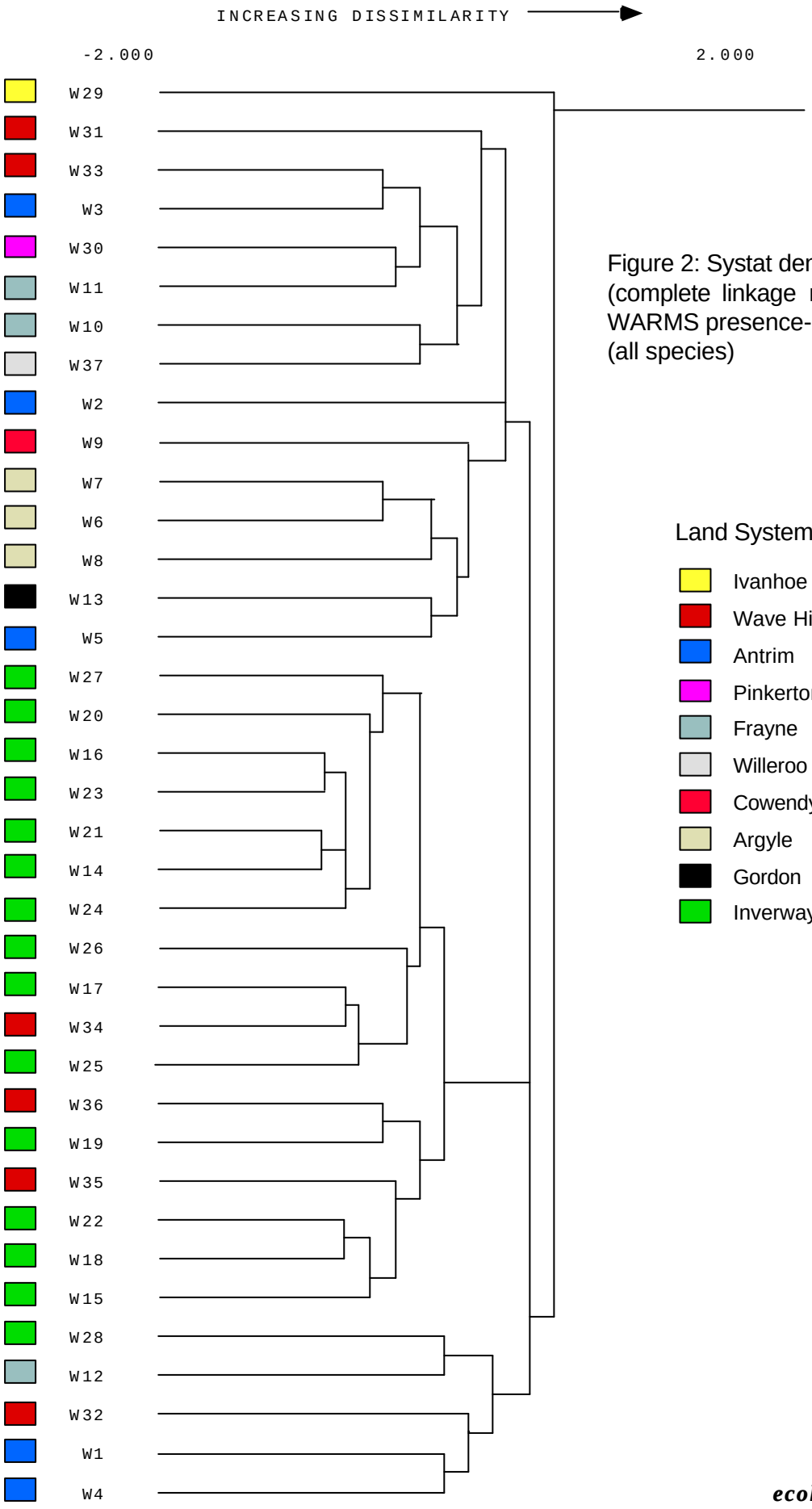


Figure 2: Systat dendrogram (complete linkage method) WARMS presence-absence data (all species)

Land Systems

- Ivanhoe
- Wave Hill
- Antrim
- Pinkerton
- Frayne
- Willeroo
- Cowendyne
- Argyle
- Gordon
- Inverway

2.4 DISCUSSION

The clear separation of the Ivanhoe site from all other sites in the analysis suggests that the black soil plain areas of this Land System are significantly different in floristic composition from the other areas examined as part of this analysis. Examination of the raw data indicates that certain species that were widespread throughout the majority of WARMS sites were not recorded from the Ivanhoe site, including the grasses Aristida latifolia, Chrysopogon fallax, Iseilema vaginiflorum and Panicum decompositum, and several species of Mitchell Grass Astrebla spp. Of these species, only Iseilema vaginiflorum is considered to be an annual (Wheeler et al., 1992).

It is unfortunate that the Ivanhoe data is restricted to a single site, since this suggests the possibility that the clear separation of this site from all others is due to a chance effect or an anomaly in the data, despite the consistent methodology employed by AGWest in the acquisition of the data. It seems evident, however, that the overall analysis is quite robust, since the general relationships of the sites, and their separation according to Land System as outlined above, suggests that the data is adequate. Additionally, other Land Systems represented by single sites were not clearly separated in the analysis, indicating that the Ivanhoe site is indeed unique.

Use of presence absence data may in some instances weaken the ability of the cluster analysis to clearly determine the relationship of sites, since it represents a loss of information and an imposed uniformity on the data. However, in this instance the Ivanhoe site is clearly separated from the other sites, hence further indicating the real nature of these apparently strong differences in species composition.

2.5 COMPARISON OF WARMS SITES AND ECOLOGIA SITES

A further comparison was made using Systat cluster analysis techniques to examine the relationship between the floristic composition of the 37 WARMS sites, and a series of similar sites surveyed during the biological assessment of the proposed Ord Stage II development area undertaken by ecologia Environmental Consultants.

Biological assessment survey sites selected for the analysis were Grassland communities on black soil plain areas within the Keep, Knox, Weaber, Carlton and Ivanhoe West Bank areas of the proposed development. A total of 15 sites were selected, and only dry season data was used so as to make the data comparable. As in the previous analysis, annual species were omitted, as were those species that were not adequately identified. Taken together, it was hoped that the datasets would be relatively similar, despite differences in survey technique. To further simplify matters, only presence absence data were used. The data from the two surveys were combined in a species by site matrix (Appendix A2) and a Systat cluster analysis undertaken utilising the complete linkage (farthest neighbour) method.

2.5.1 Results

The dendrogram generated from the analysis showed a relatively clear separation of the ecologia sites from the WARMS sites (Figure 3). This initial impression gained from examination of the dendrogram suggests that the ecologia sites are different from the WARMS sites, therefore seeming to indicate either a real difference in the vegetation or an artefact generated from the survey techniques employed.

However, a more detailed examination of Figure 3 reveals that, in fact, the first level of separation divides several of the ecologia sites from the remainder of the sites, including the WARMS sites. This suggests that the data resulting from the two different surveys are comparable, since there is considerable integration of

the sites within the framework of the dendrogram. The single ecologia site CP47 is also found to be amongst the WARMS sites, further indicating that integration of the two datasets is valid. Site CP47 is on a cracking clay soil plain at the eastern end of Carlton Plain, and relatively few species were recorded from this site. In common with many of the WARMS sites, Aristida latifolia, Chrysopogon fallax, Dichanthium fecundum, D. sericeum and Panicum decompositum were recorded at this site.
It is interesting to note, therefore, that WARMS Site W29, the site on the Ivanhoe Land System, is amongst the ecologia sites that are separated at the first level of the cluster diagram. This suggests that the vegetation of this area is similar to other survey sites on the Ivanhoe Land System, yet it is distinct from the great majority of the WARMS sites in other areas of the Kimberley on similar landforms and soils but within different Land Systems. Plant species recorded from several ecologia sites that were also recorded at Site W29 include Excoecaria parvifolia and Phyllanthus maderaspatensis, whereas this site lacks grasses recorded at other WARMS sites such as Aristida latifolia, Astrebla elymoides, Chrysopogon fallax and Iseilema vaginiflorum.

The second level of separation divides the majority of the ecologia sites (the exception being Site CP47) from the remaining WARMS sites. This suggests that there is a difference in floristic composition between these areas, and that the differences are consistent between survey sites. In particular, the species Abelmoschus ficulneus, Eragrostis tenellula, Hibiscus panduriformis, Iseilema fragile and Sida spinosa were recorded commonly at ecologia sites, but were recorded infrequently or not at all at WARMS sites.

Within the cluster of ecologia sites, it is evident also that there is some differentiation between the M2 Development Area and Riverside Areas, since the cluster of ecologia sites at the second level of separation includes M2 Development Area sites only, whereas the cluster at the first level of separation is composed of Riverside sites, with the exception of Site KR13.

2.6 CONCLUSIONS

Systat cluster analysis of WARMS site data from the East Kimberley indicate that the vegetation of the Ivanhoe Land System is distinct from other Land Systems with cracking clay plains. The primary floristic differences are in certain species of perennial grasses that were not recorded from the Ivanhoe Land System, but were recorded within many other areas. Given that the WARMS data from within the Ivanhoe Land System is restricted to a single site, it would be useful to obtain further information from sites within this Land System in order to perform a more rigorous regional analysis.

Further analysis of the WARMS sites in comparison to a series of similar grassland sites surveyed by ecologia in the Ord Stage II Area indicates that there is separation of WARMS sites from the Ord sites. This appears to be due to a real difference in vegetation, rather than an artefact due to differing methodology. An interesting finding of this analysis is that WARMS Site W29, located within the Ivanhoe Land System, clusters with the Ord Riverside sites.

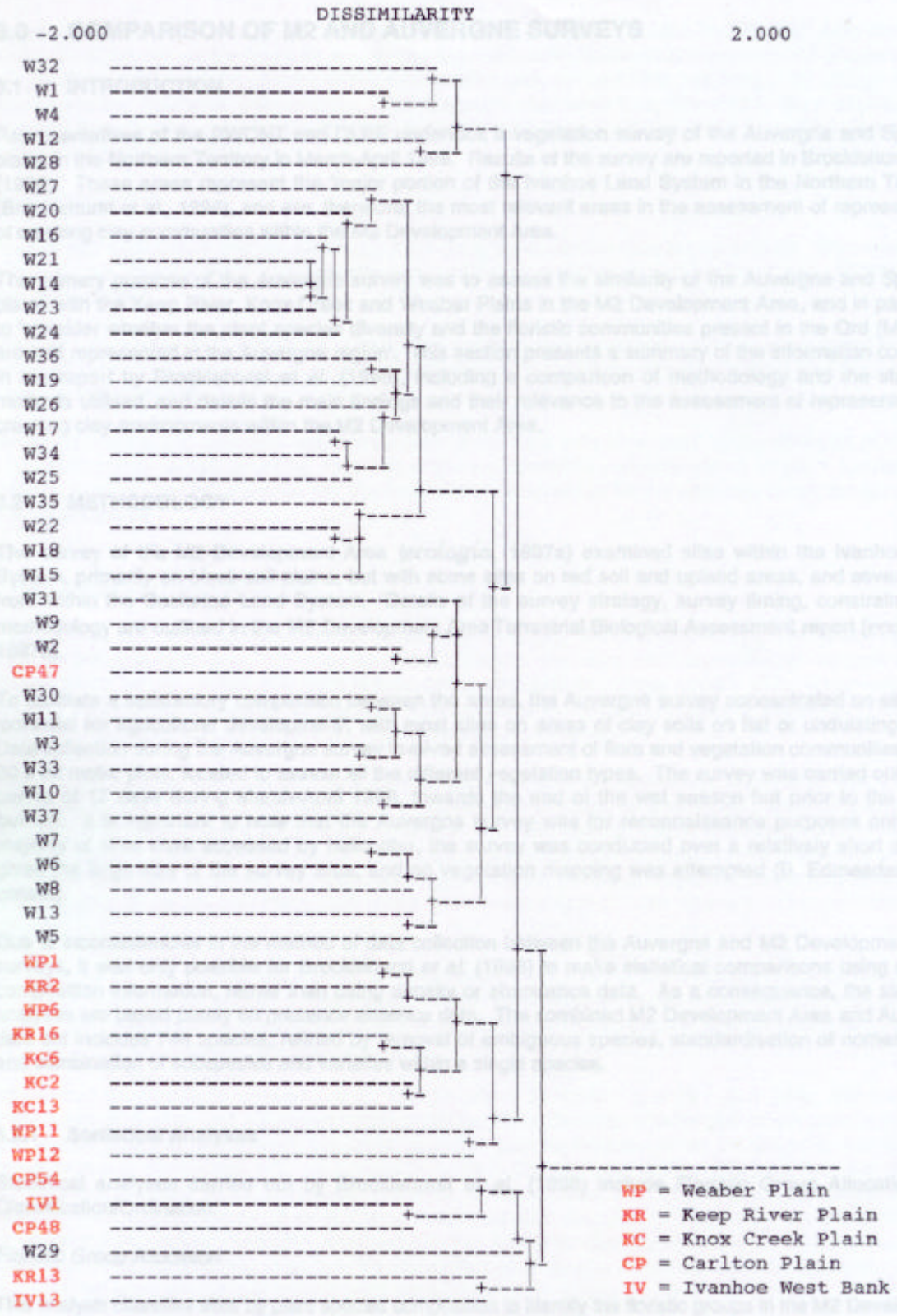


Figure 3: Systat dendrogram (complete linkage method)
WARMS Sites (plain text) and *ecologia* Ord Sites (bold)

3.0 COMPARISON OF M2 AND AUVERGNE SURVEYS

3.1 INTRODUCTION

Representatives of the PWCNT and DLPE undertook a vegetation survey of the Auvergne and Spirit Hill plains in the Northern Territory in March-April 1998. Results of the survey are reported in Brocklehurst et al. (1998). These areas represent the 'major portion of the Ivanhoe Land System in the Northern Territory' (Brocklehurst et al., 1998), and are, therefore, the most relevant areas in the assessment of representation of cracking clay communities within the M2 Development Area.

The primary purpose of the Auvergne survey was to assess the similarity of the Auvergne and Spirit Hill plains with the Keep River, Knox Creek and Weaber Plains in the M2 Development Area, and in particular, to 'consider whether the plant species diversity and the floristic communities present in the Ord (M2) area are well represented in the Auvergne region'. This section presents a summary of the information contained in the report by Brocklehurst et al. (1998), including a comparison of methodology and the statistical methods utilised, and details the main findings and their relevance to the assessment of representation of cracking clay environments within the M2 Development Area.

3.2 METHODOLOGY

The survey of the M2 Development Area (ecologia, 1997a) examined sites within the Ivanhoe Land System, primarily on black soil plains, but with some sites on red soil and upland areas, and several sites from within the Cockatoo Land System. Details of the survey strategy, survey timing, constraints, and methodology are outlined in the M2 Development Area Terrestrial Biological Assessment report (ecologia, 1997a).

To facilitate a satisfactory comparison between the areas, the Auvergne survey concentrated on sites with 'potential for agricultural development', with most sites on areas of clay soils on flat or undulating plains. Data collection during the Auvergne survey involved assessment of flora and vegetation communities at 226 20 x 20 metre plots, located to assess all the different vegetation types. The survey was carried out over a period of 17 days during March-April 1998, towards the end of the wet season but prior to the annual burnoff. It is important to note that the Auvergne survey was for reconnaissance purposes only. The majority of sites were accessed by helicopter, the survey was conducted over a relatively short duration given the large size of the survey area, and no vegetation mapping was attempted (B. Edmeades, pers. comm.).

Due to inconsistencies in the method of data collection between the Auvergne and M2 Development Area surveys, it was only possible for Brocklehurst et al. (1998) to make statistical comparisons using species composition information, rather than using density or abundance data. As a consequence, the statistical analyses are based purely on presence absence data. The combined M2 Development Area and Auvergne data set includes 744 species, refined by removal of ambiguous species, standardisation of nomenclature and combination of subspecies and varieties within a single species.

3.2.1 Statistical Analyses

Statistical analyses carried out by Brocklehurst et al. (1998) include Floristic Group Allocation and Classification/Ordination:

Floristic Group Allocation

This analysis classifies sites by plant species composition to identify the floristic groups in the M2 Development Area, using the 'Czeckanowski similarity measure and the non-hierarchical clustering routine ALOC'. Sites from the Auvergne survey are then tested to determine if they can be validly allocated to one of these groups, or if they should join an additional group, by allocating sites to groups according to their 'distance' from the group centroid, controlled by the 'allocation radius'. The analysis of the M2 Development Area data was carried out at two levels, the first with a relatively large allocation radius (0.95) resulting in 6 groups or 'broad vegetation types', and the second with a smaller allocation radius (0.85), resulting in 17 groups or 'more homogeneous vegetation communities'. The Auvergne sites were then allocated to the previously defined groups from the two levels of classification, or were placed in an additional group if the distance was greater than the allocation radius.

Classification/Ordination

Classification with multivariate analysis was carried out using the combined data set for all sites. Sites were classified using the 'Czeckanowski similarity measure and the hierarchical agglomerative routine UPGMA'. 14 groups were defined.

Ordination was also used to examine the relationship between the combined series of sites, using the 'Czeckanowski similarity measure and multidimensional scaling'. A four dimensional ordination was required to obtain an acceptable stress level.

The primary limitations and concerns with comparison of the data sets expressed by Brocklehurst et al. (1998) are differences in the sampling methods employed, possible inconsistencies in plant species identifications between the two surveys, and the (necessary) requirement for the analyses to rely solely on presence absence data.

3.3 RESULTS AND COMPARISONS

A total of 512 flora taxa were collected during the Auvergne survey. Brocklehurst et al. (1998) divide the vegetation of the Auvergne area into a series of associations, including 15 Grassland and Sedgeland associations, and a variety of open woodland to open forest associations (canopy cover > 2%). These latter associations include areas dominated by (number of associations in brackets) Acacia (2), Eucalyptus (17), Excoecaria (2), Lysiphyllum (2), Melaleuca (7), Terminalia (5) and 'other' (2).

The overlap in the species lists from the two survey areas is low, and Brocklehurst et al. consider that it is 'lower than expected considering the geographic proximity and similarity in land types'. Only 35% (264 species) of taxa were recorded from both survey areas, with 286 species (38%) recorded from the M2 Development Area only, and 194 species (26%) restricted to the Auvergne survey. Broad similarities are evident in the data, for example many of the more common families, genera and species are common to the two areas, however, there are also many differences, most noticeably in species diversity and composition (Table 2).

Possible reasons for the greater number of species recorded in the M2 Development Area (682) as opposed to the Auvergne survey (512) may relate to either methodology, survey timing and effort, or are attributable to real differences in floristic diversity. Consideration of these reasons, and an examination of their influence on floristic diversity, are given below.

The methodology adopted by Brocklehurst et al. (1998) involved the utilisation of 20 x 20 m plots, and a full floristic assessment of sites was attempted where possible. The generally smaller size of the plots in the Auvergne survey may partially explain the lower recorded species richness when compared to the M2 Development Area, in comparison with the general focus on collection in the M2 Development Area survey and less restriction to clearly demarcated plots. However, as Brocklehurst et al. (1998) point out, it does not adequately explain the discrepancy, given the 'large number of sites surveyed and the aim to sample all the variation within the vegetation' during the Auvergne survey. A greater diversity of land types within the M2 Development Area would also help to explain the higher recorded species richness, however, the reality of the situation is that a greater number of land types were investigated during the Auvergne survey.

Table 2: Comparison between the M2 Development Area and Auvergne botanical surveys.

	M2 Development Area	Auvergne
Number of survey sites	86 in dry 45 in wet	226 in late wet
Number of flora taxa	682 overall 418 in dry	512 overall
Number of families recorded	87	82
Number of genera recorded	276	244
Families with most taxa: (Number of taxa in brackets)	Poaceae (133) Fabaceae (63) Cyperaceae (44) Myrtaceae (30) Convolvulaceae (28)	Poaceae (100) Fabaceae (47) Cyperaceae (56) Myrtaceae (27) Mimosaceae (22)
Genera with most taxa: (Number of taxa in brackets)	*Fimbristylis* (18) Cyperus (15) Acacia (14) Ipomoea (12) Eucalyptus (11) Goodenia (11)	*Fimbristylis* (23) Acacia (15) Eucalyptus (14) Goodenia (12) Cyperus (10) Terminalia (9)
Most widely distributed species:	*Lysiphyllum cunninghamii* *Chrysopogon fallax* *Themeda triandra* *Eucalyptus microtheca* *Iseilema fragile* *Panicum decompositum*	*Sorghum bulbosum* *Chrysopogon fallax* *Lysiphyllum cunninghamii* *Eriachne obtusa* *Sehima nervosa*

Survey timing will partially determine the number of species recorded, since there are many annual and facultative perennial species in the Kimberley that are either absent or extremely difficult to identify during the dry season, particularly in the latter stages of the dry when the land becomes parched. The M2 Development Area survey included both a dry season and a wet season survey. Although the wet season survey was limited in duration, the focus on collection and the large number of annual species present facilitated detailed assessment of many of the vegetation communities. The Auvergne survey was conducted towards the end of the wet season, before the annual burnoff, hence it would be expected that the majority of species would be present and suitable for collection and identification, and in fact the

majority of sites were visited 'as they were drying out' (A. Fisher, pers. comm.). Survey timing and effort, therefore, may also partially explain the differences in species richness, since a greater period of time was spent in the M2 Development Area. However, a similar suite of species, including annuals present only during the wet season, were recorded during both surveys, suggesting that other factors are involved. Additionally, the majority of the M2 Development Area survey effort was expended during the dry season.

The final conclusion that seems unavoidable, after investigation of the various factors that contribute to recorded species richness, is that the greater number of species recorded in the M2 Development Area is founded upon a real effect. A possible reason is that the differences may relate to greater landform diversity in the M2 Development Area, although from the information available this possibility is not substantiated. This suggests, therefore, that hydrological (drainage, inundation effects) or edaphic (soil-related) factors are likely to be the major determinants at a local scale. At a regional scale, the pronounced effect of the rainfall gradient from north to south on the vegetation composition in the Ord-Victoria region described by Perry (1970), may be important. Regardless of the origins of the high plant species diversity in the M2 Development Area, the value of this biological diversity should be taken into account in the planning of future developments.

3.3.1 Results Of Statistical Analyses

Floristic Group Allocation

6-Group level

The majority of Auvergne sites could be allocated to one of the six groups ('broad vegetation types') derived from the M2 Development Area data, with only 17 Auvergne sites (7.5%) not allocated. Most M2 Development Area sites were classified into Group 5, representing sites generally of grassland on cracking clay, and consisting predominantly of dry season sites (Table 3). A relatively large number of Auvergne sites were allocated to Group 5, however, many Auvergne sites were also allocated to Group 2, which may reflect the greater variety of land units surveyed and fewer cracking clay sites in the Auvergne survey area (Brocklehurst et al., 1998).

Table 3: Summary of 6-group level allocation.

Group	No. of M2 sites	No. of Auv. sites*	Landform and Soils	Vegetation	Comments
1	28	9	cracking clays	Characterised by sedges and herbs in understorey.	Mostly wet season sites, many annuals
2	25	79	red-browns; hills; Cc LS peripheral	Frequently Heteropogon contortus, Cayratia trifolia, Eucalyptus confertiflora, Grewia retusifolia.	Many Auv. sites. Reflects more non cracking clay sites
3	3	2	rivers, creeks; inundated; saline	Xerochloa, Trianthema, Sesbania cannabina, Panicum decompositum. Avicennia, Halosarcia, etc.	Few sites. Many halophytes.
4	8	11	red-browns; Cc LS; peripheral	Unique species include Acacia hemiglauca, Drosera ordensis, Senna artemisioides	Marginal land units
5	56	87	cracking clays; other	Frequently Chrysopogon fallax, Lysiphyllum cunninghamii, P. decompositum, Aristida latifolia, Themeda, Sida, Sorghum, Ophiuros	Most M2 sites Mostly dry season Most Auv. sites

6	10	19	creek & wetland margins	Frequently Excoecaria parvifolia and Eucalyptus microtheca	Mainly creeks and waterholes
n =	130	224			

* Auvergne sites allocated to M2-derived groups, with 17 Auvergne sites allocated to 4 additional groups.
KEY: No. = Number; Auv. = Auvergne; Cc LS = Cockatoo Land System

Brocklehurst et al. (1998) have made several comments concerning the information summarised in Table 3, the most relevant being that they feel that Group 1, given that it consists primarily of M2 Development Area wet season sites, is presumably the wet season equivalent of Group 5, but the large number of annual species collected during the wet season has sufficiently biased the data so that the sites fall out in separate groups. In some cases, there may be identical sites surveyed during both the dry and wet season that have been classified in this analysis into Group 5 and Group 1.

Group 3 consists of very few sites, both for the M2 area and Auvergne, and includes inundated areas and saline sites, supporting halophytic species such as Saltbush Halosarcia sp. and mangroves Avicennia spp. Group 6 primarily includes wetland and riverine sites and their margins, including species characteristic of seasonally inundated sites such as Gutta-Percha Tree Excoecaria parvifolia and Flooded Box Eucalyptus microtheca.

17-Group level

At the 17 group level, due to the more homogeneous nature of the groups and the smaller allocation radius, the allocation of Auvergne sites was less successful, with 85 sites (38 %) allocated to additional groups. In particular, no Auvergne sites were allocated to Groups 2, 3, 4 and 7, and Groups 5 and 8 had only a single Auvergne site allocated. Characteristics of the groups with no or few sites allocated are detailed below (Table 4).

Table 4: Characteristics of Groups with poor allocation of Auvergne sites.

Group	Characteristics
2	On scattered rocky hills or outcrops. Similar communities in the Auvergne area may not have been sampled.
3	Generally woodlands bordering rivers or waterholes, often subject to inundation. Vegetation variable, 'defined by herbs and twiners in the ground layer'.
4	Single M2 Development Area site, a mixed species woodland on red soil.
7	Single M2 Development Area wet season site with some infrequently recorded ground layer species.
5	Sites adjacent to rivers with halophytic species.
8	Sites on sandy soils adjacent to hills or on the Cockatoo Land System.

The greatest number of M2 Development Area sites were placed in Group 11 (38 sites), which consists of cracking clay sites with, characteristically, Lysiphyllum cunninghamii in the upper storey and Iseilema fragile, Chrysopogon fallax and Aristida latifolia in the ground layer. A fairly large number of Auvergne sites were

also allocated to Group 11. The second largest number of M2 Development Area sites were placed in Group 1. They are primarily wet season sites and are poorly represented by Auvergne sites.

Classification

A total of 14 groups were derived from a classification of the combined M2 Development Area and Auvergne data sets. Brocklehurst et al. (1998) noted a 'tendency for sites from the two surveys to divide into separate groups'. Three of the groups (Groups 4, 7 & 12) contain sites only from the Auvergne survey areas, and Group 10 only includes M2 Development Area sites. M2 Development Area sites also represent less than 3 % of the sites in Groups 3 and 13. Groups 8, 10 and 14 were dominated by M2 Development Area sites, with few Auvergne sites. Pertinent floristic information for these Groups is given in Table 5.

Table 5: Floristics of groups dominated by M2 Development Area sites.

Group	Frequent species	Unique species
8	*Phyllanthus maderaspatensis, Commelina ensifolia, Cyanotis axillaris, Cyperus microcephala*	*Euphorbia kimberleyensis*
10	-	*Digitaria brownii, Tricosanthes cucumerina*
14	*Chrysopogon fallax, Iseilema fragile, Panicum decompositum, Aristida latifolia, Sorghum timorense, Hibiscus panduriformis, Lysiphyllum cunninghamii, Sida spinosa, Brachyachne convergens*	-

Statistical analysis of the distribution of the sites within the group classification derived by Brocklehurst et al. (1998), using the contingency table chi-square test, suggests that there is a significant difference ($p < 0.001$, $df = 13$) in the proportion of sites within the groups. This tendency for the sites to segregate between groups within the classification suggests an intrinsic difference between the majority of sites in the two survey areas.

Ordination

Ordination of the M2 Development Area and Auvergne sites, based on the first and second axis of a four-dimensional ordination, indicates a tendency for the M2 Development Area and Auvergne sites to occupy different areas of the ordination space. There is considerable overlap between the sites, however M2 Development Area sites tend to occupy the top and left portions of the ordination space, whereas Auvergne sites are generally lower. There is a wide spread of Auvergne sites, suggesting that they 'incorporate most of the total variation in vegetation composition found in the two surveys'. The greater diversity of land types surveyed during the Auvergne survey may have contributed to this spread of sites.

3.4 CONCLUSIONS

The primary findings of the report by Brocklehurst et al. (1998) in relation to the M2 Development Area Area can be summarised as follows:

i. Plant species diversity and vegetation communities of the M2 Development Area and Auvergne areas were compared.

ii. The greater variety of vegetation communities identified during the Auvergne survey may reflect the greater variety of land types surveyed.

iii. The greater number of plant species recorded during the M2 Development Area survey, including 38% of the combined species only from the M2 Development Area, may be based upon a real effect, rather than methodology or survey timing.

iv. Broad vegetation types (6-group level) were represented in both survey areas.

v. Seven of the 17 vegetation communities from the M2 Development Area were not or poorly represented in the Auvergne survey, although six of these are associated with non-clay soils that may not have been sampled during the Auvergne survey.

vi. There are broad similarities in the vegetation of the two areas, but also evidence of real floristic differences.

vii. A limited survey in the M2 Development Area using the Auvergne methodology (or vice versa) may help to clarify the floristic relationships.

Particular reference should be made to several of these points. Firstly, the greater biodiversity in the M2 Development Area does not appear to be a direct result of differences in survey methodology or timing between the Auvergne and M2 Development Area surveys, although these may have been contributing factors. Both surveys involved collection of annual species during the wet season in addition to records of perennial grasses and woody species, and were aimed at covering the diversity of vegetation within the survey area, hence similar species richness would be expected.

Secondly, although broad vegetation types were represented in both the Auvergne and M2 Development Area survey areas, finer scale associations were not well represented. This finding indicates that more detailed information on vegetation associations is required not only for the Ord area, but also for other areas within the Victoria-Bonaparte bioregion, since the information available at present is at a very coarse scale, and is fragmentary. Further vegetation survey work within the M2 Development Area to delineate vegetation communities is vital in order to facilitate accurate mapping and detailed assessment of representation, and hence conservation values.

4.0 COMPARISON OF M2 AND RIVERSIDE DEVELOPMENT AREAS

4.1 INTRODUCTION

This section describes an analysis made of the relationship between the vegetation communities of the M2 Development Area, including the Keep River, Knox Creek and Weaber Plains, and the Riverside Development Area, incorporating the Mantinea Flats, Carlton Plain and Ivanhoe West Bank areas.

Systat cluster analysis was used to determine the relationship between the sites based on flora species presence absence data. A combined species by site table was formulated based on all the dry season survey sites, and a similar procedure was followed as in earlier analyses whereby the data set was standardised and subspecies and varieties were amalgamated into single species.

The methodology used in these surveys is described in detail in ecologia (1997a, 1997b).

4.2 RESULTS AND INTERPRETATION

The Systat dendrogram derived from the combined Ord data indicates separation of the M2 Development Area and Riverside Development Area sites at the extremes of the dendrogram, and intermingling of the sites within the middle portion (Figure 4). The top half is dominated by M2 Development Area sites and the bottom half by Riverside sites. Where there is apparent intermingling, it is also noticeable that there is clumping of sites where they are from the same area.

Looking first at the series of 26 sites at the top of the dendrogram, it is evident that a single Riverside Development Area site, CP47, is clustered with a series of M2 Development Area sites. Examination of the M2 Development Area site descriptions indicates that these sites are predominantly on black soil plains, and many of them are on areas of soil type 1, Cununurra normal phase. Other sites are on related soil types such as 1c or 1g, or are on aquitaine phase soils, types 5a and 5b. The vegetation at these sites is characterised by an overstorey of Lysiphyllum cunninghamii, often with Eucalyptus microtheca and Excoecaria parvifolia, presumably on wetter or seasonally inundated sites. The understorey frequently includes Chrysopogon fallax, other common grasses including Themeda triandra, Panicum decompositum and Aristida latifolia. These sites are generally described as open woodlands over grassland, although there are two purely Grassland sites. Site CP47, the single Riverside site, is a cracking clay plain grassland of Dichanthium fecundum, Aristida latifolia and Chrysopogon fallax. All these grass species are present at the M2 Development Area sites, and as mentioned, C. fallax is particularly common.

The next grouping consists of 18 sites which includes ten M2 Development Area and eight Riverside Development Area sites. The M2 Development Area sites are predominantly from the Weaber Plain whereas the Riverside Development Area sites are mixed. The M2 Development Area sites include a series of sites that are transitional, lying at the margin of rock outcrops or at the edge of the black soil plain. A series of soil types are represented, including 4a and 4b (cracking clays in depressions), 7b (eroded cracking clays adjacent to creeks and rivers), and 8a (soil complex at the edge of upland areas). These soils are generally in patches, or are at the periphery of the black soil plain.

The vegetation of the Riverside Development Area sites is similar to the M2 Development Area sites, common species in both areas including Lysiphyllum cunninghamii, Chrysopogon fallax, Aristida latifolia, Dichanthium fecundum, Iseilema fragile, Carissa lanceolata and Panicum decompositum. The M2 Development Area sites generally include Themeda triandra and Ophiuros exaltatus as dominant species in the grass layer, with an overstorey of Lysiphyllum cunninghamii, Corymbia bella and other species.

Dichanthium fecundum is commonly encountered in the grass layer of the Riverside sites, with the overstorey including Lysiphyllum cunninghamii and Acacia farnesiana.

The intermediate clusters are a mixture of M2 Development Area and Riverside Development Area sites, and no clear picture emerges from an examination of soil type, landforms, or dominant vegetation.

Figure 4: Systat dendrogram (complete linkage method) M2 and Riverside presence absence data
M2 sites in plain text, Riverside in red

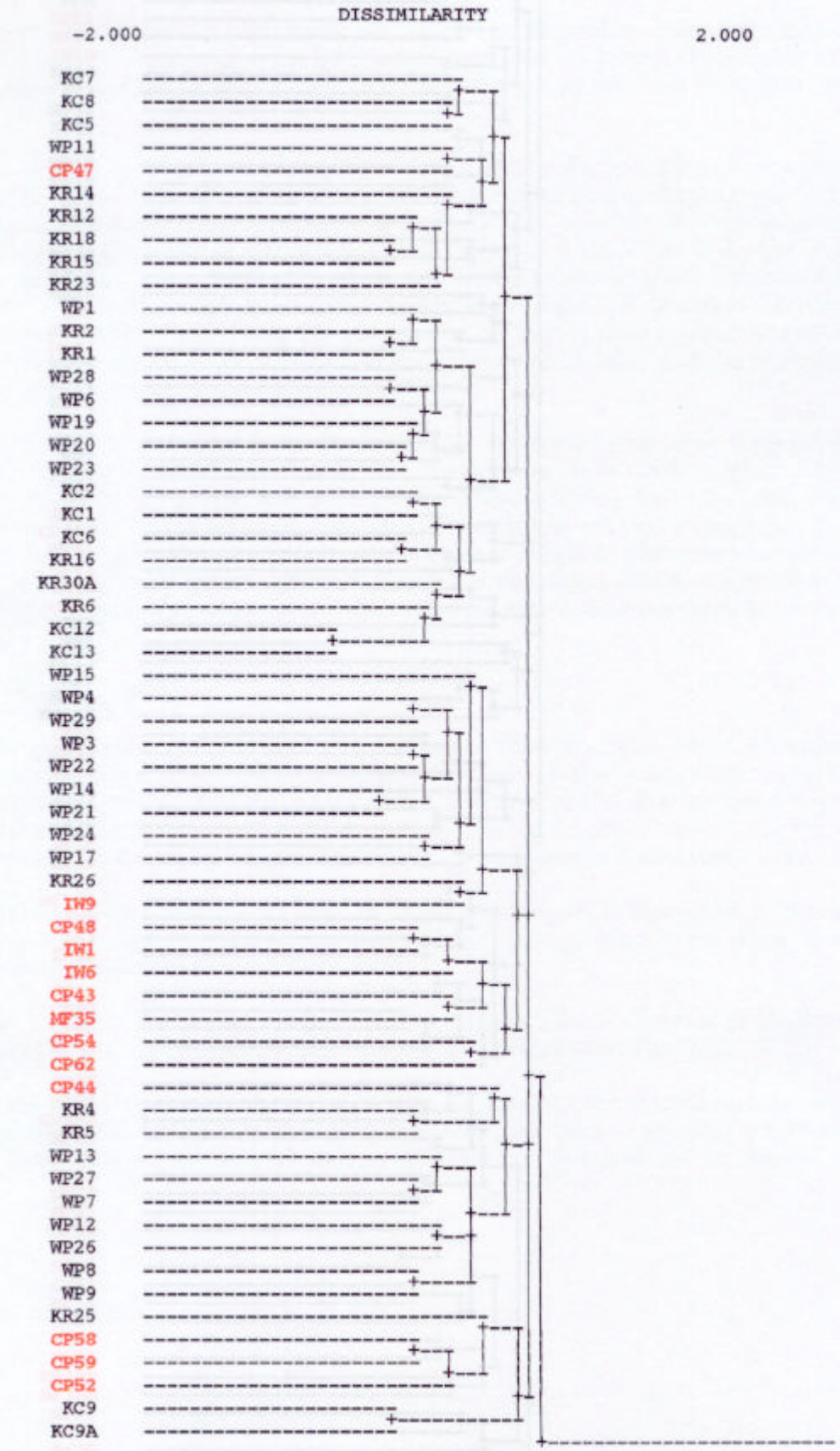
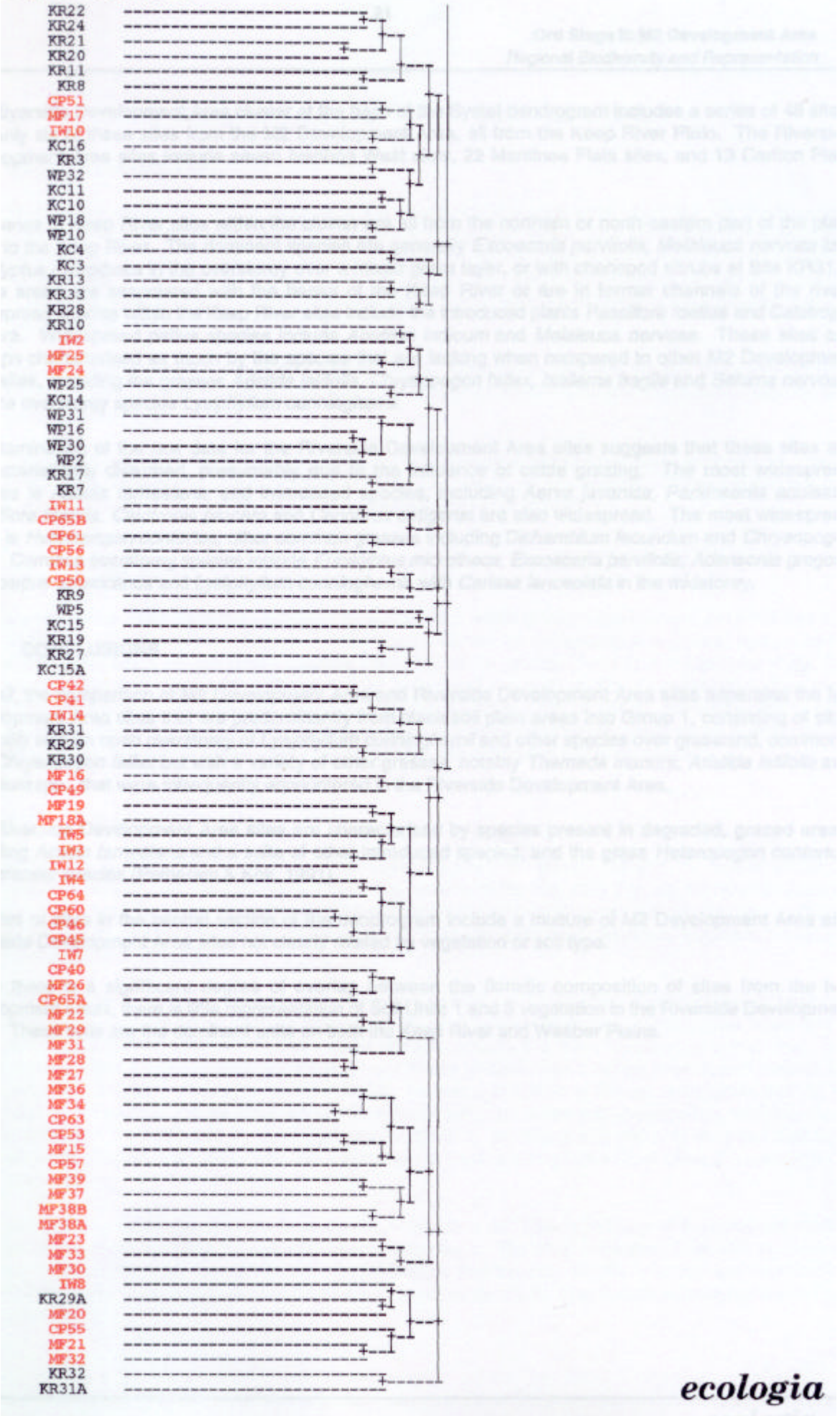


Figure 4: continued.



The Riverside Development Area cluster at the base of the Systat dendrogram includes a series of 48 sites, with only six of these sites from the M2 Development Area, all from the Keep River Plain. The Riverside Development Area sites include seven Ivanhoe West sites, 22 Mantinea Flats sites, and 13 Carlton Plain sites.

The series of Keep River sites within the cluster are all from the northern or north-eastern part of the plain close to the Keep River. The dominant species are generally Excoecaria parvifolia, Melaleuca nervosa and Eucalyptus microtheca in the overstorey over a mixed grass layer, or with chenopod shrubs at Site KR31A. These areas are associated with the banks of the Keep River or are in former channels of the river. Widespread species within the Keep River sites include the introduced plants Passiflora foetida and Calotropis procera. Widespread native species include Abutilon indicum and Melaleuca nervosa. These sites are perhaps characterised as much by the species that are lacking when compared to other M2 Development Area sites, including the grasses Aristida latifolia, Chrysopogon fallax, Iseilema fragile and Sehima nervosa, and the overstorey species Lysiphyllum cunninghamii.

An examination of the raw data for the Riverside Development Area sites suggests that these sites are characteristically disturbed, presumably due to the influence of cattle grazing. The most widespread species is Acacia farnesiana, and introduced species, including Aerva javanica, Parkinsonia aculeata, Passiflora foetida, Calotropis procera and Cenchrus setigerus are also widespread. The most widespread grass is Heteropogon contortus, other common grasses including Dichanthium fecundum and Chrysopogon fallax. Common overstorey species include Eucalyptus microtheca, Excoecaria parvifolia, Adansonia gregorii, Gyrocarpus americanus and Lysiphyllum cunninghamii, with Carissa lanceolata in the midstorey.

4.3 CONCLUSIONS

Overall, the comparison of M2 Development Area and Riverside Development Area sites separates the M2 Development Area sites that are predominantly from black soil plain areas into Group 1, consisting of sites generally with an open overstorey of Lysiphyllum cunninghamii and other species over grassland, commonly with Chrysopogon fallax but with a variety of other grasses, notably Themeda triandra, Aristida latifolia and Sorghum spp., that were infrequently encountered in the Riverside Development Area.

The Riverside Development Area sites are characterised by species present in degraded, grazed areas, including Acacia farnesiana and a suite of other introduced species, and the grass Heteropogon contortus, an increaser species (Petheram & Kok, 1991).

A series of sites in the central section of the dendrogram include a mixture of M2 Development Area and Riverside Development Area sites not clearly related by vegetation or soil type.

While there is a significant degree of overlap between the floristic composition of sites from the two development areas, there is little representation of Soil Units 1 and 5 vegetation in the Riverside Development Area. These soils are the dominant units on both the Keep River and Weaber Plains.

5.0 COMPARISONS WITHIN THE M2 DEVELOPMENT AREA

5.1 INTRODUCTION

This section describes cluster analysis of the vegetation at survey sites within the M2 Development Area, involving those on the Keep River, Knox Creek and Weaber Plains. This represents the finest scale of the analyses so far, and serves to compare the vegetation of the areas that are most likely to be impacted by the proposal. The areas are in close proximity to each other and it is therefore expected that the vegetation associations will be similar, varying with local scale factors such as soil type, surface geology and landform, and drainage.

Systat cluster analysis was used to determine the relationship between the M2 Development Area sites based on flora species presence absence data. A species by site table was formulated based on all the dry season survey sites.

The methodology used in the M2 Development Area survey is described in detail in ecologia (1997a). The preference of plant species for certain soil or substrate types as described in this section are based on information from Petheram and Kok (1991) and Wheeler et al. (1992).

5.2 RESULTS

Systat cluster analysis of the vegetation at survey sites within the M2 Development Area resulted in a broad separation into two groups (Figure 5). The first group can be designated in a general fashion as including sites on the black soil plain with cracking clay soils of the normal (Type 1) and aquitaine (Type 5) phase, cracking clays in depressions (Type 4), and associated areas of creeks, channels and other seasonally inundated areas. The second group includes those sites lying on other, generally patchy soil types, including red soils, hills of sandstone and dolomite and sites underlain by these rocks, former channels and river banks, and sandy soils. These two subgroups are discussed separately below.

5.2.1 Black Soil Plain Sites

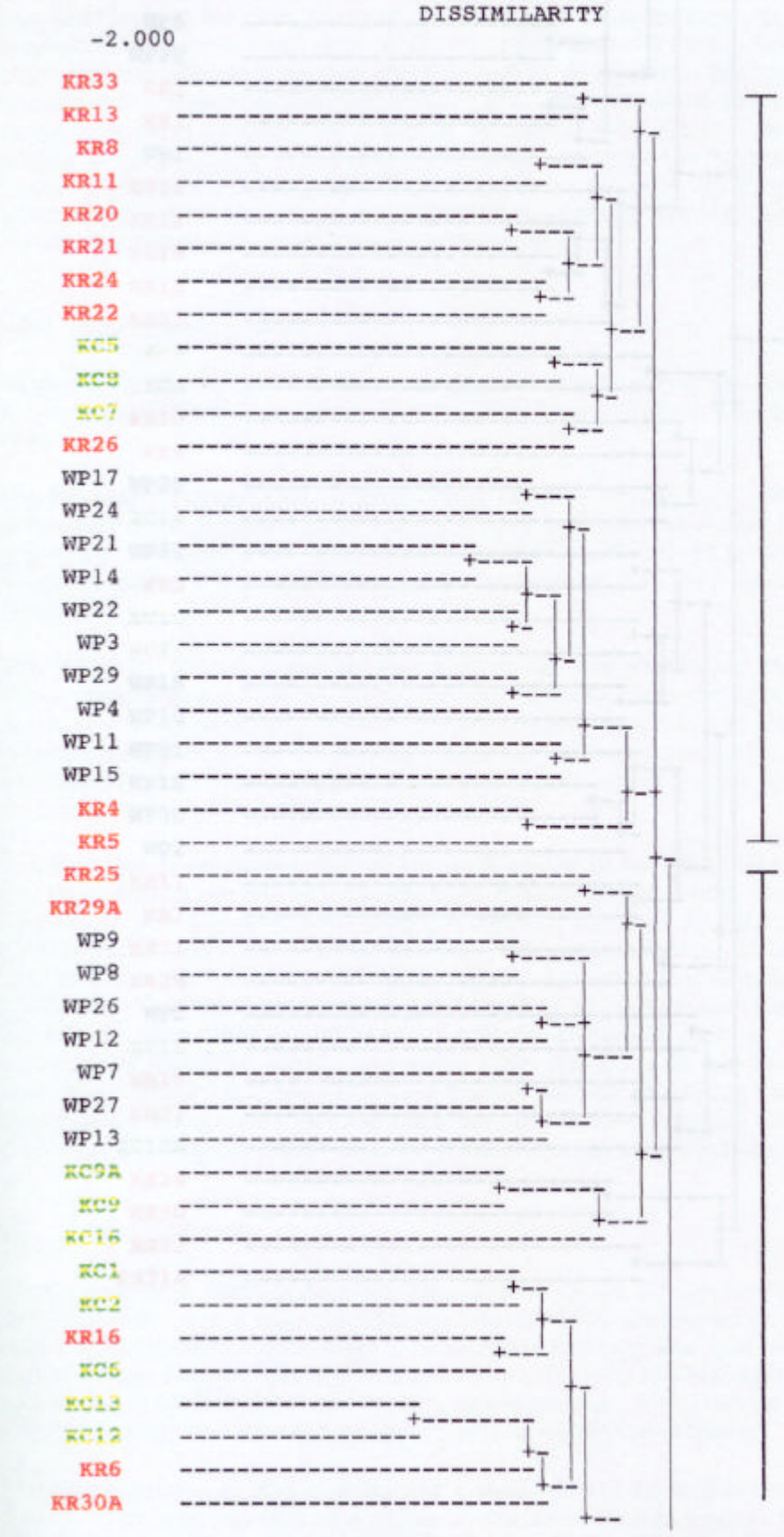
Within the cluster of black soil plain sites, there are two main groups, 1a and 1b. Within Group 1a are a series of sites on black soil plains that generally have cracking clay soils that are not normal phase cracking clays (soil type 1). The soils in these areas predominantly include soil types 4 (cracking clays in depressions) and 5 (aquitaine cracking clays), with a series of other soil types associated with black soil plains or lying at the margin of the plains.

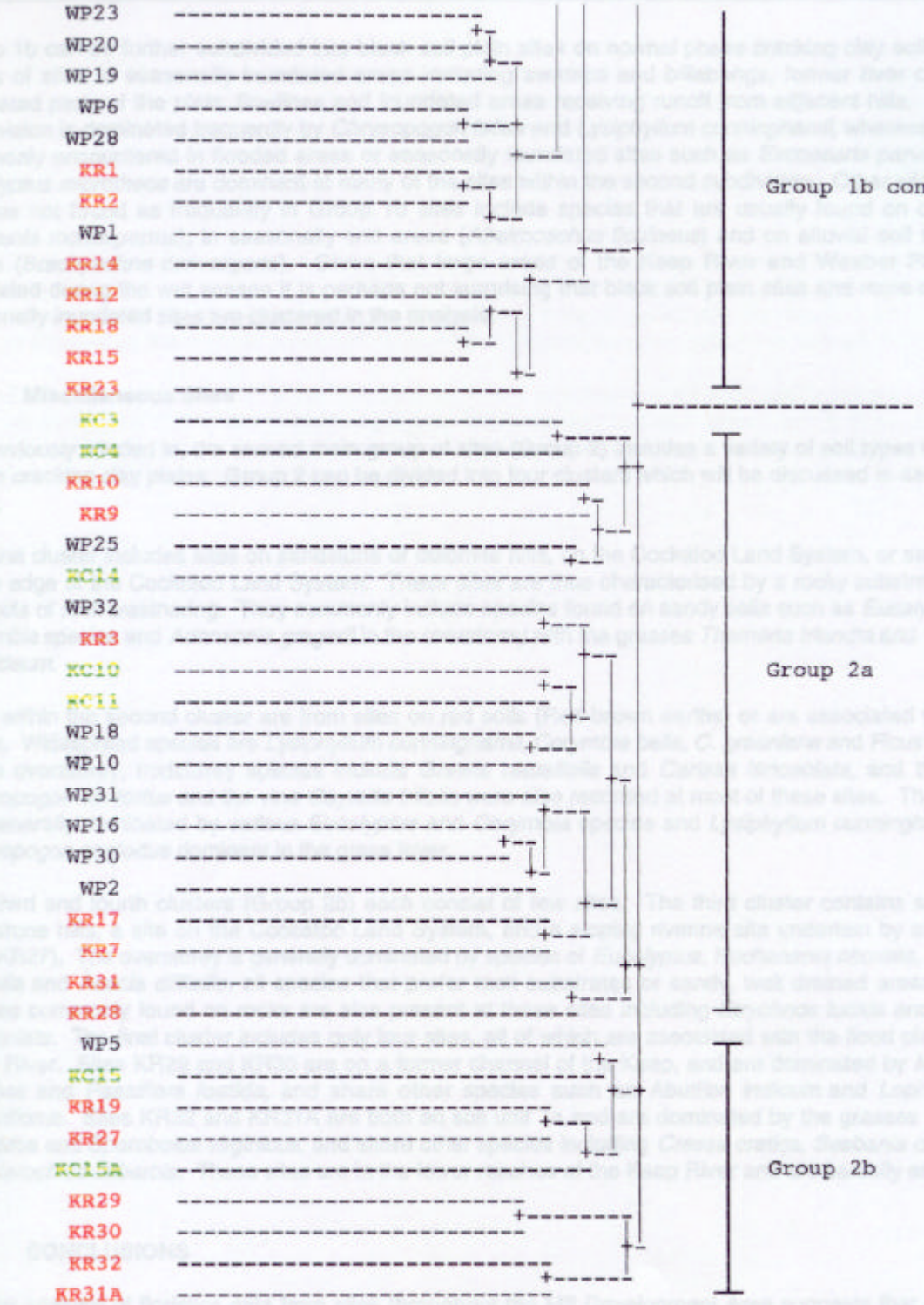
The vegetation of the Group 1a areas commonly consists of *Lysiphyllum cunninghamii* in the overstorey, with a grass layer dominated by species such as *Themeda triandra*, *Chrysopogon fallax* and *Sehima nervosum*. Other commonly encountered species include the trees *Eucalyptus microtheca*, *Terminalia oblongata* and *Corymbia bella*, shrubs such as *Carissa lanceolata* and *Acacia bidwillii*, and grasses *Ophiuros exaltatus*, *Aristida latifolia* and *Iseilema fragile*. Further subdivision of Group 1a suggests that the series of sites at the head of the dendrogram are from black soil plain areas with depressions, whereas the second subdivision is dominated by sites that are marginal to the black soil plain, or in areas that intergrade between different soil types. The first subdivision is dominated by Keep River sites, the second by Weaber Plain sites.

Group 1b contains sites that are more clearly of the black soil type, with many of the dominant plant species similar to those in Group 1a, but in different proportions. The most widespread species in these

sites are the grasses Panicum decompositum, Aristida latifolia and Iseilema fragile. Widespread overstorey species are similar to those in Group 1a and include Excoecaria parvifolia, Lysiphyllum cunninghamii and Eucalyptus microtheca.

Figure 5: Systat dendrogram (complete linkage method)
M2 presence absence data




WP23
WP20
WP19
WP6
WP28
KR1
KR2
WP1
KR14
KR12
KR18
KR15
KR23
KC3
KC4
KR10
KR9
WP25
KC14
WP32
KR3
KC10
KC11
WP18
WP10
WP31
WP16
WP30
WP2
KR17
KR7
KR31
KR28
WP5
KC15
KR19
KR27
KC15A
KR29
KR30
KR32
KR31A
Group 1b cont.
Group 2a
Group 2b

Group 1b can be further subdivided into black soil plain sites on normal phase cracking clay soils, and a series of sites in seasonally inundated areas including swamps and billabongs, former river channels, inundated parts of the plain, flowlines and inundated areas receiving runoff from adjacent hills. The first subdivision is dominated frequently by Chrysopogon fallax and Lysiphyllum cunninghamii, whereas species commonly encountered in flooded areas or seasonally inundated sites such as Excoecaria parvifolia and Eucalyptus microtheca are dominant at many of the sites within the second subdivision. Other widespread species not found as frequently in Group 1b sites include species that are usually found on clay soils (Neptunia monosperma), in seasonally wet areas (Abelmoschus ficulneus) and on alluvial soil and river banks (Brachyachne convergens). Given that large areas of the Keep River and Weaber Plains are inundated during the wet season it is perhaps not surprising that black soil plain sites and more obviously seasonally inundated sites are clustered in the analysis.

5.2.2 Miscellaneous Sites

As previously alluded to, the second main group of sites (Group 2) includes a variety of soil types with sites not on cracking clay plains. Group 2 can be divided into four clusters which will be discussed in descending order.

The first cluster includes sites on sandstone or dolomite hills, on the Cockatoo Land System, or sandy soils at the edge of the Cockatoo Land System. These sites are thus characterised by a rocky substrate or the products of rock weathering. They commonly include species found on sandy soils such as Eucalyptus and Corymbia species and Adansonia gregorii in the overstorey with the grasses Themeda triandra and Sorghum stipoideum.

Sites within the second cluster are from sites on red soils (Red-brown earths) or are associated with river banks. Widespread species are Lysiphyllum cunninghamii, Corymbia bella, C. greeniana and Ficus opposita in the overstorey, midstorey species include Grewia retusifolia and Carissa lanceolata, and the grass Heteropogon contortus and the vine Cayratia trifolia were also recorded at most of these sites. These sites are generally dominated by various Eucalyptus and Corymbia species and Lysiphyllum cunninghamii with Heteropogon contortus dominant in the grass layer.

The third and fourth clusters (Group 2b) each consist of few sites. The third cluster contains sites from sandstone hills, a site on the Cockatoo Land System, and a sloping riverine site underlain by sandstone (Site KR27). The overstorey is generally dominated by species of Eucalyptus, Buchanania obovata, Grevillea agrifolia and Acacia difficilis, all species that prefer rock substrates or sandy, well drained areas. Other species commonly found on rocks are also present at these sites including Strychnos lucida and Calytrix exstipulata. The final cluster includes only four sites, all of which are associated with the flood plain of the Keep River. Sites KR29 and KR30 are on a former channel of the Keep, and are dominated by Melaleuca nervosa and Passiflora foetida, and share other species such as Abutilon indicum and Lophostemon grandiflorus. Sites KR32 and KR31A are both on soil unit 7a and are dominated by the grasses Imperata cylindrica and Sporobolus virginicus, and share other species including Cressa cretica, Sesbania cannabina and Xerochloa imberbis. These sites are in the lower reaches of the Keep River and are partially saline.

5.3 CONCLUSIONS

Cluster analysis of floristics data from sites throughout the M2 Development Area suggests that there are two broad categories of sites, the black soil plain sites that are located on the Cununurra clay normal phase soils and associated cracking clays in depressions and aquitaine soils, and a second series of sites on a

miscellaneous array of soils and substrate types including red soil, sandy or stony substrates or upland areas such as the Cockatoo Land System, and riverbanks. Within the 'black soil' group, one cluster of sites includes swamps and other seasonally or permanently inundated areas.

This broad grouping of sites is similar to the description of the vegetation of the Weaber Plain provided by Dixon (1996), who recognised a series of concentric zones inwards from the perimeter, outer areas characterised by Aquitaine phase soils (Unit 5) grading to Cununurra normal phase soils (Unit 1) in inner areas. From the outer perimeter, generally treeless grasslands occur on Unit 5c soils, followed by Eucalyptus tectifica and Excoecaria parvifolia over grasses on Unit 5a soils, more variable vegetation on Unit 5b, and in the interior of the plain Unit 1 where Lysiphyllum cunninghamii becomes the dominant overstorey species with generally treeless areas in the centre of the plain with Sorghum spp. grasses dominating (Dixon, 1996). Dixon (1996) considers that these changes in vegetation most likely reflect the drainage, and seasonal inundation is presumably a major determinant. Where a stream or river passes across the plain the broad pattern is broken.

Dixon (1996) further recognises the distinctiveness of the vegetation on the scattered areas of red soils on the plain. Grasses include Heteropogon contortus and Themeda triandra, and Eucalypts are common in the overstorey. Within the current analysis, sites with red soils clustered with riverine sites and sites over sandy or stony soils, these areas representing vegetation outside the broad pattern described by Dixon (1996).

Cracking clay ('black soil') areas are most amenable to irrigated agriculture and therefore are most likely to be developed during the proposed project. Development of these areas needs to be examined in the context of vegetation communities and their representation and the extent of each soil unit (and sub-unit) over the M2 Development Area.

6.0 GENERAL CONCLUSIONS

6.1 INTRODUCTION

The proposed development of the M2 Area will affect significant areas of black soil plain country in the East Kimberley and adjacent Northern Territory in an area that is poorly known biologically. Consequently, environmental issues must be carefully considered to ensure maintenance of biological diversity and protection of biological values. Due to the limited extent of the Ivanhoe Land System in the East Kimberley and the distinctive nature of the vegetation in the M2 Development Area, it is desirable that adequate representation of these areas be maintained. Adequate assessment of the flora and vegetation of the project area is necessary to provide comprehensive information on species diversity and the array of vegetation communities that occur.

Knowledge of the biota of the Victoria-Bonaparte bioregion is relatively poor, with few surveys of flora and fauna. This lack of knowledge is due presumably to the inaccessible nature of much of the region, the low population density, and the fact that few experienced observers have undertaken detailed studies. Most information available that is pertinent to the M2 Development Area is at a very broad scale, including vegetation (Beard, 1979), landforms (Stewart et al., 1970) and soils (Aldrick & Moody, 1977; Dixon, 1996; Schoknecht & Grose, 1996). There are few records of the fauna of the area with the exception of opportunistic data from the Kimberley Research Station. This situation has been remedied to some degree by undertaking a biological survey of the area (ecologia, 1997a).

This document has been prepared in order to examine the vegetation of the M2 Development Area in a bioregional context. The bioregional level is taken to be the Victoria-Bonaparte bioregion, and the majority of information discussed refers to sites within this area. Within this bioregion the vegetation has been examined at four levels at diminishing spatial scales:

1. Between Land Systems within the East Kimberley;

2. Between areas of the Ivanhoe Land System within the Victoria-Bonaparte bioregion;

3. Between the M2 and Riverside Areas within the Ord Basin; and

4. Between the three plains that make up the M2 Area itself.

A summary of the findings within the context of these spatial scales is given below, followed by a discussion of their implications and the main conclusions that have been reached.

6.2 COMPARISONS

6.2.1 Land Systems within the East Kimberley

The floristic composition of a series of 37 WARMS sites located within ten of the Land Systems identified for the Ord-Victoria area by Stewart et al. (1970) were compared. Areas located on land units described as having gentle slopes or on plains were included, since they were considered sufficiently similar to the black soil plains of the M2 Development Area to warrant comparison. The soils of these areas are described as predominantly grey and brown cracking clays of the Kununurra, Argyle and Barkly soil families.

The great majority of the M2 Development Area, and the Ord Stage II Area in general, lies within the Ivanhoe Land System. Within the Ord-Victoria Area, relatively few Land Systems include substantial areas of cracking clays, and they are in the main utilised by pastoralists, with few areas protected in reserves. A clear separation of the Ivanhoe site from all other sites in the analysis suggests that the black soil plain areas of this Land System posess a different floristic composition to the other areas examined. Unfortunately, the WARMS Ivanhoe data is restricted to a single site, making it difficult to come to any any firm conclusions.

A further comparison was made between the floristic composition of the 37 WARMS sites, and a series of 15 similar sites within the within the Keep, Knox, Weaber, Carlton and Ivanhoe West Bank areas of the proposed Ord Stage II. Analysis indicated a generally clear separation of WARMS sites from the Ord sites. This separation appears to be due to real floristic differences rather than an artefact of differing methodology. The single WARMS site located within the Ivanhoe Land System clustered with the Ord sites, and, significantly, with the Carlton Plain sites which are from a similar location.

6.2.2 Ivanhoe Land System Areas within the Victoria-Bonaparte Bioregion

A report on a reconnaissance land resource survey by NT Government personnel (Brocklehurst et al., 1998) compared the composition of the vegetation of the M2 Development Area with vegetation from areas within the Ivanhoe Land System in the Northern Territory on Auvergne and Spirit Hills stations, the largest portions of the Ivanhoe Land System within the Northern Territory. Their aim was to 'consider whether the plant species diversity and the floristic communities present in the M2 Development Area are well represented in the Auvergne region'. To facilitate a satisfactory comparison between the areas, the NT survey concentrated on sites with 'potential for agricultural development', with most sites on areas of clay soils on flat or undulating plains.

The primary findings relevant to the proposed M2 Development Area are that the greater variety of vegetation communities identified during the NT survey may reflect the greater variety of land types surveyed, and the greater number of plant species recorded during the M2 Development Area survey was not thought to be due to differences in survey methodology or timing, and therefore is presumably based on a real effect. The reasons behind the greater observed biological diversity in the M2 Development Area are unclear. Broad vegetation types were represented in both survey areas, however, finer scale vegetation communities from the M2 Development Area were not well represented in the NT survey. Overall, there are considered to be broad similarities in the vegetation of the two areas, but also significant and real floristic differences.

6.2.3 M2 Development Area and Riverside Areas within the Ord Basin

The M2 Development Area and Riverside Development Areas are thought to have had relatively similar geological histories, although within different time frames. The underlying geology of the two areas is similar, with both areas incorporating Cainozoic 'black soil' plains of the Ivanhoe Land System, however, the distribution and coverage of soil types differs between the two areas.

Cluster analysis of plant presence absence data from all dry season sites within the M2 Development Area and Riverside Development Area was undertaken. The analysis separated the M2 Development Area sites that are predominantly from black soil plain areas into a broad group characterised by sites generally with an open woodland of Lysiphyllum cunninghamii and other species over grassland, commonly with Chrysopogon fallax but with a variety of other grasses, notably Themeda triandra, Aristida latifolia and Sorghum spp.. Sites with a similar array of species were infrequently encountered in the Riverside

Development Area. The M2 Development Area sites are generally on Unit 1 and 5 soils, which include the broad areas of Cununurra normal phase soils and associated wetter areas on the black soil plains. The assumption is that similar areas are poorly represented within the Riverside Development Area, with a single site from Carlton Plain falling within this group. Vegetation of the black soil plains of the M2 Development Area seem thus to form a distinct unit.

The Riverside Development Area sites, at the other extreme, are characterised more by plant species indicative of degraded, grazed areas, including Acacia farnesiana and other introduced species, and the grass Heteropogon contortus, an increaser species. These grazing effects may have obscured the true relationship between the vegetation of the two areas. Between the extremes of the M2 Development Area black soil sites and the degraded Riverside Development Area sites there is considerable overlap of M2 Development Area and Riverside Development Area sites, and the vegetation may be considered broadly similar.
Poor differentiation of sites within the cluster diagram may indicate that insufficient sites have been surveyed to adequately detail the vegetation. This would appear to be the case based on the poor correlation between vegetation associations and soil type. An alternative possibility is that there are a very large number of associations in the area with characteristic species composition, hence this heterogeneity of the vegetation has been depicted in the separation of sites within the dendrogram. In either case, further investigations into the flora and vegetation of the M2 Development Area are required to refine knowledge of vegetation composition and distribution of vegetation associations.

6.2.4 Weaber Plain, Keep River Plain and Knox Creek Plain within the M2 Area

The floristic composition of the three plains within the M2 Development Area was compared. It is at the finest scale of the analyses, and serves to compare the vegetation of the areas that will be impacted in the M2 Development Area. It should be noted that while the plains of the M2 Development Area have been considered separately for the purposes of the soil surveys undertaken previously, they occupy different portions of a contiguous drainage system and therefore the boundaries between them are to a degree arbitrary. Consequently, it is expected that the vegetation associations will be relatively similar, varying with local scale factors.

Cluster analysis divided the M2 Development Area into two broad categories which are referred to as black soil plain sites and patch sites. The 'black soil plain' cluster of sites includes a group with sites typically on normal phase cracking clay soils (Unit 1), and a second group generally with soils other than these, predominantly including soil types 4 (cracking clays with microrelief) and 5 (aquitaine cracking clays), with a series of other soil types associated with the plains or lying at their margins.

A series of miscellaneous sites includes black soil plain periphery and upland areas (Units 8, 8a, 8b, and 11, and Cockatoo Land System), riverine woodland along Keep River, Border Creek and lower Knox Creek (Units 7a & 7b), rock outcrops of dolomite, sandstone or limestone (Units 6, 6a, 6b, 6d & 6e), and billabongs and permanent wetlands (Unit B/s).

Sites on areas of red-brown earths are generally well drained and are characterised by distinctive vegetation with an overstorey of Eucalypts (Dixon, 1996). These areas include Soil Units 2a, 2b, 2c and 2d. Soil Units 4a, 4b, 4c, 4d and 4e show considerable microrelief including shelfs and depressions. The depressions are generally poorly drained and become inundated during the wet season.

The first group of the more typical 'black soil plain' sites includes sites on the poorly drained Aquitaine phase soils (Soil Units 5a, 5b, 5c), swamps and lagoons and their margins. The second group of black soil

plain sites are predominantly from Soil Unit 1. The vegetation is quite variable, althou generally a low woodland over grassland. The most widespread association has Lysiphyllum cunninghamii as the dominant species in the overstorey over Chrysopogon fallax grassland. Further more detailed investigation of these areas is necessary in order that a more comprehensive analysis can be undertaken, including an assessment of the representation of vegetation communities in relation to the reserves system of the Victoria-Bonaparte bioregion.

More detailed information is required not only for the Ord area, but also for other locations within the bioregion. The information available at present is at a very coarse scale, is limited in scope, and is fragmentary. Further investigation of species of conservation value identified in the M2 Development Area should be undertaken to assess representation of these species and the communities of which they form a part within the Kimberley and adjacent Northern Territory. This should be achieved prior to further development to ensure protection and maintenance of biological diversity.

6.2.5 Conclusions

Several general conclusions can be derived from the analyses of floristic composition at the four spatial scales referred to in this section:

A) At the Land System level within the East Kimberley, sites on the Ivanhoe Land System differ significantly from all other Land Systems with cracking clay soils.

B) A comparison of the M2 Development Area with other areas of the Ivanhoe Land System within the Northern Territory indicates that there is a higher plant species diversity within the M2 Development Area. In addition, whilst there are broad scale similarities in the vegetation of the two areas, at a finer scale vegetation community or association level, there are clear differences.

C) Comparison of the M2 Development Area and Riverside Development Areas, indicates that again whilst there are broad similarities in vegetation types and overlap in floristic composition between these two areas, the two development areas are dominated by distinctly different community types. Significantly, there is no representation of the vegetation communities which occur on major Soil Units 1 and 5 of the M2 Development Area within the Riverside Development Area.

D) Finally, the vegetation of the M2 Development Area can be broadly divided into black soil plain sites and sites on other soil types. There is a differing degree of representation of these community types on each of the three plains.

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APPENDIX A1

APPENDIX A1. WARMS SPECIES by SITE DATA

Appendix A1: WARMS species by site data.

SPECIES NAME	Longevity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37
Abelmoschus ficulneus	A	1																																				
Abelmoschus moschatus	A																										1					1				1		
Abelmoschus species	A								1																													
Abutilon andrewsianum	P		1			1																											1					
Abutilon oxycarpum	P												1																									
Abutilon sp.	P	1																																				
Abutilon sp.	P		1																																			
Abutilon sp.	P			1																																		
Abutilon sp.	P				1																																	
Abutilon sp.	P										1																											
Abutilon sp.	P											1																										
Abutilon sp.	P																																	1				
Abutilon sp.	P																																		1			
Abutilon sp.	P																																			1		
Acacia farnesiana	P	1		1	1						1		1			1																1	1				1	
Aerva javanica	P				1																																	
Alysicarpus muelleri																																				1		
Aristida latifolia	P	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1
Astrebla elymoides	P			1		1	1		1				1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	
Astrebla pectinata	P			1			1	1							1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1		
Astrebla sp.	P																																		1			
Astrebla squarrosa	P						1	1	1		1			1	1	1	1		1		1	1	1	1	1													
Atalaya hemiglauca	P																															1					1	
Boerhavia sp.	P																															1						
Brachiaria reptans																													1									
Brachyachne convergens	A	1		1		1			1			1			1		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1			1		1	
Bulbostylis sp. (B. barbata?)	A														1							1						1										
Calotropis procera	P			1								1	1																				1	1			1	
Carissa lanceolata	P					1				1				1																		1						1
Chionachne hubbardiana	A						1																			1						1				1		
Chionachne sp.	A																																					1
Chrysopogon fallax	P		1	1		1	1	1	1	1	1	1		1	1	1	1		1	1		1	1	1	1		1				1	1		1		1	1	1
Corynotheca micrantha	P			1																												1	1					
Corynotheca sp. (C. micrantha?)	P								1				1																									1
Crotalaria medicaginea	P																																1					
Crotalaria sp.	P/FP												1			1																						
Cyperus macrostachyos	P										1																											1
Cyperus microcephalus	P																													1								
Dichanthium fecundum	P		1	1		1	1	1		1	1	1		1		1			1				1							1	1			1		1		1
Dichanthium sericeum	FP		1								1				1	1	1			1	1	1	1	1	1	1		1				1				1	1	1
Diplachne parviflora	P																										1											
Dolichandrone heterophylla	P												1																			1						
Enneapogon polyphyllus	FP																															1						
Enneapogon purpurascens	FP											1																				1						
Enneapogon sp.	FP													1																								
Eriachne obtusa	P													1																								
Eucalyptus dichromophloia (E.arenaria?)	P		1							1																						1						
Eucalyptus pruinosa	P																															1						
Eucalyptus sp.	P		1																																			

Appendix A1: WARMS species by site data.

SPECIES NAME	Longevity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37
Eucalyptus sp.	P									1																												
Eucalyptus sp.	P																												1									
Eucalyptus sp. (E.dichromophloia?)	P																																					1
Eulalia aurea	P																								1				1									
Euphorbia schizolepis	A				1																																	
Euphorbia sp.	A				1																																	
Euphorbia sp.	A																														1							
Excoecaria parvifolia?	P																												1									
Flemingia pauciflora	P			1	1	1	1	1						1																								
Grevillea dimidiata	P									1																												
Heteropogon contortus	P																																					1
Iseilema fragile	A																														1							
Iseilema sp.	A																														1							
Iseilema vaginiflorum	A			1			1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1			1	1	1	1	1
Jacquemontia browniana	P																															1						
Jacquemontia paniculata	P	1		1							1	1	1																									1
Lysiphyllum cunninghamii	P	1			1	1					1	1		1																			1					
Marsilea sp.	P																													1								
Neptunia monosperma	P					1									1		1				1	1		1	1		1	1										
Neptunia sp.	P		1																																			
Neptunia sp.	P				1																																	
Neptunia sp.	P															1																						
Panicum decompositum	P	1		1	1		1		1	1	1	1	1	1		1	1	1	1	1	1		1			1	1				1	1	1	1	1	1	1	1
Parkinsonia aculeata	P		1																																			
Phyllanthus maderaspatensis	P																													1								
Ptilotus sp.	P							1																														
Rhynchosia minima	P	1			1					1	1	1	1			1				1							1		1			1	1	1				
Sclerolaena sp.	A/FP																											1										
Sehima nervosum	P													1																	1							
Sida fibulifera	P					1																																
Sida sp.	A/P	1																																				
Sida sp.	A/P		1																																			
Sida sp.	A/P																												1									
Sorghum timorense	A																																1					
Sporobolus australasicus	A					1																																
Stemodia spp	P																													1								
Tephrosia rosea	P									1																												
Terminalia arostrata	P			1								1																				1	1	1	1				1
Terminalia oblongata (ex T. volucris)	P				1		1				1		1																									
Themeda avenacea	P									1																												
Themeda triandra	P																																					1
Trichodesma zeylandicum	FP					1	1	1	1	1			1																									
Triodia sp.	P					1																																
Unknown annual grass	A																													1								
Unknown shrub or tree	A																																				1	
Wedelia asperrima	A						1	1	1		1																					1	1	1				1
Whiteochloa airoides	P														1	1	1		1			1		1		1	1	1	1					1				

APPENDIX A2. ecologia ORD STAGE II DATA USED FOR COMPARISON WITH WARMS SITES

Appendix A2: *ecologia* Ord Stage II data used for comparison with WARMS sites.

Species	KC2	KC6	KC13	KR2	KR13	KR16	WP1	WP6	WP11	WP12	IW1	IW13	CP47	CP48	CP54
**Achyranthes aspera*	1													1	
**Aerva javanica*												1			
*†*Calotropis procera* Cl. B (NT);		1													1
*†*Parkinsonia aculeata* Cl. B (NT);										1					
Abelmoschus ficulneus	1	1	1	1		1	1	1							
Acacia bidwillii		1		1		1	1								
Acacia farnesiana											1			1	
Acacia hemignosta							1								
Aeschynomene indica			1						1	1					
Alloteropsis semialata										1					
Ampelocissus acetosa					1										
Aristida holathera var. *holathera*					1							1			
Aristida latifolia	1	1	1	1		1	1	1	1	1	1		1	1	
Astrebla squarrosa	1														
Atalaya hemiglauca	1	1	1	1		1									
†Atalaya salicifolia 3 r (NT)								1	1						
Barringtonia acutangula										1					
Bonamia ?media		1	1		1										
Bonamia pannosa												1			
Bothriochloa b. subsp. *bladhii*					1										
Brachyachne convergens	1	1	1	1	1	1	1		1					1	
Capparis lasiantha				1											
Capparis spinosa var. *nummularia*							1								
Carissa lanceolata									1		1			1	
Chrysopogon fallax	1	1	1	1		1	1	1	1		1	1	1	1	
†Corchorus fascicularis 3 r (N.T.)	1	1	1							1					
**Corchorus olitorius*			1				1			1					1
Corymbia bella									1	1					
Crotalaria juncea							1								
Cyanotis axillaris															1
Cyperus bifax	1			1											1
Cyperus conicus										1					
Cyperus sp.			1			1			1						
Dichanthium fecundum				1				1			1		1		1
Dichanthium sericeum				1			1		1	1			1		1
Dolichandrone heterophylla					1		1								
Ehretia saligna	1			1				1	1						
†Enteropogon minutus									1						
Eragrostis tenellula			1	1				1	1	1					1
Eriachne glauca									1		1				
Eriachne ?obtusa (fine culms)											1				
Erythrophleum chlorostachys					1										
Eucalyptus camaldulensis												1			
†Eucalyptus microtheca	1		1		1										
Eucalyptus pruinosa											1				
Eulalia aurea										1					
†Excoecaria parvifolia	1					1			1						
Ficus opposita					1							1			1
Flemingia pauciflora	1	1		1		1	1	1							
Gomphrena canescens												1			
Grewia retusifolia							1		1						
Heteropogon contortus					1						1	1		1	
Hibiscus panduriformis		1		1	1	1	1			1					
Indigofera trita				1			1	1							
Ischaemum australe										1					
Iseilema fragile	1	1	1	1		1	1	1	1		1		1	1	1
Leptochloa neesii									1	1					
Ludwigia perennis									1						
Lysiphyllum cunninghamii	1	1	1	1		1	1	1	1		1			1	1
Melia azedarach															1
Melochia pyramidata		1				1				1					1
Neptunia cf. dimorphantha		1													1

* = Introduced Taxa; † = Flora of Interest

Appendix A2: *ecologia* Ord Stage II data used for comparison with WARMS sites.

Species	KC2	KC6	KC13	KR2	KR13	KR16	WP1	WP6	WP11	WP12	IW1	IW13	CP47	CP48	CP54
Neptunia major											1				
Neptunia monosperma			1	1		1	1	1		1					
Ophiuros exaltatus				1	1		1			1					1
Panicum decompositum	1		1	1		1	1	1	1	1	1		1	1	1
Panicum laevinode						1			1						
Phyllanthus maderaspatensis			1				1	1			1				
Polymeria sp. A 'Kimberley'				1							1		1		1
Pterocaulon serrulatum											1	1			
Ptilotus spicatus	1	1	1					1							
Rhynchosia minima		1		1			1	1							
Sauropus trachyspermus										1					
Sehima nervosum				1			1								
Senna planiticola											1				
Sesbania simpliciuscula	1						1	1	1	1					
Sida spinosa	1	1	1	1		1	1	1	1	1					
Sorghum timorense				1		1	1	1		1					
Stemodia tephropelina			1		1										
Streptoglossa bubakii											1				
Terminalia oblongata				1			1	1							
Themeda triandra				1	1		1		1		1				
Tinospora smilacina												1			
Trichodesma zeylanicum		1		1		1		1							1
Triumfetta ?grisella												1			
Urochloa reptans				1			1								
Ventilago viminea			1												
Waltheria indica											1				

* = Introduced Taxa; † = Flora of Interest