ELLENBROOK MANAGEMENT PTY LTD

ELLENBROOK DEVELOPMENT
PUBLIC ENVIRONMENTAL REVIEW

Volume 3

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Feilman Planning Consultants

ELLENBROOK DEVELOPMENT
PUBLIC ENVIRONMENTAL REVIEW

APPENDIX A1

Local Climate, Vegetation And Flora, Fauna And Landscaping

LOCAL CLIMATE, VEGETATION AND FLORA, FAUNA AND LANDSCAPING OF THE ELLENBROOK PROJECT AREA

for

Feilman Planning Consultants

DAMES & MOORE

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SUMMARY

The Ellenbrook Project Area, east of the Gnangara Pine Plantation, was surveyed by car and on foot on 11, 16 and 18 October 1989 for vegetation, for rare, restricted and poorly collected species of flora, and for habitats for these species. Faunal habitats were also noted during these surveys. Meteorological data were collected in a desk top study.

Statistical analyses of climatic data compare Upper Swan Station, less than 1km from the Ellenbrook Project Area, with data from other Swan Coastal Plain Meteorological Stations. Results indicate that local climatic conditions at the Project Area fall into general climatic trends for the northern Swan Coastal Plain and it is unlikely that any special local climate occurs at the site. Some suggestions for ameliorating climate, such as reducing the impact of easterly summer winds, are discussed.

Banksia woodlands cover most of the Project Area, with Paperbark and Swamp Banksia woodlands and seasonal swamps in many depressions, especially in the north-west corner.

The list of species searched for during the rare and endangered flora survey of the Project Area was compiled from two published lists and various working lists and other information provided by the staff of the Western Australian Wildlife Research Centre.

Only one of the species in the list was found during the survey. This species, Restio stenostachyus, is poorly collected or recorded and is apparently geographically restricted.

Another vascular plant species found but not in the list, Drosera pulchella, is wide-spread but is uncommon or rare on the Coastal Plain. A second significant but unlisted species, Aotus cordifolius, appears to be restricted to the Perth Flora Region.

The Banksia woodlands and wetlands in the north-west corner of the Project Area, whilst not unique, are in good condition compared to much of the coastal plain swampland. These wetlands are worthy of protection, the level and nature of which can only be determined after more detailed investigation.

No Western Swamp Tortoises or Western Swamp Tortoise habitats were found in the Project Area, nor were other rare fauna, or restricted habitats for them, found.

There are no major landscaping constraints in the Ellenbrook Project Area. However, a wide variety of drainage and soil types are present and landscaping should take advantage of these features.

LOCAL CLIMATE, VEGETATION AND FLORA, FAUNA AND LANDSCAPING OF THE ELLENBROOK PROJECT AREA

1.0 INTRODUCTION

The Ellenbrook Project Area, comprising approximately 1800ha and located about 20km north-east of Perth Central Business District (Figure 1), is seen as providing about 20% - 25% of Perth's metropolitan urban growth over the next 5 to 10 years. The broad region within which the Project Area lies is of planning and management interest to CALM, the Environmental Protection Authority (EPA), the Water Authority of Western Australia (Water Authority) and the Department of Planning and Urban Development (previously the State Planning Commission).

The Project Area is in the south-east part of the Gnangara Water Mound, partly in the Gnangara Water Reserve, in the Water Authority's Lexia Groundwater Source area (Dames & Moore, 1986). Gozzard (1982, 1986) shows approximately 12 Water Authority observation boreholes and three production boreholes in the Project Area.

The area proposed as Stage 1 of the residential development planned for the Project Area is located within the south-west corner and includes a section of pine plantation currently vested in the Department of Conservation and Land Management (CALM).

None of the System 6 areas recommended for conservation by the Environmental Protection Authority (1983) is in the Project Area. However, EPA Recommendation M13 (Whiteman Park) is immediately to the south, M17 (Ellen Brook and Twin Swamps Reserves) is a few kilometres to the east and north-east, and M19 (Swan River) is closer to the east.

Initial natural and social environment studies have indicated that there will be no insurmountable short-term or long-term adverse environmental impacts associated with the Project, although earlier studies on conservation aspects of the region (Dames & Moore, 1988) identified specific concerns relating to wetlands in parts of the Project Area and west of it and recommended that further investigations be carried out.

This report describes and discusses the results of aerial photograph interpretation, field surveys and data analysis of the Ellenbrook Project Area (Figure 1) to determine:

- opportunities for protecting and enhancing natural features of the environment,
- local climatic conditions which might present any constraints to development,

- the nature, composition, condition and extent of each vegetation type in the Project Area,
- what species of Gazetted Rare Flora or other restricted or unusual plant species occur in the Project Area, where they occur and what constraints they might have on the Project,
- basic landscape characteristics in respect to use of pines for landscaping and reafforestation,
- whether the rare Western Swamp Tortoise, or habitat favourable for it or other Gazetted Rare Fauna, is present in the Project Area.

2.0 METHODOLOGY

2.1 LOCAL CLIMATE

Meteorological data were obtained from the Bureau of Meteorology for Upper Swan (Station No. 09067), Perth Regional (Station No. 09034), Pearce (Station No. 09053) and Wanneroo (Station No. 09186).

Although definitive statements on climatic conditions at the Project Area are not possible because there are no climatic data for the site, the nearest meteorological station, Upper Swan, is located at co-ordinates 31°45'S and 116°01'E, (Figure 1), less than 1km north of the Project Area and approximately the same distance from the Darling Scarp. Thus, for the purpose of this study, it is considered broadly representative of meteorological conditions at the Project Area. The other stations cover a wide area from near-coastal districts (Wanneroo, Perth) to the eastern limit of the Swan Coastal Plain (Pearce).

The following data were obtained for analysis:

- Mean monthly maximum temperature (°C)
- Mean monthly minimum temperature (°C)
- Relative humidity at 0900 hours (%)
- Relative humidity at 1500 hours (%)
- Mean monthly rainfall (mm)

Correlation matrices were prepared for temperature, humidity and rainfall data using Microstat Statistical Package Version 4.2.

No formal statistical analyses were carried out for wind data for the following reasons:

- Wanneroo station does not collect wind data and it was therefore felt that the dataset would be too small for results to be meaningful.
- The format in which wind data are collected would mean that the dataset would be multi-dimensional, and thus unnecessarily complex.

Instead, visual examination of wind data and evaluation of trends were performed.

2.2 VEGETATION AND FLORA

The Project Area was surveyed by Dames & Moore staff on 11, 16 and 18 October 1989 for native vegetation, for rare, restricted and poorly collected species of flora, and for habitats for these species. Sites considered most likely to support rare or endangered species were more intensively surveyed. These most likely sites were selected on the basis of examination of a large, colour aerial mosaic which was photographed in April 1987.

2.3 FAUNA

Staff from CALM's Western Australian Wildlife Research Centre (WAWRC) examined, at Dames & Moore's request, the north-west corner (Loc. 45, Maralla Road) for conservation value in August 1989 and for Swamp Tortoise habitat on 13 October 1989. Dames & Moore staff also evaluated faunal habitats while undertaking botanical studies.

3.0 PHYSICAL ENVIRONMENT

As most of the Ellenbrook Project Area is within the area covered by the "Gnangara Mound Groundwater Resources Environmental Review and Management Programme" (ERMP) (Dames & Moore, 1986), descriptions of the regional physical environment given in the ERMP also apply to the Project Area. The landforms and environmental geology of the Project Area are detailed by the Muchea and Perth environmental geology sheets (Gozzard, 1982; 1986).

The climate of the Project Area is temperate Mediterranean, with warm, dry summers and mild, wet winters. Summer evapotranspiration rates are high, and few of the wetlands are permanent in the broader area within which the Project Area lies. Climatically, there is no evidence that the rainfall, (which either directly or indirectly supplies the lakes and swamps) has varied significantly over recent history (Figure 2). There may have been some local decline in water table caused by the nearby pine plantations (Havel, 1975).

McArthur and Mattiske (1985) have produced a 1:50,000 scale map of Gnangara Mound landforms, soils and vegetation which shows the western two-thirds of the Project Area as being within the Jandakot (Ja) and Gavin (G) units of the Bassendean Dune System, with smaller areas of Joel (J) and Seasonal Swamps (Ws) landforms, soils and vegetation. There is a small area in the north-eastern corner of the Project Area designated Drainage Line (DL). An anonymous 1:25,000 scale map provided by the Shire of Swan planning office indicates that most of these landform types extend into the eastern third of the Project Area. In the Project Area Yanga Alluvial Terrain (Y) occurs only in the eastern third.

The Perth and Muchea environmental geology (1:50,000 scale) and landform (1:100,000 scale) maps (Gozzard 1982, 1986) show all of the Project Area, some of it in more detail than the McArthur and Mattiske map. Gozzard shows most of the Project Area as being on Bassendean sands (S8, S10), with smaller areas of peaty clay (Cps) and marshes in interdunal swales (Lm), particularly in the west. Some southern and eastern parts of the Project Area are on Guildford Formation pebbly silt (Mgs1).

The swamps found in the Project Area may not be of perched water table origin, as they appear to hold water for a much shorter time, at the end of winter, than do the known perched swamps to the east. If so, they will be affected by any activities which cause a rise or fall in the water table. In fact, they may already have been affected by a lowered water table caused by the nearby pine plantations.

4.0 LOCAL CLIMATE

4.1 INTRODUCTION

Concern has been expressed by the developers that the Ellenbrook Project Area may exist in an usual local climate. In particular, it is considered that factors such as rainfall, humidity and wind speeds and direction may differ near the Project Area from those found at other locations on the Swan Coastal Plain.

If it were shown that meteorological data representative of Ellenbrook varied from other comparable data from the Swan Coastal Plain, consequent management programmes would have to recognise the altered impacts the local climate may induce.

Statistical analyses of some meteorological data and visual comparison of wind speed and direction were carried out in order to test the hypothesis that the Ellenbrook Project Area is located in an unusual local climate. The impacts that the climate may have are discussed and management strategies are put forward in the light of findings.

4.2 RESULTS AND DISCUSSION

Correlation matrices (Appendix A) give results for comparison of maximum temperature, minimum temperature, relative humidity at 0900 hours, relative humidity at 1500 hours and rainfall respectively.

These matrices show that there is an extremely good correlation between Upper Swan data and the other stations examined. This indicates that the local climate at the stations studied is remarkably constant: most correlations are more than 98%.

One apparent anomaly, the relative humidity at 1500 hours, shows Wanneroo as having a lesser correlation. However, two factors should be noted when evaluating these data; namely, Wanneroo station's presence near pine forest, which tends to retain humid conditions, and the relatively short period of time that data have been collected for Wanneroo station since 1983. Taking these factors into consideration, a reasonably good correlation exists (the figure of significance is 0.499 at 95% confidence level).

Visual comparison of wind data indicates that these also correspond very well and no major differences can be seen in diurnal wind intensity or direction. Figure 3 shows seasonal wind roses for Upper Swan station. Winds tend to be south-westerly and easterly during summer and autumn months, north and north-easterlies in winter, and south-westerlies in spring. This conforms to general regional trends for the northern Swan Coastal Plain. For completeness, a summary of the Upper Swan data is presented in Appendix B.

Thus, although there are no Project Area data for comparison, the nearest data available is not significantly different from that of other Swan Coastal Plain weather stations. We believe the local climate will be substantially the same.

5.0 VEGETATION AND FLORA

5.1 INTRODUCTION

Beard (1979) and Heddle et al. (1980) map the pre-European settlement native vegetation (i.e. the vegetation that would be there if it had not been cleared) of the Project Area at a scale of 1:250,000. Beard (1980) also maps it at a scale of 1:1,000,000. McArthur and Mattiske (1985) have mapped the pre-European native vegetation of most of the Ellenbrook Project Area at a scale of 1:50,000. The relevant portion of the McArthur and Mattiske map provides the basis for the map of vegetation (and landforms and soils) of the Project Area presented on Figure 4. Summaries of their descriptions, with modifications based upon Dames & Moore traverses in the Project Area, are given below.

Representative photographs of the vegetation units found in the Project Area are illustrated and described in Plates 1-3. The locations of these photographs are shown on Figure 4.

5.2 VEGETATION

5.2.1 Banksia woodlands

The most widespread vegetation in the Project Area is Banksia Low Open Woodland, and its dense understorey shrub layer, which belongs to the Jandakot (Ja) and Gavin (Ga, G) Vegetation Complexes. The Jandakot unit has low hills and ridges of more than 5m relief, while the Gavin unit has a flat or gently undulating landscape with scattered emergent Marri (Eucalyptus calophylla) and Moonah Paperbark (Melaleuca preissiana) trees in the Banksia woodland.

The density of the woodland, and frequency of emergents within it, varies through the Project Area. Banksia attenuata and B. menziesii are the dominant trees in Ja Banksia woodland. B. ilicifolia joins them in the Ga woodland, in which Moonah Paperbark is common. Many Ga woodlands also have Marri and some have Jarrah (Eucalyptus marginata). She-oaks (Allocasuarina fraseriana) and Pricklybark (Eucalyptus todtiana) are common in the woodlands.

The composition of the Banksia woodland understorey also varies widely through the Project Area. In general, swales and other low-lying areas are characterised by Blackboys (Xanthorrhoea preissii), often without trunks, Patersonia occidentalis, Phlebocarya ciliata and Dasypogon bromeliifolius. Eremaea pauciflora, Hibbertia hypericoides and Stirlingia latifolia are characteristic of upland Banksia woodlands. Dense stands of Adenanthos cygnorum are locally common on some slopes and depressions in the woodland, and dense thickets of Regelia inops are common on lower slopes.

The Banksia woodland vegetation is mostly in good condition and shows little evidence of disturbance.

5.2.2 Seasonal Swamps

McArthur and Mattiske (1975) recognise two types of seasonal swamp and poorly drained depression vegetation in the Project Area: Joel (J) and Seasonal Swamps (Ws). The two types of vegetation differ mainly in that Ws vegetation has reeds and sedges in the centre of the depression, which has free water in it during the winter, whereas Joel swamps are less reedy and may simply be low-lying heathlands.

Seasonal swamps (includes Joel) in the Project Area, particularly in the western part of it, are characterised by one or more, often overlapping, concentric belts of differing vegetation. These belts, or zones, are:

1. Jointed Sedge (Baumea articulata) in the deepest, usually winter-inundated area, often with Villarsia albiflora.

2. Astartea fascicularis or terete-leaved sedges (Baumea ? acuta and Lepidosperma ? tenue) or both, sometimes with Melaleuca teretifolia or M. lateritia.

3. Moonah Paperbark (Melaleuca preissiana), often with Lepidosperma longitudinale beneath, and sometimes together with Astartea fascicularis.

4. Swamp Banksia (Banksia littoralis), sometimes with Astartea fascicularis, species of Melaleuca and various smaller shrubs and herbaceous plants.

5. Dense Pericalymma ellipticum Swamp Teatree Shrubland.

6. Hypocalymma angustifolium, often with Euchilopsis linearis, Platytheca galioides and Pultenaea sp.

7. Terete-leaved sedges (Baumea ? acuta and Lepidosperma ? tenue), often with one or more species of orchids.

The sequence of vegetation belts is often abbreviated or mixed and, especially in the eastern, more or less alluvial part of the Project Area, Swamp Paperbark (Melaleuca rhaphiophylla) takes the place of Belt 1 or 2. Holly-leaved Banksia (Banksia ilicifolia) sometimes occurs in Belts 5, 6 and 7. Flooded Gum (Eucalyptus rudis) occurs in some swamps or around their margins.

Most of the north-western swamps (Figure 4) are disturbed to only a minor extent and are amongst the few left on the Swan Coastal plain in a near-pristine condition.

Halse (1989) estimates that since European settlement 70% of wetlands on the Swan Coastal Plain have been either lost or drastically modified by vegetation clearing. Most of the remaining 30 are far from pristine, having been affected by fire, grazing and other impacts. Halse also suggests that the loss of wetlands is continuing, and that the only areas on the Swan Coastal Plain that now contain truly pristine or near pristine wetlands are the Northern Coastal Plain west of Gingin and Yalgorup National Park. It is unlikely that Halse has surveyed the Project Area which is privately owned land, and not readily accessible.

5.2.3 Permanent and Semi-permanent Swamps

Swamps in the north-eastern third of the Project Area are commonly of the type described in Dames & Moore (1988): a woodland of Flooded Gum (Eucalyptus rudis), often with 2m to 4m tall shrubland dominated by Swamp Paperbark (Melaleuca rhaphiophylla) and Wattles (Acacia saligna). Moonah Paperbark, Viminaria juncea, Astartea fascicularis, M. viminea and, to a lesser extent, M. lanceolata, M. huegelii, Kunzea recurva/micrantha, Hakea varia, Jacksonia furcellata and J. sternbergiana are also common in the swamps, sometimes as understoreys and sometimes in thickets or low forests.

5.3 SIGNIFICANT PLANT SPECIES AND HABITATS OF THE PROJECT AREA

5.3.1 Background

The importance of rare or vulnerable plant species is based upon a complexity of the meaning of these terms, how they are applied, and how they are dealt with by botanists. In order to appreciate these complexities a discussion of the origins of terms and their current application is presented in Appendix C.

The species searched for during the botanical survey of the Project Area are those on two published lists and two sets of unpublished lists plus others highlighted during discussions with WAWRC botanists. The lists are:

- Gazetted Rare Flora (Government Gazette of 14 July 1989, pp. 2159, 2160),
- Rare, Geographically Restricted and Poorly Collected Species of Vascular Plants that might occur in or near the Gnangara Mound Region (Weston, 1986).
- Priority One, Two and Three Species of the Metropolitan Region (WAWRC, October 1989, pers. comm.) and
- Eight Gazetted Rare Flora recorded from the Metropolitan Region (WAWRC, October 1989, pers. comm).

The first three lists are presented in Appendix C. The fourth is used as the basis for Table 1, which also gives the currently known distribution, habitat and flowering time for each of the eight species listed. During the Project Area survey, an emphasis was placed on finding these eight species and one other, Ptychosema pusillum. Ptychosema pusillum is known from the Gingin area (and from nowhere else), north of the Metropolitan Area and the Project Area, and is not discussed by Marchant et al. (1987). Information about the species is given by Rye and Hopper (1981).

The eight species listed in Table 1 are all herbaceous plants and flower in the period between August and November. Most are species of low-lying areas and seasonal wetlands. Photographs of all of these species are shown in Plates 2 and 3. The Ptychosema, also known as Dwarf Pea, is a tiny shrub that flowers in October and November.

The flowering times given in the table suggest the period when a survey for the species could be undertaken most productively. However, in the case of the Drakaeas and the Drosera the leaves are distinctive enough for identification of the species before they flower. Consequently, the surveys carried out for this study should be able to identify the species in Table 1 and Ptychosema pusillum if any populations of these exist in the area.

TABLE 1

GAZETTED RARE FLORA (DRF) OF THE METROPOLITAN REGION

Species and Family	*Localities and Distribution*	*Habitat*	*Flowering Times*
Aponogeton hexatepalus APONOGETONACEAE	17: Kenwick-Darradup-Augusta	Shallow winter pools on clayey soils	Aug-Sept
Caladenia sp. A (coastal plain) S.D. Hopper 3400 ORCHIDACEAE	11: Gnangara-Yallingup-Margaret River	Sandy soils in Banksia and eucalypt woodlands, often with Allocasuarina fraseriana and usually low on the landscape	Sept-Oct
Diuris purdiei ORCHIDACEAE	9: Perth area-Harvey	Seasonal semi-swamp on sand-over-clay soils, usually in Regelia and Pericalymma shrublands; flowers in habitats which were burnt the previous dry season	Sept-Nov
Diuris sp. (Kwinana) aff. laxiflora A.P. Brown 10/9/94 ORCHIDACEAE	2: Kwinana	Small shallow winter-wet swamps; amongst short sedgeland, predominantly of Lepidosperma longitudinale, on sandy-clayey soils	Aug-Sept
Drakaea jeanensis ORCHIDACEAE	8: Canning Vale -Busselton	Sandy soils, often firm and very white, in Kunzea ericifolia tall shrubland and Banksia woodland, low in the landscape	Sept-Nov
Drakaea sp. (south west) S.D. Hopper 3566 ORCHIDACEAE	5: Canning Vale, Yarloop, Mowen, Bakers Junction	Sandy soils in scrub and woodlands low in the landscape, often near swamps	Sept-Oct
Drosera occidentalis DROSERACEAE	9: Malaga-Karnup	With short Centrolepidaceae sedges on sandy soils which are winter-inundated, usually shallowly, in swampy areas	Oct-Nov
Hydrocotyle lemnoides	3: Upper Swan-Kenwick	Shallow winter pools on clayey soils	Sept-Oct

Note: The information in this table was compiled from Rye and Hopper (1981), Hoffman and Andrews (1984), Marchant et al. (1987), information provided by L. Mutter and botanists of the Western Australian Herbarium and the WAWRC, and field work by A. S. Weston during September and October 1989. There may be a few more localities for some of the orchids than the number given in the table, but the species are no longer found in some of the localities where they were previously recorded

5.3.2 Significant Plant Species and Habitats Found in the Project Area

No Gazetted Rare (DRF) species was found in the Project Area, but other significant species were found during the survey. One of the species in the Priority Three list for the Metropolitan Region (Appendix C; Table 3) was found during the survey. This species, Restio stenostachyus, is poorly collected or recorded and is apparently geographically restricted. Another vascular plant species, Drosera pulchella, is wide-spread but is uncommon or rare on the Swan Coastal Plain. A third vascular plant species, Aotus cordifolius, appears to be restricted to the Perth Flora Region (Marchant et al., 1987) and is on Priority Three lists for the Department of Conservation and Land Management Northern Forest and Central Forest Regions.

A few small stands of Restio stenostachyus were found in Site 24 (Figure 4), a low forest of Acacia saligna associated with Moonah Paperbark, Swamp Paperbark and Swamp Banksia trees. Site 24 is near the eastern boundary of the Project Area south of its north-eastern arm.

The rare species are described in Appendix C.

6.0 FAUNA OF THE PROJECT AREA

6.1 INTRODUCTION

No specific surveys for fauna have been carried out, however, Harold (1985) has conducted extensive surveys of the northern Swan Coastal Plain which are applicable to the present study. The following comments, based mainly on this source, pertain particularly to woodlands, which constitute the major native vegetation type encountered in the proposed development area. Pine plantations and cleared agricultural land also occur in the area. These would be expected to be less rich in native faunal species. Minor areas of riverine and swamp associations are also present.

6.2 MAMMALS

A survey conducted by the Western Australian Museum during 1977/78 confirmed the presence of only 12 native species of mammals on the northern Swan Coastal Plain:

Short-beaked Echidna	Tachyglossus aculeatus
Common Brushtail Possum	Trichosurus vulpecula
Honey Possum	Tarsipes rostratus
Western Brush Wallaby	Macropus irma
Western Grey Kangaroo	M. fuliginosus
Lesser Long-eared Bat	Nyctophilus geoffroyi
Goulds Wattled Bat	Chalinolobus gouldii
King River Eptesicus	Eptesicus regulus
Water Rat	Hydromys chrysogaster
Ashey Grey Mouse	Pseudomys albocinereus
Bush Rat	Rattus fuscipes
Southern Brown Bandicoot	Isoodon obesulus

In addition, another three species were considered to be possibly still present in the region, although they have not been sighted for several years.

Western Quoll	Dasyurus geoffroii Last collected in 1972
Western Pygmy Possum	Cercartetus concinnus Last collected in 1966
Chocolate Wattled Bat	Chalinolobus morio Last collected in 1951

All of the above 15 species inhabit heath, shrubland or woodland habitats, with the exceptions of the Southern Brown Bandicoot, Water Rat and Bush Rat, which prefer swamps and lakes.

The Honey Possum (Tarsipes rostratus), is known to occur in Yanchep National Park and at Mindarie, east of Burns Beach, where it depends on a year round supply of flowering plants.

6.3 HERPETOFAUNA

The northern Swan Coastal Plain supports a relatively rich herpetofauna with 42 genera and 70 species distributed amongst 11 families (Storr et al., 1978a). They are:

Ground Frogs	(Leptodactylidae)	7 genera, 11 species
Tree Frogs	(Hylidae)	1 genus, 2 species
Side-necked Turtles	(Cheluidae)	2 genera, 2 species
Geckos	(Gekkonidae)	4 genera, 6 species
Legless Lizards	(Pygopodidae)	6 genera, 8 species
Dragon Lizards	(Agamidae)	1 genus, 2 species
Skink Lizards	(Scincidae)	10 genera, 19 species
Blind Snakes	(Typhlopidae)	1 genus, 3 species
Pythons	(Boidae)	2 genera, 2 species
Front-fanged Snakes	(Elapidae)	7 genera, 13 species

Seventeen of the above species and sub-species listed in Storr et al., (1978a) are considered to be scarce or rare, primarily due to lack of suitable habitat on the coastal plain, although they are more common elsewhere in the south-west. Four of the seventeen are at the limits of their distributions. A further twelve species are endemic or nearly endemic to the west coast and coastal plains from the North West Cape to Geographe Bay, though none is restricted to the northern Swan Coastal Plain.

6.4 BIRDS

The avifauna of the region was documented by Storr et al., (1978b) who compiled an annotated list which included local distribution, relative abundance, faunal status (i.e. visitors, resident, etc.), habitat preferences and breeding season. Data were derived from the literature, W.A. Museum catalogues, journals of local naturalists and survey work undertaken by W.A. Museum staff during 1977-78. A summary is reproduced below. Figures in brackets refer to species which formerly occurred on the Swan Coastal Plain but for which no definite records exist.

TABLE 2

BIRDS OF THE SWAN COASTAL PLAIN

	Non-Passerines	*Passerines*	*Total*
Residents	52(3)	48(7)	100(10)
Breeding Visitors	14	5	19
Non-breeding Visitors	73	10	83
Vagrants	12	2	14
Established Exotics	5	2	7
TOTAL	156(3)	67(7)	223(10)

Of the birds that have declined or become locally extinct, Storr et al. (1978b) noted that most were either wetland or forest inhabiting (not woodland inhabitating) species.

6.5 RARE FAUNA

Of particular interest to the Ellenbrook Project Area is the Western Swamp Tortoise (Pseudemydura umbrina) which occurs in two nature reserves, 1km and 5km north east of the Project Area. These nature reserves contain possibly the last remnant populations of this extremely rare reptile. The tortoises require vegetation near the wetlands where they can find

refuge from desiccation in summer. These types of vegetation must have deep litter layers in which the animals can bury themselves, fallen logs under which they can hide, or burrows in which they can go deep into the earth. When wetlands have dried out, and water stress is at a maximum, the refuges must remain intact. Hence, predator pressure, bushfires and other factors which would damage the refuges, or expose the tortoises, are also important in influencing the survival or decline of the Western Swamp Tortoise.

No general, systematic fauna survey was undertaken during this study, but Dr A.A. Burbridge (WAWRC) the authority on Western Swamp Tortoises and P. Fuller, also familiar with tortoise habitat requirements, inspected most of the uncleared parts of the Project Area for the tortoises and their habitats.

Dr. Burbidge concluded that the landscape they inspected had no habitats suitable for Western Swamp Tortoises. The deeper, peaty swamps they visited in the Project Area are more typical of coastal plain swamps near Perth rather than the shallow, perched swamps that are the tortoises' habitat in Twin Swamps Nature Reserve (refer Section 3.0).

The possible suitability of the undisturbed bushland area for reintroduction of rare faunal species, in particular the Numbat (Myrmecobius fasciatus), was also considered. Discussions with Mr Anthony Friend of the WAWRC indicate that the habitat could potentially support the Numbat but that the animals require at least 40ha each in order to survive. To establish and maintain a viable population of Numbats at least a hundred times this area (i.e. 4,000ha) would be required, and probably much more. Relatively undisturbed bushland available as a fauna sanctuary in the Project Area totals about 1600ha and is therefore well below the minimum viable area.

The habitat is, however, probably of suitable size to provide a managed sanctuary for some native mammals, although species selection, habitat requirements, etc, would need to be determined after consideration of possible management scenarios.

7.0 LANDSCAPE EVALUATION

7.1 INTRODUCTION

An evaluation of the Ellenbrook Project Area in terms of ease of rehabilitation, landscaping constraints, the significance of the pine plantations in landscaping and the possibility of dieback disease affecting developments was required as part of the scope of the study brief. These components of the study are discussed below.

7.2 EASE OF REHABILITATION

In this context rehabilitation refers not only to areas within the development which will be cleared and later restored, but also to construction of parklands, establishment of domestic gardens, etc.

The success of large-scale vegetation establishment, assuming that irrigation is not carried out, is dependent on soil type, drainage and plant species selections. Native species should be planted wherever possible and residents of the development should be encouraged to plant native gardens in preference to exotic species, as native species are more attractive to fauna, are less water-demanding and are more suited to local soil conditions.

In the Project Area there are three basic soil types; deep sands, clay soils and peaty swamp soils (Section 3.0). Each of these soils has special requirements for revegetation.

Sands

The sandy soils of the Project Area are either white, with poor nutrient-retention abilities, or yellow, with some capacity to hold nutrients. In both situations, although less so with the yellow sands, some application of nutrients is of value in re-establishing native flora. These fertiliser applications should be of low volume, and preferably of the slow-release type.

As these soils are highly porous and well drained, the best time for re-establishment of plants is in late autumn, when winter rains can allow root growth before summer moisture stress becomes apparent.

Most native plants are easy to grow on sandy soils.

Clay Soils

Clay soils have good nutrient-retention ability but tend to dry out completely and become rock-hard in summer or waterlogged in winter. Moisture control is therefore more important than nutrients.

In many clayey soils it may be necessary to undertake some soil amelioration activities before attempting to re-establish native vegetation. Suitable actions are:

- o removal of the clay and replacement with sandy soil
- o burial of the clay under at least 0.5m of sandy soil
- o mixing the soil with sand
- o addition of gypsum (calcium sulphate) to the soil to break up the clay's hard-setting capacity.

The best method of amelioration for the Ellenbrook Project Area will depend on the area to be treated, cost considerations and the intended end land-use.

Further, some drainage may be required in waterlogged areas, or irrigation in very dry areas, although the latter is not favoured. This is because irrigation usually leads to rapid weed establishment competing with native plants, becoming unsightly and creating a fire hazard.

Plant species selection will be critical when rehabilitating clay soils as many native plants will not grow under these conditions.

Peaty Soils

Peaty soils usually retain nutrients well, but are very acidic and waterlog in winter. Addition of nutrients is generally not required for successful rehabilitation.

If the wetland character of the area is to be retained then revegetation is usually just a matter of selecting appropriate species. These species are generally acid-tolerant swamp species which can stand partial inundation.

If the wetland character is not to be retained drainage is usually required, with or without soil amelioration by the addition of sand.

7.3 LANDSCAPING CONSTRAINTS

There are no major landscaping constraints in the Ellenbrook Project Area. However, the wide variety of drainage and soil types and the variable topography suggest that landscaping should take advantage of these features. This is more efficient and less costly than modifying the environment to suit the development concept.

Assuming that landscaping procedures follow the dictates of the environment, the main features to be discussed are the soil and drainage characteristics outlined in Section 7.2.

Climatic conditions, discussed in Section 4.0, should also be evaluated. Although the local climate at Ellenbrook is, based on available data, not statistically different from nearby areas on the Swan Coastal Plain, there are some general characteristics of regional climate worthy of consideration. These are primarily:

- high summer temperatures
- strong easterly winds in summer.

Landscape design can help to ameliorate these climatic conditions and can assist in long-term land management.

High summer temperatures can be made more comfortable by retention of as many trees as possible in the residential areas. The trees will provide shade, reducing ground temperatures and will cool the air by evapotranspiration. Dames & Moore staff have recorded temperature differences of up to 8°C between wooded (20% canopy cover) and unwooded areas on the Swan Coastal Plain.

Trees also assist in reducing ground-surface wind speeds, especially during periods of summer easterlies. This effect, in turn, reduces wind erosion and dust generation and lowers ground-surface moisture evaporation rates. The latter can, in some circumstances, greatly reduce irrigation costs for lawns and gardens.

A further consideration indirectly related to high summer temperatures and wind speeds is the need for fire protection. Although the risk of bushfire is high in any bushland area, and especially in spring, summer and autumn seasons, appropriate landscaping can greatly reduce the risk to life and property.

Golf courses, playing fields, moats and lakes, roads and even pathways and cycle tracks can form effective fire barriers or provide access for fire-fighting equipment. Design of these types of features into the Project Area can provide a high level of fire protection at little or no additional cost.

7.4 PINE PLANTATIONS

Pine plantations cover most of the Stage I component of the Ellenbrook Project Area. The trees (Pinus pinaster) are attractive, although these do not look natural because their planting in ordered rows contrasts to the native vegetation.
The retention of the pine trees as part of Project landscaping is acceptable, providing the developers are not concerned about the visual aspects. In the Murdoch area south of Perth, for example, retention of some pine trees from an old plantation have given the suburb a unique character.

A further consideration is that even if the aim is to replace the pines with native trees in the long term, there is considerable merit in retaining many of them in the interim. As noted above, trees, including pines, will shade and cool the area and help to reduce wind speeds while native trees are becoming established.

The pine tree is noted for a relatively weak and predominantly shallow root system, and, although stable when alive, tends to fall over if the tree dies. This probability is increased if the trees are exposed to strong winds by being in isolated locations. Retention of pines for landscaping purposed would therefore be better aimed at retaining small copses of, say 10-20 individuals, rather than retaining single isolated specimens.

Use of pine trees for landscaping in areas not presently under pine is not recommended. The main reasons are:

- the existing pine plantations are located on the best soils for pine, therefore it follows that other areas are less suitable;
- the developers may see a merit in retaining the use of Australian native plants for landscaping;
- native plants are much less water-demanding;
- pines have very limited value for native fauna;
- the presence of native fauna (i.e. birds, insects, etc.) enhances the environment for humans and would increase with the use of native vegetation.

7.5 DIEBACK DISEASE

Dieback disease (Phytophthora spp.) is a soil-borne root-rot fungus disease widspread in the south-west of Western Australia. The disease affects and eventually kills almost all native plant species, although some species are more susceptible than others.

In the Ellenbrook Project Area susceptible families of plants such as Myrtaceae (e.g. the eucalypts and melaleucas), Proteaceae (e.g. Banksia, Grevillea and Hakea) and Fabaceae (e.g. Jacksonia, Daviesia) are very abundant. There is therefore high risk of the disease becoming established.

Dieback disease is generally considered not native to Western Australia (although this is still under debate). It is generally introduced to an area on the wheels and underbodies of vehicles, especially earth-moving equipment. Thus, there is a possibility that the disease is already present in the Project Area, having been introduced during firebreak construction, pine plantation establishment, etc.

Even if the disease is not already present there is a risk of introduction during project development. If the disease becomes established it has the potential to destroy almost all the native vegetation in the Project Area.

The control of the disease is comparatively simple; the primary methods being:

- construction of a washdown area and sump where potentially dieback contaminated water can drain away. This washdown and sump should be located as low as possible in the landscape;
- washing down, with high pressure hoses, all heavy machinery entering the Project Area;
- with tracked vehicles using a crowbar or other means to clean as much soil from the tracks and understructure as possible, then hosing down;
- once inside the development area, repeating washdown if a heavy vehicle, especially a tracked one, is to move from one major area to another;
- taking care to obtain dieback-free gravel and soils for use in roadmaking and landscaping.

Further details on dieback disease control and management can be readily obtained from the Department of Conservation and Land Management.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CLIMATE

The results of statistical analyses of temperature, humidity and rainfall data, and visual examination of wind data, suggest that the local climate in the Ellenbrook Project Area is within the range of climatic variation normal on the Swan Coastal Plain. There is a high level of correlation for all major climatic variables and the one slight variation in the level of statistical agreement can be explained by shortcomings in the dataset.

It must be recognised that a full evaluation of local climate can only be provided if a local weather station were installed. However, based on available data it can be concluded that the Ellenbrook Project Area appears to fall into general climatic trends for the northern Swan Coastal Plain region. A programme for the amelioration of impacts should be designed considering these regional meteorological data.

Considerations in respect of climate and management programme design can be summarised as follows.

Recommendation 1

Site clearing should be kept to a minimum so that the impact of easterly summer winds is minimised and a shelterbelt of vegetation is maintained.

Retention of vegetation also helps to minimise the visual impact of the project on surrounding rural and bushland areas.

Recommendation 2

Any rehabilitation and vegetation growing programmes should be planned to coincide with winter and spring rainfall.

Thus, plants can become established before summer and the need for summer watering is reduced.

Relative humidity is highest and temperatures are lower during early morning.

Recommendation 3

Any watering should ideally coincide with the early morning to reduce evaporation.

Winds are strongest from late spring to mid-summer.

Recommendation 4

Fire danger is likely to increase during late spring and summer and management precautions need to be taken.

8.2 VEGETATION AND FLORA

The vegetation of the north-western part of the Project Area, while not unique, is in good condition and less disturbed than much of the other bushland of the Swan Coastal Plain. The swamps in this area are also of value, as much of the wetland which existed on the Swan Coastal Plain prior to European settlement has now been destroyed (Halse, 1989).

Recommendation 5

The Banksia woodlands and seasonal swamps in the north-western section of the Project Area should be further assessed with a view to developing appropriate management to preserve part or all of them in their present condition.

No rare or unusual habitats were found during the survey.

8.3 FAUNA

Based on expert opinion (WAWRC), the natural bushland remnants in the Project Area are too small to support a viable population of an animal such as the Numbat, and almost certainly the swamps do not support the Western Short-necked Tortoise.

The bushland surrounding the north-western swamps undoubtedly has high conservation value as it is one of the few areas left on the Swan Coastal Plain with relatively undisturbed swamps. Additionally, the isolation of the area from urban development almost certainly ensures that some native fauna may still exist, whereas they have been lost from other, more populated areas. Thus, despite the unsuitability of the area for the aforementioned rare species, the bushland is of intrinsic value. Recommendation 5 refers to this area and is reiterated here. **The remnant bushland should be managed and either preserved in its present form or developed as a managed wildlife habitat.**

8.4 LANDSCAPE ISSUES

Soils of the Ellenbrook Project Area are believed to be suitable for rehabilitation, gardens and vegetation programmes with a minimum of amelioration or management. The success of such programmes does, however, depend on appropriate species selection, planting methods and follow-up treatment.

Recommendation 6

It is recommended that native species be planted wherever possible and that residents of the development be encouraged to plant native gardens in preference to exotic species.

Recommendation 7

Landscaping programmes should be undertaken with due regard to the soils of the Project Area. Suitable species, planting methods and follow-up treatment should be carried out according to expert advice.

There are no major landscape constraints in the Project Area although the human environment could be greatly enhanced by sensitive planning. Other advantages to environmentally sensitive landscaping include temperature amelioration, reduction in water demand, fire protection and aesthetics.

Recommendation 8

Landscaping should take into account other factors such as minimising temperature increases through vegetation retention, use of appropriate species to minimise water demand, and correct positioning of vegetation to improve fire management.

The existing pine plantations can be directly incorporated into landscape planning, providing certain constraints, as discussed in the body of this report, are observed.

Recommendation 9

Use of pines for rehabilitation or landscaping is not recommended in areas where they do not already occur.

There is a considerable risk of the introduction or spread of dieback disease in the Project Area, mainly because of the anticipated need for the use of heavy earthmoving machinery. This risk can be greatly minimised by a number of simple and inexpensive procedures. These are discussed in Section 7.5.

Recommendation 10

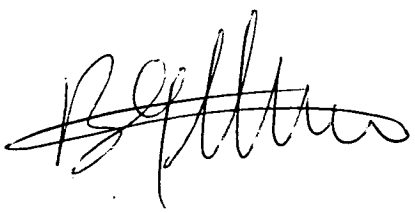
It is recommended that the Department of Conservation and Land Management be contacted to provided specialist advice on methods of minimising the risk of dieback infection, both during the construction phase of the project and following its completion.

9.0 ACKNOWLEDGEMENTS

Western Australian Herbarium and WAWRC botanists and zoologists have provided advice, information, and other assistance with the project.

* * *

Respectfully submitted
DAMES & MOORE



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BGM:/21170-001-071/dk:143-3762

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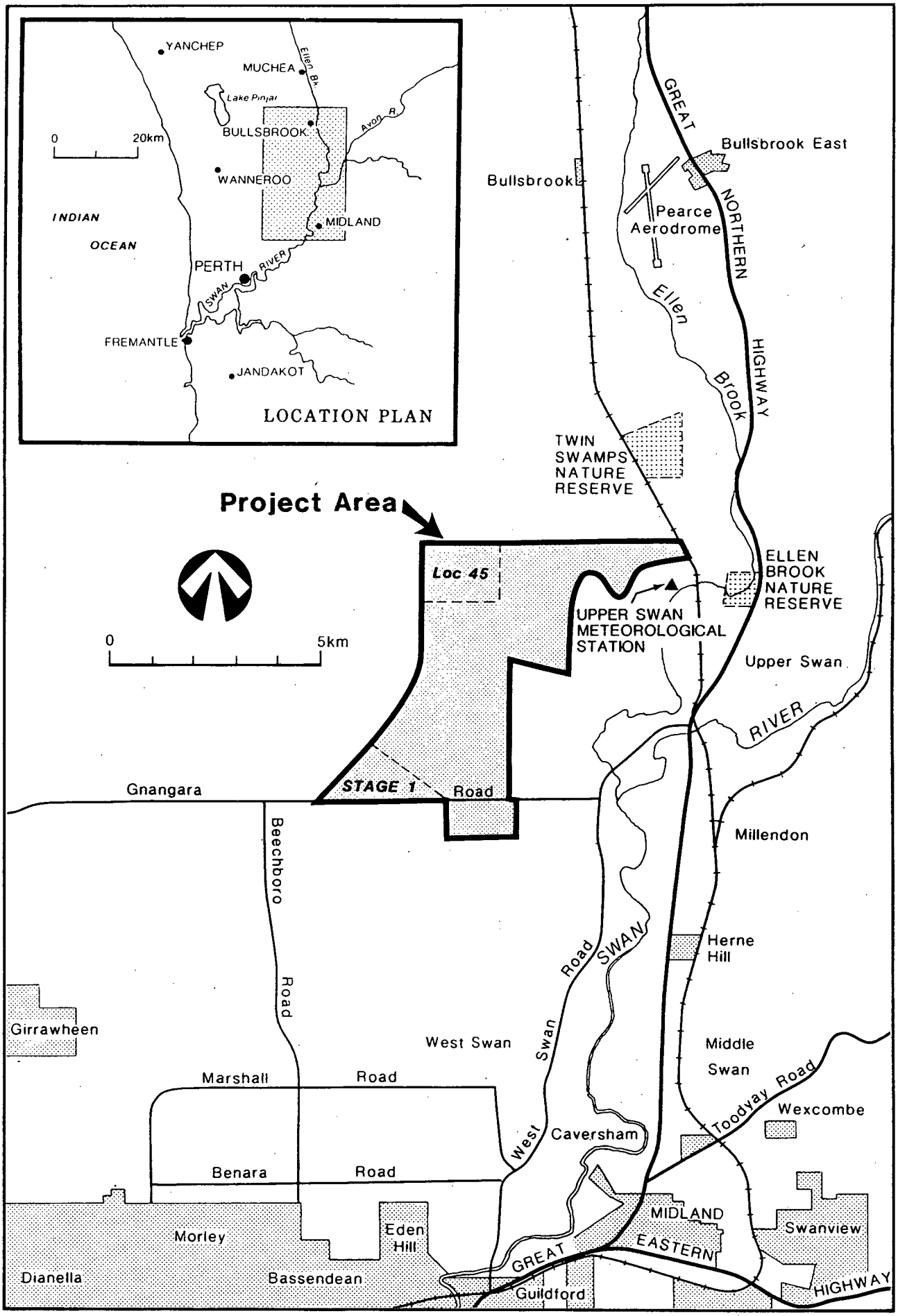
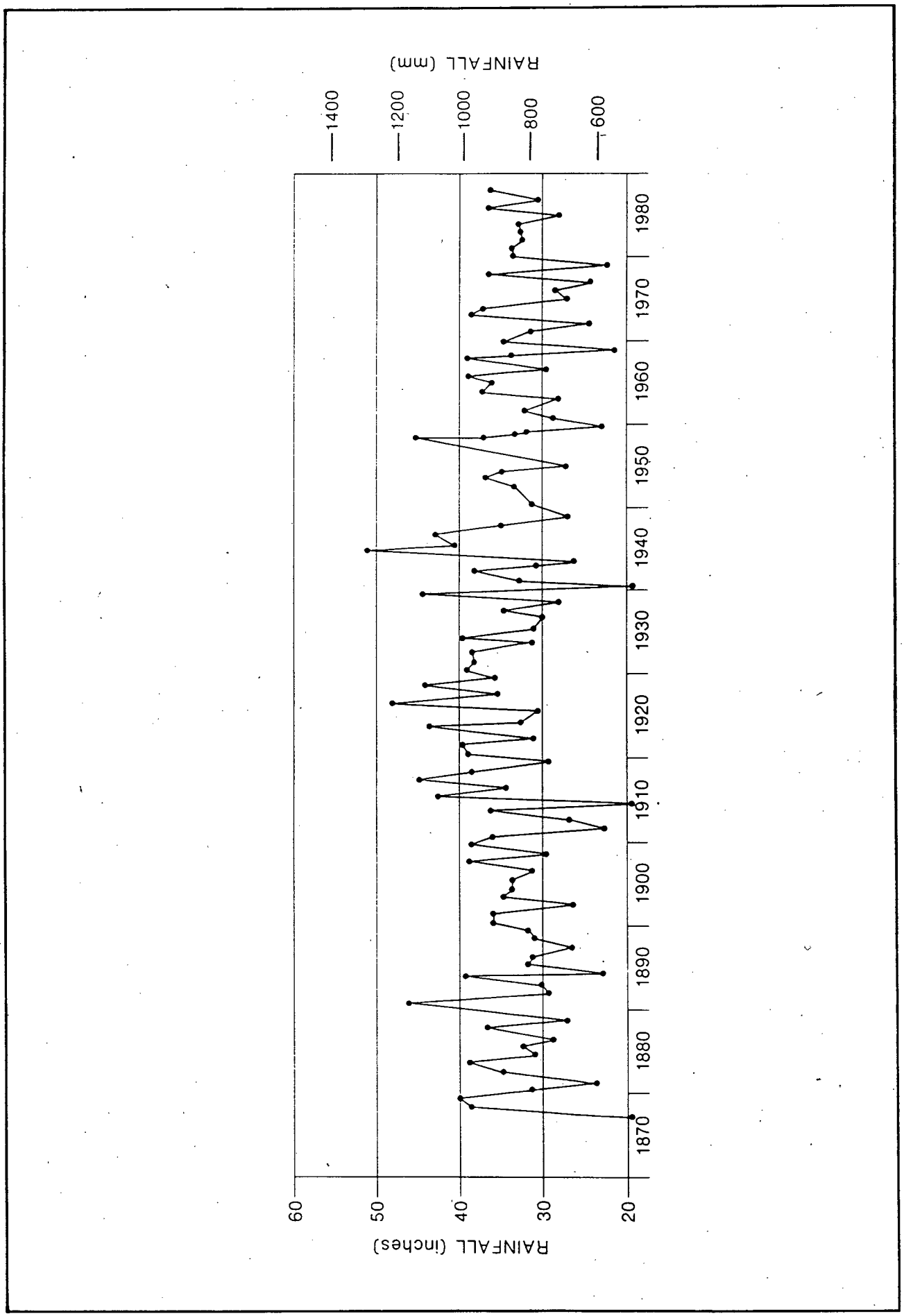
Figures



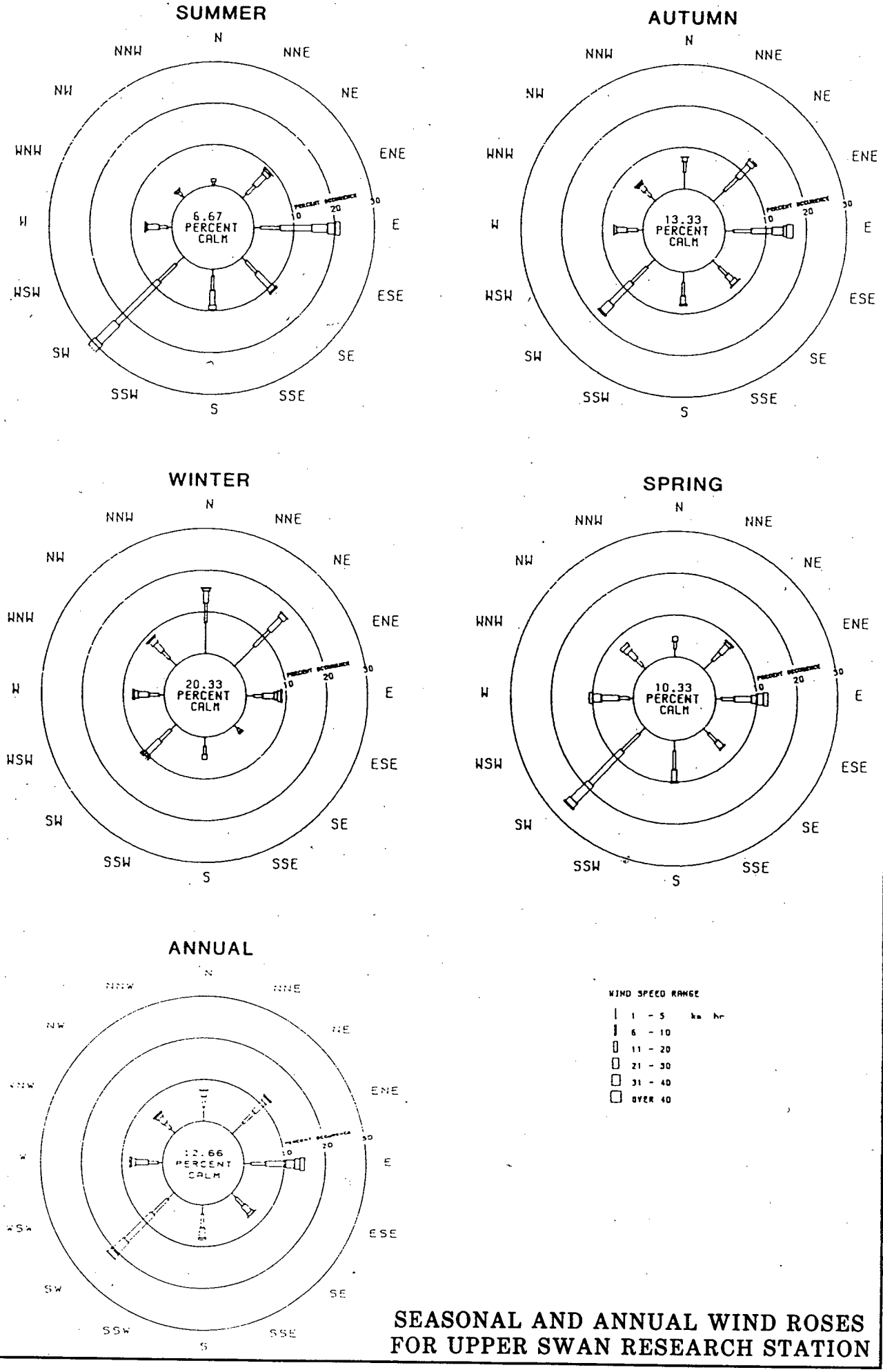
LOCALITY PLAN

FIGURE 1
DAMES & MOORE



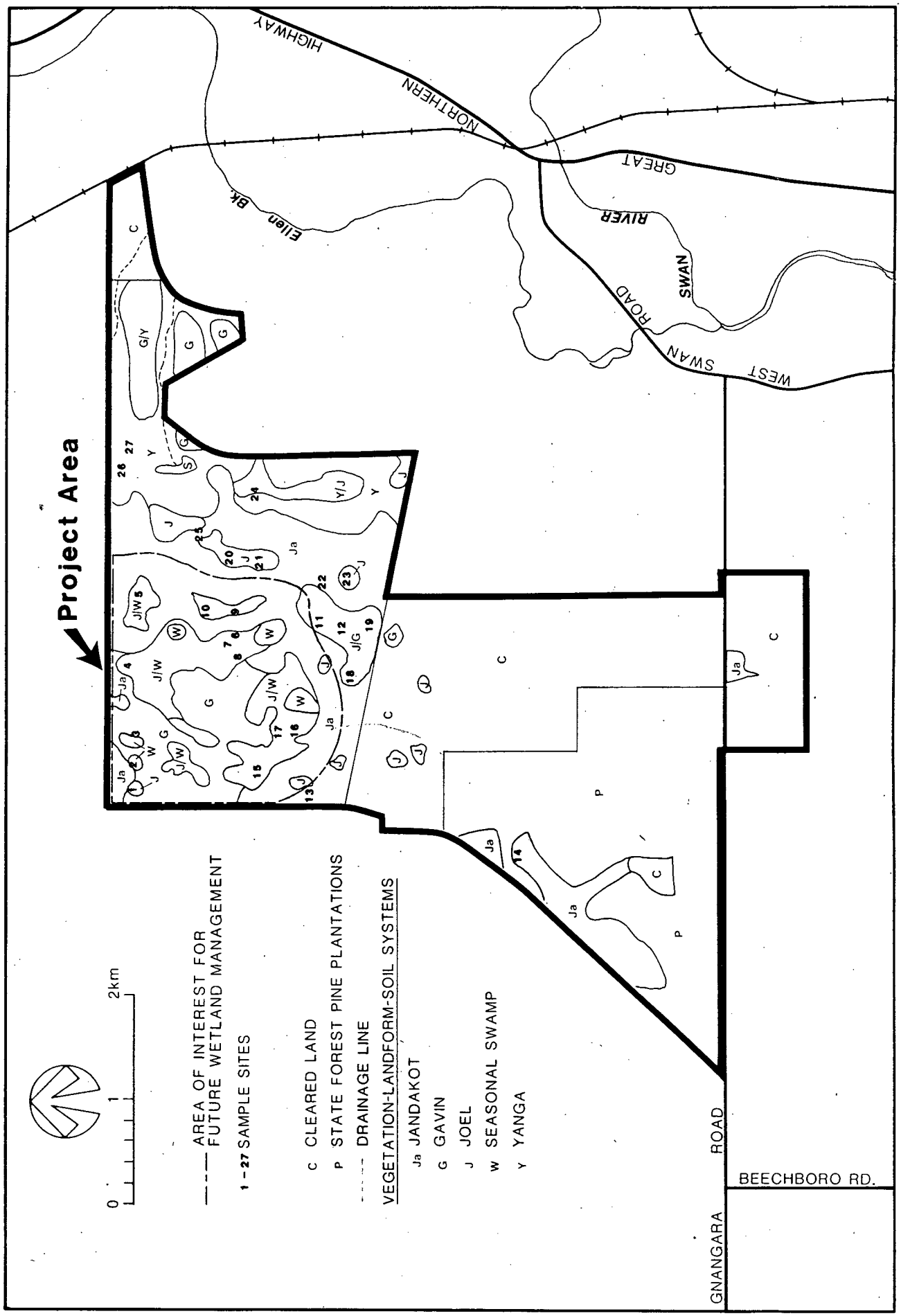
ANNUAL RAINFALL 1876-1988, PERTH

FIGURE 2
DAMES & MOORE



SEASONAL AND ANNUAL WIND ROSES FOR UPPER SWAN RESEARCH STATION

FIGURE 3
DAMES & MOORE



VEGETATION-LANDFORM-SOIL SYSTEMS & SAMPLE SITES

FIGURE 4
DAMES & MOORE

Plates

CAPTIONS - PLATE 1

Vegetation and Plants of the Ellenbrook Project Area

A Site 1 *Eremaea pauciflora* Low Heath in a depression surrounded by Banksia Low Woodland regenerating after 1988(?) burn. Dominants: *Eremaea pauciflora* (to 50cm tall), *Xanthorrhoea preissii, Phlebocarya ciliata, Patersonia ? occidentalis* and *Dasypogon bromeliifolius*. Also: emergent *Banksia ilicifolia* and *Eriostemon spicatus, Calytrix* sp., *Hibbertia* spp., *Stylidium* spp. (>6), *Acacia pulchella, Burchardia ? umbellata, Tricoryne elatior, Dampiera ? linearis, Bossiaea eriocarpa* and other species. (ASW89.10.I-6)

B Site 2 Seasonal swamp comprising overlapping and somehat variable rings of vegetation, which may differ from the pre-burn vegetation: Ring (circle) 1 (centre) - *Baumea articulata* on peat. Ring 2 - More or less bare, white sand. Ring 3 - Thin-, terete-leafed, 80cm tall sedge (*?Baumea acuta*). Ring 4 - *Astartea fascicularis*. Ring 5 - *Hypocalymma angustifolium*. Also in Rings 4 and 5: *Pultenaea reticulata, Platytheca galioides* and *Euchilopsis linearis*. (ASW89.10.I-7)

C Site 9 Seasonal swamp woodland comprising *Melaleuca preissiana, Eucalyptus rudis* and *Banksia littoralis* as dominants, with prominent *Xanthorrhoea preissii* and the sedges *Lepidosperma ? longitudinale, Lepidosperma ? tenue* and *?Baumea acuta*. (ASW89.9.III-17)

D Site 11 Grove of Marri-Jarrah Open Forest (or Woodland), with low woodland of *Banksia attenuata, B. ilicifolia* and *B. menziesii*. (ASW89.10.I-17)

E Site 14 Upland *Banksia attenuata - B. menziesii* Low Woodland, with scattered *Eucalyptus todtiana*. Shrubs and herbaceous plants include *Adenanthos cygnorum, Eremaea pauciflora, Leucopogon ? sprengelioides, Stirlingia latifolia, Eriostemon spicatus, Jacksonia floribunda, Petrophile linearis, Anigozanthos manglesii, Anigozanthos humilis, Conostylis* sp. and *Burchardia ? umbellata*. (ASW89.10.I-20)

F Site 19 *Melaleuca preissiana - Banksia littoralis* Low Forest, with *?Baumea acuta* sparse sedge layer. Shrub sequence of *Astartea fascicularis, Pericalymma ellipticum* and *Hypocalymma angustifolium* occurs to the west of Site 19. (ASW89.9.III-16)

A

B

C

D

E

F

CAPTIONS - PLATE 2

Gazetted Rare Flora (DRF) of the Perth Metropolitan Region

A *Drosera occidentalis* **(DRF)**

Drosera occidentalis is a minute, almost stemless pygmy sundew which grows on winter-wet firm sand and sandy-peat on the coastal plain. Its stipules are 3-lobed, and the leaf petiole is much longer than the circular, 0.5-1mm broad leaf blade. The cluster of populations near Anstey Road, Forrestdale, where these plants were photographed, is estimated to contain hundreds of sundew plants. Photographed in mid-October, 1989, weeks before flowering (ASW89.10.II-16). (See Rye and Hopper 1981)

B *Aponogeton hexatepalus* **(DRF)**

The largest leaves in the centre of the photograph - one green and the other pale brown - belong to *Aponogeton hexatepalus*. The floating blades are much wider than the below-surface part of each leaf. The small round yellow leaves between them are *Hydrocotyle lemnoides*. The plants are growing in a shallow, winter pool in a clay depression near Brixton Road, Kenwick. Photographed in mid-October, weeks after flowering finished (ASW89.10.I-18). (See Rye and Hopper 1981)

C *Hydrocotyle lemnoides* **(DRF)**

These floating leaves superficially resemble the slightly smaller leaves of the unrelated Duckweed (*Lemna disperma.*), but the *Hydrocotyle* leaves are often toothed and, in this photograph, have clusters of minute, dark red flowers between them. The long green leaf crossing the centre of the photograph is *Aponogeton hexatepalus*, and the kidney-shaped leaf in the lower right-hand corner belongs to *Villarsia capitata.* Photographed in pool near '**B**' in mid-October, 1989 (ASW89.10.II-4). (See Rye and Hopper 1981)

D ***Caladenia* sp. aff. *huegelii* (coastal plain) S. D. Hopper 3400** **(DRF)**

Unofficially known as *Caladenia* 'grandis', this flower was photographed in a low-lying eucalypt-banksia-sheoak open forest on Warton Road, Canning Vale, that was burnt the previous dry season. Other sites where the plant was found flowering in 1989 had not been burnt for a few years. The flower is large and the hairs on the edge of the labellum are long, yellow and often branched. Photographed in late September, 1989 (ASW89.9.I-11).

E ***Diuris* sp. aff. *laxiflora* (Kwinana) A. P. Brown 10/9/84** **(DRF)**

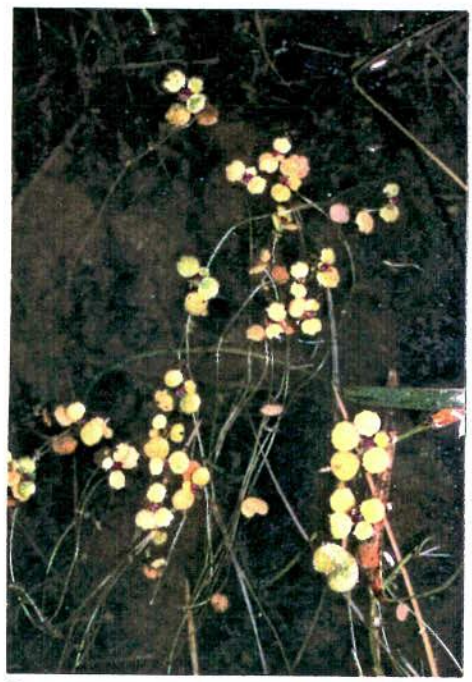
This close relative of *Diuris laxiflora*, and growing with it or nearby, is smaller, paler yellow and flowers earlier. The photographed plant is growing in a short *Lepidosperma* sedge swamp near Johnson Road, Casuarina, that is shallowly inundated in winter. Photographed in mid-September, 1989 (ASW89.9.I-1).

F *Diuris purdiei* **(DRF)**

A relatively short *Diuris* flowering in what were dense, 1m tall *Regelia ciliata* and *Pericalymma ellipticum* shrublands near Anstey Road, Forrestdale until they were destroyed by fire during the 1988-89 dry season. Photographed in mid-October, 1989 (ASW.89.10.II-13). (See Patrick and Hopper 1982)

A

B



C

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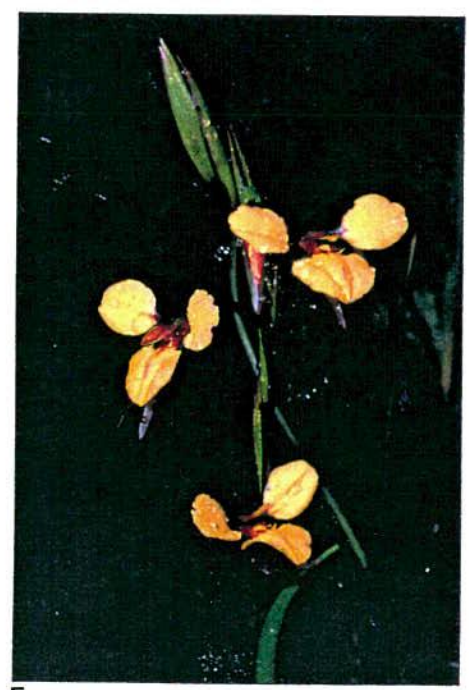


F

CAPTIONS - PLATE 3

Gazetted Rare Flora (DRF) and Some Priority Three Species (P3) of the Perth Metropolitan Region

A1 & A2 *Drakaea jeanensis* (DRF)

Flower and leaves of *Drakaea jeanensis* plants growing on firm white sandy soil in an old, long-unburnt *Kunzea ericifolia* tall shrubland near Robert Bay, Peel Inlet. Also found, previously, in then recently burnt banksia woodland in Anketell and Canning Vale. Photographed in late September, 1989 (ASW89.9.III-13 & ASW89.9.III-11).

B1 & B2 *Drakaea* sp. (south west) S. D. Hopper 3566 (DRF)

The flower and leaf of this species, unofficially called *Drakaea* 'micrantha', are the smallest of any south-western species of the genus. The whitish leaf with the dark venation, as shown in Plate B2, distinguishes it from other species. This plant was growing on sandy soil in eucalypt woodland next to Mowen Road in Mowen State Forest Block, east of Margaret River. Photographed in late September, 1989 (ASW89.9.III-22 & ASW89.9.III-21).

C ***Restio stenostachyus*** (P3)

Restio stenostachyus is a restionaceous, perennial, rhizomatous, creeping herbaceous plant recorded on the coastal plain only in the Perth Flora Region. The plant forms dense mats up to several metres broad and 0.6m tall, but where it survives in pastures it is grazed and much shorter. It is found in depressions and low areas that are wet, often with standing or flowing water, during the winter. *Restio stenostachyus* has been recorded between Gingin and a kilometre east of Serpentine River in the Lowlands area. It is more common and widespread than the Western Australian Herbarium collections indicate. Photographed near Thomas Road and Anketell Road, Oakford, in late September, 1989 (ASW89.9.II-14).

D ***Villarsia submersa*** (P3)

Like *Aponogeton hexatepalus*, with which the species sometimes occurs, *Villarsia submersa* grows in shallow, winter pools in clay depressions. It is, however, rarer than *Aponogeton hexatepalus*. Contrary to the description in the Perth Regional Flora (Marchant *et al.* 1987), the leaf blades as well as the white flowers float on the water surface. Normally the plant flowers in August and September, but in 1989 it was found still flowering in late October and early November. Until spring 1989 the species was believed to be restricted to a few localities in the south-west in the Boyanup-to-Busselton area, east of Manjimup and between Albany and Denmark (where it was found in the mid-1980s by Greg Keighery). In September 1989 the known range of *Villarsia submersa* was extended northward to the Perth Metropolitan Area, where it was found near Anstey Road, Forrestdale (by Arthur Weston) and near Brixton Road, Kenwick (by Peter Lambert). The Anstey Road populations, in which the photographed plant was growing, appear to be the largest yet recorded. Photographed in mid-September, 1989 (ASW89.9.I-21).

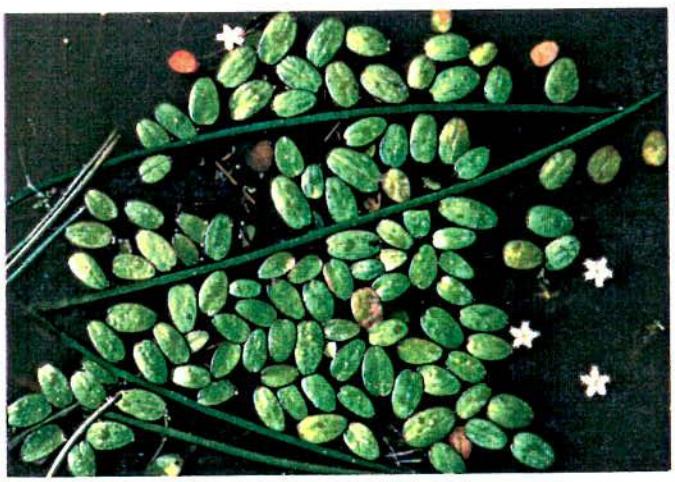
A1

B1

A2

B2

C



D

Appendix A

APPENDIX A

RESULTS OF STATISTICAL ANALYSES: LOCAL CLIMATE

APPENDIX A

RESULTS OF STATISTICAL ANALYSES: LOCAL CLIMATE

CORRELATION MATRIX
MEAN MONTHLY MAXIMUM TEMPERATURE (°C)

	Perth	Upper Swan	Pearce	Wanneroo
Perth	1.00000			
Upper Swan	0.99826	1.00000		
Pearce	0.99669	0.99586	1.00000	
Wanneroo	0.99322	0.98879	0.99398	1.00000

Critical Value (1-TAIL, 0.05) = +/- 0.49934
Critical Value (2-TAIL, 0.05) = +/- 0.57400

n = 12

CORRELATION MATRIX
MEAN MONTHLY MINIMUM TEMPERATURE (°C)

	Perth	Upper Swan	Pearce	Wanneroo
Perth	1.00000			
Upper Swan	0.98574	1.00000		
Pearce	0.98560	0.99292	1.00000	
Wanneroo	0.99486	0.98187	0.98412	1.00000

Critical Value (1-TAIL, 0.05) = +/- 0.49934
Critical Value (2-TAIL, 0.05) = +/- 0.57400

n = 12

CORRELATION MATRIX

RELATIVE HUMIDITY AT 0900 HOURS (%)

	Perth	Upper Swan	Pearce	Wanneroo
Perth	1.00000			
Upper Swan	0.99459	1.00000		
Pearce	0.99723	0.99255	1.00000	
Wanneroo	0.92310	0.93755	0.91050	1.00000

Critical Value (1-TAIL, 0.05) = +/- 0.49934
Critical Value (2-TAIL, 0.05) = +/- 0.57400

n = 12

CORRELATION MATRIX

RELATIVE HUMIDITY AT 1500 HOURS (%)

	Perth	Upper Swan	Pearce	Wanneroo
Perth	1.00000			
Upper Swan	0.98922	1.00000		
Pearce	0.99328	0.98748	1.00000	
Wanneroo	0.77417	0.74057	0.74709	1.00000

Critical Value (1-TAIL, 0.05) = +/- 0.49934
Critical Value (2-TAIL, 0.05) = +/- 0.57400

n = 12

CORRELATION MATRIX

MEAN MONTHLY RAINFALL (mm)

	Perth	Upper Swan	Pearce	Wanneroo
Perth	1.00000			
Upper Swan	0.99496	1.00000		
Pearce	0.99155	0.99787	1.00000	
Wanneroo	0.98382	0.99233	0.99058	1.00000

Critical Value (1-TAIL, 0.05) = +/- 0.49934
Critical Value (2-TAIL, 0.05) = +/- 0.57400

n = 12

Appendix B

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APPENDIX C

RARE, PRIORITY AND SIGNIFICANT FLORA

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APPENDIX C

RARE, PRIORITY AND SIGNIFICANT FLORA

C1.0 ORIGIN AND MEANING OF TERMS

C1.1 INTRODUCTION

Before one can evaluate the importance of an area for rare plant species, it is necessary to understand the term "rare", how this term originated, and how the significance of a rare species is determined. The following discussion is necessary to put the findings in the Project Area into perspective.

In 1975 Western Australia's Fauna Conservation Act was retitled as the Wildlife Conservation Act, and in 1979 the Act was amended to provide protection for specified flora as well as for fauna. The first plant species to be declared by the Minister as protected rare flora under the Act were listed in the WA Government Gazette on 14 November 1980. Periodically, the Minister publishes notices in the Government Gazette deleting and adding species to the list of protected flora. While a species, or other taxon, is gazetted as protected no-one is allowed to "gather, pluck, cut, pull up, destroy, dig up, remove or injure" a plant belonging to a wild population of that species without special written consent of the Minister (Rye and Hopper 1981). Fines may be imposed for breaching provisions of the Act.

The first list of gazetted flora comprised 100 species. The current list, printed in the WA Government Gazette on 14 July 1989, comprises 238 species. Some of the species first gazetted in 1980 are absent from the current list, because they have been found to be more abundant or wide-ranging than previously indicated by collections and records, or because they appear to be well-protected in nature reserves and national parks.

In general, species are gazetted or declared as rare flora not only because they are rare (i.e. because fewer than a few thousand reproductively mature plants of the species are known to exist in the wild) or geographically restricted but also because their continued, long-term survival in the wild is believed to be threatened.

Gazetted rare species (usually referred to as Declared Rare Flora - DRF) are not the only Western Australian plants that are rare, geographically restricted, threatened or vulnerable. In fact, they probably constitute only a small proportion of such species.

For example, Marchant and Keighery (1979) listed more than 2,000 species that were rare or poorly collected or were geographically restricted to a range of less than 160 kilometres. This section discusses such species, particularly ones that are gazetted as declared rare flora (DRF), and have been recorded in the Perth metropolitan region.

C1.2 PUBLISHED LISTS OF RARE, RESTRICTED AND POORLY COLLECTED SPECIES

Australia-wide treatments of rare, geographically restricted and endangered species by Specht, Roe and Boughton (1974), Hartley and Leigh (1979), Leigh, Briggs and Hartley (1981) and Briggs and Leigh (1988) also contain Western Australian lists, which are based upon publications or other information provided by botanists. They cover presumably rare or threatened plants but do not deal with the adequacy of collection of any species.

"Extinct and Endangered Plants of Australia", by Leigh, Boden and Briggs (1984), lists endangered and presumably extinct species and the presumed threats to their survival. The book also describes and illustrates many endangered and extinct species, discusses the inconsistent use of terms to indicate various degrees of threat and rarity, and describes the binary system developed by Hartley and Leigh (1979) to classify rare, restricted and threatened species.

The first western Australian publication on rare and restricted flora, by Marchant and Keighery (1979), is based upon the numbers of specimens of each native Western Australian species lodged in the Western Australian Herbarium and the geographical range of the collections for each species. Marchant and Keighery classify most of their 2,022 listed species as geographically restricted, presumably rare or poorly collected.

Four reports dealing with rare, restricted and threatened species have been published by the Department of Fisheries and Wildlife. One, by Rye (1982), lists geographically restricted south-western plants, and another, by Rye, Hopper and Watson (1980), is concerned with the distribution and conservation status of commercially exploited native plants. The first two lists of gazetted rare Western Australian flora are presented and the listed species are described and illustrated in Rye and Hopper (1981) and Patrick and Hopper (1982).

C1.3 "SIGNIFICANT" SPECIES

The term 'significant species' as used in this report refers to species that are:

- o rare, geographically restricted or apparently rare or restricted because they are poorly collected or recorded,
- o at the limits of their ranges or in areas outside their normal ranges or habitats,
- o particularly susceptible or vulnerable to environmental changes, especially ones caused either directly or indirectly by humans,
- o diminishing significantly in abundance or geographical range due to clearing and other environmental changes associated with agriculture, mining, recreation, urbanisation and provision of services, or
- o poorly represented in secure conservation reserves.

The term 'significant' is used in this report instead of 'vulnerable', 'sensitive', 'threatened', 'depleted' or 'endangered' because these terms either are too limited in their scope or implications or, as Leigh, Boden and Briggs (1984) put it, "have become highly emotive through popular usage, making it difficult to develop objective criteria for use in ascribing species to various categories". Leigh, Boden and Briggs discuss appropriate terminology in more detail.

All of the species in the lists appended to this report are significant species. Some significant species are gazetted as DRF; most are not.

The accuracy of most lists of significant Western Australian species is limited by the fact that they are incomplete. They do not contain varieties, subspecies or undescribed species, some of which are also rare, and the intensity, uniformity and seasonal coverage of collecting and systematic surveying have been insufficient to distinguish between genuinely rare (and restricted) species and species which only appear to be rare (or restricted) because they have been poorly collected. Systematic surveying and collecting by Western Australian Wildlife Research Centre (WAWRC) botanists, and others, are slowly correcting this deficiency.

In some cases, significant species are found in areas where they were not previously known to occur. For instance, Villarsia submersa, a small water-lily type plant, was believed to be restricted to a few small seasonal ponds between Bunbury and Busselton until recent years, when it was found near Denmark, west of Manjimup and, in 1989, in a few ponds in the

Metropolitan Region. Synaphea pinnata is a plant species previously gazetted as rare (Government Gazette, 14 November 1980) which has since been found to be more common or widespread than previously believed and is no longer gazetted.

In other cases, species are no longer found in areas where they have been previously recorded, often due to habitat destruction or alteration. However, there are many species which emerge and flower for only one or a few years after fire, then disappear until after the next burn. For example, a population of the gazetted orchid Drakaea jeanensis recorded in the metropolitan area a few years ago has not been found recently.

Other sources of incompleteness and ambiguity in distribution and abundance information are:

- o insufficient locality information given on the labels which accompany herbarium specimens,
- o inaccurate identification of specimens, and
- o treatment of groups of species as single species.

So little is known about the abundance, distribution and taxonomy of nonvascular plants that few, if any, such species are gazetted as rare flora or are included in lists of rare species, Although many of them may also be rare or geographically restricted.

C1.4 GAZETTED RARE SPECIES

The first list of declared rare flora, gazetted in 1980, was based upon assessment of the Marchant and Keighery (1979) list, addition of newly described species and local botanists' knowledge of species distributions and abundance. Gazettal of a species is now generally preceded by relatively detailed searches made in the field to locate populations of the species proposed as rare.

The gazetted list of DRF does not include all, or probably even a majority of, rare species. The current list (14 July 1989) concentrates on the south-western part of Western Australia and particular groups of species, which have, in general, been studied in greater detail than others.

For example, members of the families Proteaceae, Myrtaceae, Leguminosae and Orchidaceae account for more than 150, well over half, of the DRF on the July 1989 list. It is likely that in the south-west alone there are many more ungazetted rare and restricted species than gazetted ones.

The two lists of DRF in Rye and Hopper (1981) and Patrick and Hopper (1982) comprise about 150 species, and the most recent (1989) list contains 238 species, probably only a small proportion of Western Australian plants that could be considered as rare. Another list, in Rye (1982), contains 527 species of southern Western Australian flowering plants that are geographically restricted and includes most, if not all, of the species gazetted at that time as rare. The Rye list is based upon investigation of collections upon which the Marchant and Keighery (1979) list was based, taxonomic publications and rare plant records of the WAWRC.

Since the early 1980s WAWRC botanists have been compiling lists, descriptions, illustrations and records of significant species throughout Western Australia on a regional basis. The lists were originally compiled from herbarium records of the species listed in Rye (1982) and Marchant and Keighery (1979) and from taxonomic literature. These lists and records, along with relevant taxonomic studies, provide the basis for the lists of species proposed for gazettal and being considered for gazettal.

C1.5 PRIORITY SPECIES

The WAWRC now has continuing programmes of research and, in addition to the list of gazetted species, has five unofficial priority lists of rare and restricted species for each of the eleven management regions into which CALM has divided the State:

- Priority One (P1) Species - species known from only a few localities, which are on lands under immediate threat, and are in urgent need of further survey work,
- Priority Two (P2) Species - species known from only a few localities, which are on lands not under immediate threat, and are in urgent need of further survey work,
- Priority Three (P3) Species - species known from several localities, some of which are on lands not under immediate threat, and are in need of further survey work,
- Priority Four (P4) Species - species presumed to be extinct, and
- Priority Five (P5) Species - species considered to have been adequately surveyed and are not endangered or in need of special protection but could be if circumstances change.

These lists are modified and updated as relevant information and results of survey work become available. Priority One, Two and Three species are under consideration for declaration as rare flora, pending the outcome of further survey work.

The following descriptions are based upon field records and observations by Dames & Moore staff and upon information in Marchant et al. (1987).

C2.0 PLANTS SPECIES WITHIN THE PROJECT AREA

C2.1 RESTIO STENOSTACHYUS

Restio stenostachyus is a rhizomatous restionaceous sedge which has been recorded only in the Perth Flora Region, on the coastal plain between Gingin and Serpentine River. It is a Priority 3 species. The plant forms dense mats up to 0.6m tall, but where it survives in pastures it is grazed and is much shorter. It is found on sandy soil in depressions and low areas that are wet during the winter, often with standing or flowing water.

C2.2 DROSERA PULCHELLA

Drosera pulchella is a rosetted pygmy sundew found in perennially moist habitats between Perth and Albany. It is rare on the Swan Coastal Plain and, in the Darling Range, it usually occurs only on watercourses.

C2.2 AOTUS CORDIFOLIUS

Aotus cordifolia is a weakly erect, yellow-flowered pea with distinctive trios of whorled leaves. It has been recorded both on the coastal plain and in the Darling Range between Perth, Gidgegannup and Dwellingup. It is generally in dense swampy vegetation and appears, according to Marchant et al. (1987), to be endemic to the Perth Flora Region. However, it is recorded on the Central Forest Priority Three species list as occuring in the Witchcliffe area, in the far south-west corner of the State.

TABLE C1

GAZETTED RARE FLORA

(Government Gazette, WA of 14 July 1989)

Most of the named species in the current list of gazetted rare species are listed in the Census of the Vascular Plants of Western Australia (Green 1985). The Flora of the Perth Region (Marchant et al. 1987) describes 12 of these species as occurring in the Perth Region.

APPENDIX B

CLIMATIC DATA: UPPER SWAN METEOROLOGICAL STATION

APPENDIX B

CLIMATIC DATA: UPPER SWAN METEOROLOGICAL STATION

The Bureau of Meteorology has been recording climatic data at the Upper Swan Research Station, located immediately to the east of the Ellenbrook Project Area, since 1957. The Project Area is characterised by a temperate mediterranean climate, experiencing warm, dry summers and mild, wet winters. The seasonal rainfall results from westerly frontal systems bringing moist air from the ocean.

Lowest temperatures are normally experienced in August, when the average monthly minimum and maximum temperatures are 7°C and 18°C respectively. Maximum temperatures occur in February, when the average monthly minimum temperature is 16°C and the average monthly maximum temperature is 34°.

Average evaporation exceeds rainfall for eight months of the year. The annual average evaporation of 1609mm exceeds the annual average rainfall of 728mm by 881mm. Most of the rainfall is during the winter months, with 58% of the annual average falling between June and August. The summer season, from November to March, receives only 9% of the annual rainfall.

Mean daily evaporation is highest during the summer months, peaking in January (11mm), then decreasing until midwinter, with the lowest mean during July (2mm). Table 1 shows mean daily Class A pan evaporation levels for the Upper Swan Research Station.

TABLE B1

MEAN DAILY CLASS A PAN EVAPORATION (mm)
FOR UPPER SWAN RESEARCH STATION
FROM 1973 TO 1983

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL AVERAGE
Mean daily evaporation	11	9	7	5	3	3	2	3	3	5	7	8	1750
Lowest mean daily reading	8	7	6	4	2	2	2	2	3	4	6	7	
Highest mean daily reading	19	11	9	6	4	3	3	3	4	7	8	9	

SOURCE: Bureau of Meteorology

Table 2 shows mean monthly relative humidity for 0900 and 1500 hours. The highest relative humidity is in July, and the lowest in January and February.

TABLE B2

MEAN MONTHLY RELATIVE HUMIDITY (%)
FOR UPPER SWAN RESEARCH STATION
0900 AND 1500 HOURS

MONTH	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL AVERAGE
0900 HOURS	47	48	53	65	71	79	80	75	71	62	55	48	63
1500 HOURS	35	32	37	49	53	61	61	58	56	50	45	35	48

Source: Bureau of Meteorology

Based on records from the Upper Swan Research Station, the most common winds are south-westerlies, which are particularly prevalent in spring and summer (at 30% to 40% occurrence) at 1500 hours. During summer, approximately 55% of the winds are easterlies at 0900 hours but only 25% are from this direction at 1500 hours. Prevailing winds tend to be easterly in the mornings and south-westerly in the afternoons. Records from the Bureau of Meteorology also show the dominance of winds from the western quadrant, on a monthly basis.

WILDLIFE CONSERVATION ACT 1950

019882F3701.

PURSUANT to the provisions of subsection (2) of section 23F of the Wildlife Conservation Act 1950, I hereby declare that protected flora of the taxa listed in the schedule to this Notice growing in its original state and not in its domesticated or cultivated state are rare flora throughout the whole of the State.

The previous notice relating to rare flora published in the *Government Gazette* on 15 July 1988 is hereby cancelled.

IAN TAYLOR,
Minister for Conservation
and Land Management.

Declared Rare Flora Schedule

1989

Acacia anomala
Acacia aphylla
Acacia argutifolia
Acacia denticulosa
Acacia depressa
Acacia forrestiana
Acacia guinetii
Acacia lanuginosa
Acacia merrickae
Acacia pharangites
Acacia semicircinalis
Acacia simulans
Acacia vassalii
Acacia sp. (Chiddarcooping) J. Brown 59 & A. Williams
Acacia sp. (Dandaragan) S. van Leeuwen 269
Acacia sp. (Wongan Hills) K. F. Kenneally 7496
Adenanthos cunninghamii
Adenanthos dobagii
Adenanthos ellipticus
Adenanthos eyrei
Adenanthos ileticus
Adenanthos pungens
Adenanthos velutinus
Allocasuarina fibrosa
Allocasuarina sp. (Lake King) M. Graham 1127
Anigozanthos bicolor subsp. *minor*
Anigozanthos humilis subsp. *chrysanthus*
Anigozanthos viridis subsp. *terraspectans*
Apium prostratum subsp. *(Porongurups) G. J. Keighery 8873*
Aponogeton hexatepalus
Asplenium obtusatum
Asterolasia drummondii
Asterolasia grandiflora
Asterolasia nivea
Baeckea arbuscula
Banksia brownii
Banksia cuneata
Banksia goodii
Banksia oligantha
Banksia sphaerocarpa var. dolichostyla
Banksia tricuspis
Banksia verticillata
Billardiera mollis
Boronia adamsiana
Boronia revoluta
Caladenia bryceana
Caladenia cristata
Caladenia dorrienii
Caladenia integra
Caladenia wanosa
Caledenia sp. (Cape Naturaliste) S. D. Hopper 4518
Caladenia sp. (coastal plain) S. D. Hopper 3400
Caladeia sp. (Dunsborough) S. D. Hopper 5520b
Caladenia sp. (Esperance) D. R. Voigt 36
Caladenia sp. (Leeuwin-Naturaliste) S. D. Hopper 4670
Caladenia sp. (Moresby Range) G. J. Keighery 3328
Caladenia sp. (Muir) S. D. Hopper 3521
Caladenia sp. (Murchison) S. D. Hopper 3270
Caladenia sp. (Northampton) S. D. Hopper 3347
Caladenia sp. (salt lakes) S. D. Hopper 4162
Caladenia sp. (southern forest) S. D. Hopper 3553
Chamelaucium sp. (Busselton) G. J. Keighery 3655
Chamelaucium sp. (Cataby) G. J. Keighery 11009
Chamelaucium sp. (S coastal plain) R. D. Royce 4872
Conospermum toddii
Conostylis drummondii
Conostylis lepidospermoides
Conostylis micrantha
Conostylis misera
Conostylis rogeri
Conostylis scorsiflora subsp. *trichophylla*
Conostylis wonganensis
Coopernookia georgei
Corybas sp. (Albany) L. Byrne 10
Darwinia acerosa
Darwinia apiculata
Darwinia carnea
Darwinia collina
Darwinia macrostegia
Darwinia masonii
Darwinia meeboldii
Darwinia oxylepis
Darwinia squarrosa
Darwinia wittwerorum
Darwinia sp. (Scott River) G. J. Keighery 3582
Darwinia sp. (Stirling Range) G. J. Keighery 5732
Daviesia euphorbioides
Daviesia purpurascens
Daviesia spiralis
Daviesia sp. (central wheatbelt) M. D. Crisp 6612
Daviesia sp. (Eneabba) S. D. Hopper 4829
Daviesia sp. (Norseman) M. D. Crisp 5943
Daviesia sp. (Ravensthorpe) M. D. Crisp 6065
Daviesia sp. (Stirling Range) K. R. Newbey 5113
Daviesia sp. (Three Springs) M. D. Crisp 6480
Diuris drummondii
Diuris purdiei
Diuris sp. (Kwinana) A. P. Brown 10/9/84
Diuris sp. (Northampton) A. P. Brown 203
Drakaea jeanensis
Drakaea sp. (Great Southern) S. D. Hopper 3461
Drakaea sp. (Kalbarri) A. P. Brown 8.82
Drakaea sp. (south west) S. D. Hopper 3566
Drosera fimbriata
Drosera occidentalis
Drummondita ericoides
Drummondita hassellii var. *longifolia*
Dryandra serratuloides
Dryandra sp. (Kamballup) M. Pieroni 20/9/88
Dryandra sp. (Stirling Range) F. Lullfitz 3379
Eremophila denticulata
Eremophila inflata
Eremophila merrallii
Eremophila microtheca
Eremophila nivea
Eremophila racemosa
Eremophila resinosa
Eremophila serpens
Eremophila ternifolia
Eremophila verticillata
Eremophila virens
Eremophila viscida
Eremophila sp. (Lake King) S. D. Hopper 1807
Eremophila sp. (Newdegate—Kondinin) L. Haegi 1087
Eriostemon wonganensis
Eucalyptus beardiana
Eucalyptus bennettiae

Eucalyptus brevipes
Eucalyptus burdettiana
Eucalyptus ceracea
Eucalyptus cerasiformis
Eucalyptus coronata
Eucalyptus crucis subsp. *crucis*
Eucalyptus crucis subsp. (Paynes Find) S. D. Hopper 1842
Eucalyptus erectifolia
Eucalyptus goniantha subsp. *goniantha*
Eucalyptus insularis
Eucalyptus johnsoniana
Eucalyptus latens
Eucalyptus lateritica
Eucalyptus merrickiae
Eucalyptus mooreana
Eucalyptus rhodantha
Eucalyptus steedmanii
Eucalyptus suberea
Eucalyptus synandra subsp.(wheatbelt) A. S. George 16203
Eucalyptus sp. (Badgingarra) M.I.H. Brooker 9026
Eucalyptus sp. (Cape Naturaliste) K. H. Rechinger 58888
Eucalyptus sp. (Dandaragan) M. I. H. Brooker 9744
Eucalyptus sp. (E. Nambung) M. I. H. Brooker 9025
Eucalyptus sp. (Eneabba) M. I. H. Brooker 9736
Eucalyptus sp. (Lake Minigwal) M. I. H. Brooker 9686
Eucalyptus sp. (Midlands Highway) M. I. H. Brooker 8734
Eucalyptus sp. (Moresby Range) S. D. Hopper 2759
Eucalyptus sp. (Norseman) S. D. Hopper 2936
Eucalyptus sp. (N. Coomallo) M. I. H. Brooker 8823
Eucalyptus sp. (Northampton) M. I. H. Brooker 9196
Eucalyptus sp. (Pingaring) M. I. H. Brooker 9109
Eucalyptus sp. (Wagerup) M. I. H. Brooker 9807
Eucalyptus sp. (Yanchep) M. I. H. Brooker 8608
Eucalyptus sp. (Yandanooka) M. I. H. Brooker 9205
Gastrolobium appressum
Gastrolobium glaucum
Gastrolobium tomentosum
Grevillea cirsiifolia
Grevillea dryandroides
Grevillea inconspicua
Grevillea infundibularis
Grevillea involucrata
Grevillea prostrata
Grevillea saccata
Grevillea scapigera
Grevillea sp. (Dandaragan) S. D. Hopper 6350
Hakea aculeata
Hakea megalosperma
Halosarcia bulbosa
Hemiandra gardneri
Hemiandra rutilans
Hemigenia viscida
Hensmania chapmanii
Hibbertia bracteosa
Hydrocotyle lemnoides
Kennedia beckxiana
Kennedia glabrata
Kennedia macrophylla
Lambertia echinata
Lambertia fairallii
Lambertia orbifolia
Laxmannia jamesii
Lechenaultia chlorantha
Lechenaultia laricina
Lechenaultia pulvinaris
Lechenaultia superba
Lepidium catapycnon
Leucopogon obtectus
Melaleuca sciotostyla
Microtis globula
Microcorys eremophiloides
Myoporum salsoloides
Myoporum turbinatum
Myriophyllum petraeum
Pandanus spiralis var. *flammeus*
Pittosporum moluccanum
Pityrodia augustensis
Prostanthera carrickiana
Prostanthera magnifica
Pterostylis sp. (Northampton) S. D. Hopper 3349
Ptychosema pusillum
Pultenaea pauciflora
Rhagodia acicularis
Rhizanthella gardneri
Ricinocarpos trichophorus
Roycea pycnophylloides
Spirogardnera rubescens
Stawellia dimorphantha
Stylidium coroniforme
Stylidium galioides
Stylidium plantagineum
Stylidium scabridum
Tetratheca aphylla
Tetratheca harperi
Thelymitra psammophila
Thelymitra stellata
Thomasia montana
Thomasia sp. (York) A. S. George 8075
Thryptomene wittweri
Tribonanthes purpurea
Verreauxia verreauxii
Verticordia fimbrilepis
Verticordia helichrysantha
Verticordia hughanii
Verticordia staminosa
Verticordia sp. (Fitzgerald) C. A. Gardner 9148
Villarsia calthifolia
Wurmbea sp. (Cape Naturaliste) S. D. Hopper 5871
Wurmbea drummondii
Wurmbea tubulosa
Xyris sp. (Stirling Range) G. J. Keighery 7951

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

South Coast Region Draft Management Plan—Extension of Public Submission Period

THE Department of Conservation and Land Management has extended the public submission period on the Draft Management Plan for the South Coast Region from 31 July 1989 to 29 September 1989.

The South Coast Region is one of the eleven administrative regions of the Department of Conservation and Land Management. It stretches from the Irwin Inlet, west of Denmark, through to Eucla on the Western Australian/South Australian Border in the east. The region presently includes 13 national parks, 2 timber reserves, 4 forest blocks and over 100 nature reserves.

The draft management plan, released 2 May 1989, identifies the conservation, recreation and commercial values of the Region, and details management issues and strategies.

Copies of the draft may be purchased for $10 from the Department of Conservation and Land Management State Operations Headquarters, the South Coastal Regional Office at Albany, and the Esperance District Office. Reference copies are available for inspection at these offices, at CALM Regional Offices and at local authorities and libraries throughout the region.

Submissions should be directed to—

The Regional Plan Co-ordinator,
Department of Conservation and Land Management,
44 Serpentine Road,
Albany WA 6330.

SYD SHEA,
Executive Director.

TABLE C2

Rare, Geographically Restricted and Poorly Collected Species of Vascular Plants that might occur in or near the Gnangara Mound Region
(Table 2 from Weston, 1986)

The list, of 13 species and with information about the species' principal habitats, distributions, flowering times and numbers of collections in the Western Australian Herbarium in 1986, is based upon surveys of plant collections in the Western Australian Herbarium between 1978 and 1986. The species are listed in alphabetical order, with species and family names conforming to Green (1985). Gaps in information in the original table have been filled by reference to Marchant et al. (1987).

The number of collections of a species in the Western Australian Herbarium may give some indication of the rarity of a species, although species believed to be rare now tend to be collected more frequently, especially if they are conspicuous.

Eight of the 13 species in Table 2 have been recorded in wetland habitats. The other five have been collected in Banksia woodland and scrub vegetation. Although habitats for some of the listed species do not occur in the Project Area, all of the species were sought during the survey.

At the time the table was compiled, in 1986, the only one of the 13 species gazetted as rare was Stachystemon axillaris. That species is no longer gazetted, nor are any of the other species on the list gazetted. Two of them, however, Conostephium minus and Stylidium utriculariodes, are Priority One species.

TABLE 2

RARE, GEOGRAPHICALLY RESTRICTED AND POORLY COLLECTED SPECIES OF VASCULAR PLANTS THAT MIGHT OCCUR IN OR NEAR THE GNANGARA MOUND REGION

Scientific Name	Family	Habitat	Roots[1]	Flower[2]	Distribution[3]	No.[4]	Reserves[5]
Cartonema philydroides	COMME	Low-lying sandy soils in open jarrah/marri woodland	Shallow	7, 10-11	Kemerton - Kalbarri (E of Yanchep)	9	Yes
Conospermum huegelii	PROTE	Sandy/gravelly soil; often around granite rocks or on swampy or moist ground	Medium	7-10	Gleneagle-Serpentine Falls-Mogumber (Bullsbrook airfield)	29	Yes
Conostephium minus	EPACR	Sandy soil; Banksia woodland	Shallow; Root Type 5	7-10	Cataby - Perth (Gnangara)	12	?
Darwinia sp. A (D. aff. neildiana)[6]	MYRTA	Swampy or moist sandy ground	Shallow?	?	Muchea area (Mound Spring)	3?	No
Eremaea purpurea	MYRTA	Subswamp; low open Banksia woodland	Deep; Root Type 4	10-1	Gingin - Upper Swan (Perry Road, N of Pinjar)	13	?
Lhotskya brevifolia	MYRTA	Sandy/gravelly soil	?	9-12	Kings Park - Moore River (Bindoon)	4	Yes
Lycopodium serpentinum	LYCOP	Moist ground	-		Mound Spring, South Coast and eastern states (Mound Spring the only non-south coast site in WA)	1? (locally)	No
Lysinema elegans	EPACR	Sandy soil; Banksia scrub	Shallow; Root Type 1	10-11	Thompsons Lake - Regans Ford (Jandakot)	3	Yes
Restio stenostachya	RESTI	Sandy; swampy	Shallow, fibrous	6, 9-10	Gnangara - 12 km south of Gingin (Gnangara)	4	?
Stachystemon axillaris	EUPHO	Sandy soil	?		Near Wanneroo - Arrowsmith River (Melaleuca MPA)	10	Yes
Stylidium utricularioides	STYLI	Flat, swampy areas	?	10-12	Pinjarra - 31mi. peg, GNHighway (Gnangara)	15	?
Tetratheca pilifera	TREMA	Banksia woodland	Shallow ?	8-10	Yanchep/Lancelin - Wooroloo (Wanneroo)	7	Yes
Thelymitra sp. A (Th. aff. carnea)[7]	ORCHI	Swamp edges	?	9-10	Wanneroo, Cannington, Jandakot (Wanneroo)	3	?

1. The root type information is contributed by E M Mattiske. Root Types 1, 4 and 5 are briefly defined in Addendum II of Appendix A in this set of documents and are described in more detail by Dodd et al., (1984).
2. Times of flowering are based on inspection of labels on Western Australian Herbarium collections. The numbers refer to the months, e.g. 9 = September, in which specimens were collected in flower.
3. Distribution information is also based upon Western Australian Herbarium collection labels. The name in brackets is the location in or closest to the survey area in which the species has been recorded.
4. The numbers indicate the number of collections of each species in the Western Australian Herbarium.
5. Species protected in National Parks or Conservation Reserves.
6. The forthcoming flora of the Perth Region being prepared by the Western Australian Herbarium assigns the temporary, informal name 'Darwinia sp. A' to this undescribed species.
7. The Perth regional flora assigns the name 'Thelymitra sp. A' to the local orchids that have been called 'Thelymitra carnea'. The plants are, apparently, not proper species but hybrids.

TABLE 2

RARE, GEOGRAPHICALLY RESTRICTED AND POORLY COLLECTED SPECIES OF VASCULAR PLANTS THAT MIGHT OCCUR IN OR NEAR THE GNANGARA MOUND REGION

Scientific Name	Family	Habitat	Roots[1]	Flower[2]	Distribution[3]	No.[4]	Reserves[5]
Cartonema philydroides	COMME	Low-lying sandy soils in open jarrah/marri woodland	Shallow	7, 10-11	Kemerton - Kalbarri (E of Yanchep)	9	Yes
Conospermum huegelii	PROTE	Sandy/gravelly soil; often around granite rocks or on swampy or moist ground	Medium	7-10	Gleneagle-Serpentine Falls-Mogumber (Bullsbrook airfield)	29	Yes
Conostephium minus	EPACR	Sandy soil; Banksia woodland	Shallow; Root Type 5	7-10	Cataby - Perth (Gnangara)	12	?
Darwinia sp. A (D. aff. neildiana)[6]	MYRTA	Swampy or moist sandy ground	Shallow?	?	Muchea area (Mound Spring)	3?	No
Eremaea purpurea	MYRTA	Subswamp; low open Banksia woodland	Deep; Root Type 4	10-1	Gingin - Upper Swan (Perry Road, N of Pinjar)	13	?
Lhotskya brevifolia	MYRTA	Sandy/gravelly soil	?	9-12	Kings Park - Moore River (Bindoon)	4	Yes
Lycopodium serpentinum	LYCOP	Moist ground	-		Mound Spring, South Coast and eastern states (Mound Spring the only non-south coast site in WA)	1? (locally)	No
Lysinema elegans	EPACR	Sandy soil; Banksia scrub	Shallow; Root Type 1	10-11	Thompsons Lake - Regans Ford (Jandakot)	3	Yes
Restio stenostachya	RESTI	Sandy; swampy	Shallow, fibrous	6, 9-10	Gnangara - 12 km south of Gingin (Gnangara)	4	?
Stachystemon axillaris	EUPHO	Sandy soil	?		Near Wanneroo - Arrowsmith River (Melaleuca MPA)	10	Yes
Stylidium utricularioides	STYLI	Flat, swampy areas	?	10-12	Pinjarra - 31mi. peg, GNHighway (Gnangara)	15	?
Tetratheca pilifera	TREMA	Banksia woodland	Shallow ?	8-10	Yanchep/Lancelin - Wooroloo (Wanneroo)	7	Yes
Thelymitra sp. A (Th. aff. carnea)[7]	ORCHI	Swamp edges	?	9-10	Wanneroo, Cannington, Jandakot (Wanneroo)	3	?

1. The root type information is contributed by E M Mattiske. Root Types 1, 4 and 5 are briefly defined in Addendum II of Appendix A in this set of documents and are described in more detail by Dodd et al., (1984).
2. Times of flowering are based on inspection of labels on Western Australian Herbarium collections. The numbers refer to the months, e.g. 9 = September, in which specimens were collected in flower.
3. Distribution information is also based upon Western Australian Herbarium collection labels. The name in brackets is the location in or closest to the survey area in which the species has been recorded.
4. The numbers indicate the number of collections of each species in the Western Australian Herbarium.
5. Species protected in National Parks or Conservation Reserves.
6. The forthcoming flora of the Perth Region being prepared by the Western Australian Herbarium assigns the temporary, informal name 'Darwinia sp. A' to this undescribed species.
7. The Perth regional flora assigns the name 'Thelymitra sp. A' to the local orchids that have been called 'Thelymitra carnea'. The plants are, apparently, not proper species but hybrids.

TABLE C3

Priority One, Two and Three Species of the Metropolitan Region (pers. comm. WAWRC, October 1989)

Key:

PRIORITY CODES

Priority One Species which are known from one or a few localities on lands under immediate threat, e.g. road verges, urban areas, active mineral leases, areas grazed by feral animals, etc. These species are under consideration for declaration as rare flora but are in need of urgent high priority further survey.

Priority Two Species which are known from one or a few localities on lands not under immediate threat, e.g. nature reserves, national parks, vacant crown land, water reserves, etc. These species are under consideration for declaration as rare flora but are in need of urgent high priority further survey.

Priority Three Species which are known from several localities, some of which are on lands not under immediate threat. These species are under consideration for declaration as rare flora but are in need of further survey.

Priority Four - taxa presumed extinct
Species which have not been collected or reliably observed in the wild over the past 50 years, or whose total known wild population has been destroyed more recently.

Priority Five - taxa for high priority monitoring
Species which are considered to have be adequately surveyed and not endangered or in need of special protection, but could be if present circumstances change. These species are usually represented on reserves.

OTHER CALM REGIONS

CF	Central Forest
GAS	Gascoyne
GLD	Goldfields
M	Metropolitan
NF	Northern Forest
SC	South Coast
SF	Southern Forest
W	Wheatbelt

Priority One

METROPOLITAN

Species	Distribution	Flowering Period	Other CALM Regions
Asteridea gracilis	Gosnells	Sep-Oct	NF
Beyeria cygnorum	Reabold Hill	Nov	
Conostephium minus	Gnangara, Guildford, Belmont	Jul-Sep	GRE,NF
Grevillea thelemanniana subsp. thelemanniana	Cannington, Kenwick	Jun-Sep	NF
Hydatella dioica	Upper Swan	Sep-Nov	NF
Hydrocotyle hispidula	Garden Island	Sep-Nov	SC
Lepidosperma rostratum	Cannington	Aug	
Mitrasacme palustris	Midland	Oct	W
Schoenus andrewsii	Cannington	Jan-Feb	GRE
Schoenus pennisetis	Cannington	Aug-Sep	
Stylidium utricularioides	Canning Vale	Oct-Dec	NF
Thysanotus glaucus	Forrestdale	Nov-Feb	GRE

Priority Two

METROPOLITAN

Species	Distribution	Flowering Period	Other CALM Regions
Haloragis aculeolata	Cannington	Dec	SC
Lepidium puberulum	Rottnest Island	Aug	GRE,GAS
Leucopogon glaucifolius	Midland	Oct-Nov	SC
Lysinema elegans	Jandakot	Oct-Nov	GRE
Tripterococcus sp. (A.S. George 14234)	Cannington	Nov-Feb	CF

Priority Three

METROPOLITAN

Species	Distribution	Flowering Period	Other CALM Regions
Anthotium junciforme	Midland, Bayswater, Serpentine, Cannington, Kelmscott	Dec-Feb	NF,CF
Cartonema philydroides	Midland	Oct-Jan	GRE,CF,NF
Gonocarpus pithyoides	Fremantle	Oct-Nov	NF
Jacksonia gracilis	Perth	Jan-Feb	NF
Myriocephalus appendiculatus	Midland	Sep-Dec	GRE,SC
Philydrella drummondii	Bayswater, Guildford	Oct	NF,SF
Phlebocarya filifolia	Cannington, Jandakot	Sep-Nov	GRE,NF,
Restio stenostachyus	Canning River	Feb-Mar	NF
Rinzia crassifolia	Perth	Aug-Sep	GRE,W
Thysanotus arbuscula	Bayswater	Nov-Jan	NF,GRE,CF
Triglochin stowardii	Twin Swamps	Sep	GRE,W,CF

(SVL 13/9/89)

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ELLENBROOK DEVELOPMENT
PUBLIC ENVIRONMENTAL REVIEW

APPENDIX A2

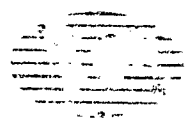
Conservation Assessment

CONSERVATION ASSESSMENT
ELLENBROOK DEVELOPMENT

for

Ellenbrook Management Pty Ltd

DAMES & MOORE



Dames & Moore Job No. 21170-001-071

January 1992

EXECUTIVE SUMMARY

The Ellenbrook New Community Project is seen as providing up to 10% of Perth's metropolitan urban growth over the next fifteen years. The project comprises approximately 1,800ha and is located about 20km northeast of the Perth Central Business District.

Environmental studies identified the Ellenbrook area as containing some significant wetlands which, because of their isolation, were in near-pristine condition. Concern for the protection of these wetlands led the proponents of the Ellenbrook Project to commission biological studies to assess which areas were most important, and to determine how they should best be managed.

Field studies were conducted between 1982 and 1991; mostly in 1990 and 1991. Vegetation organisation, vegetation cover, hydrological origin, vegetation structure, water chemistry and numerous other parameters were examined both qualitatively and statistically. Later in the studies (1991) and at the request of the Environmental Protection Authority, some observations were also made on the Brown Bandicoot.

Fauna studies were not an integral part of the overall assessment. This was because of the considerable time delays and high cost of fauna surveys, together with the frequently inconclusive results of such surveys. The approach to the study centred around the vegetation structure and floristics as adequate definition of the vegetation. By default, this approach also defines habitat and therefore identifies the likely major faunal utilisation of the area. This is a standard approach widely adopted by all land management agencies in the world.

Results indicate that the Lexia wetlands at Ellenbrook are quite heterogeneous. Qualitative analyses indicate a wide variety of wetland types which can be compared in scope with wetlands occurring regionally across the Swan Coastal Plain. Similarly, quantitative analyses show a low level of similarity between the wetlands and again emphasise the heterogeneity of the Ellenbrook Lexia wetland system. Both of these methods were able to detect differences which were not apparent to observers in the field, yet differed from each other and from intuitive variations observed during field studies.

Structural comparison of the Lexia wetlands and the quantitative analyses both suggest some basic differences between the wetlands of the eastern and western sectors of the Lexia Area. Some classification methods tend to aggregate wetlands according to hydrology (e.g. sumplands versus damplands versus seepages) and vegetation organisation and pattern. They then fail to clearly discriminate between the eastern and western section of the Lexia wetlands because they are not concerned with floristics except at a superficial level.

Water analyses show that the Ellenbrook Lexia wetlands tend to have acidic pH levels, naturally high nutrient levels and low total dissolved solids. As the Lexia wetlands can be considered to be almost pristine, it is considered that these parameters reflect a high level of bioproductivity compared to the urbanised wetlands of the Swan Coastal Plain. At the same time, the low level of natural salts reflects the lack of input from polluted waters containing sodium chloride and other minerals.

In the Sawpit Area there are no wetlands of the type found in the Lexia Area. Rather, the low-lying ground is represented by "damp woodlands" which grade into dry woodlands as the topographic altitude increases. The structure and floristics of these woodlands is similar to that recorded at Whiteman Park and Melaleuca Park, two conservation reserves in the same area. The northeastern corner of the Sawpit Area contains Sawpit Gully, a drainage line which overlies Guildford Clay soils. This gully is very degraded and weed infested at its eastern end, but improves in its conservation value towards the west. The gully contains the Gazetted Rare orchid *Caladenia huegellii* and the Priority Three species *Cartonema philydroides.*

Woodlands associated with the Lexia wetlands were found to contain areas where the Priority Three species *Cartonema philydroides* and *Conostephium minus* occurred.

In terms of conservation value the most significant part of the Ellenbrook Project Area is the Lexia wetlands. The damp woodlands and Sawpit Gully also have some importance, as do the dry woodlands, although the damp and dry woodlands are well represented in other conservation reserves. Sawpit Gully, because of its weed infestations, probably has limited long-term conservation value.

There is no evidence that any truly rare fauna occur in the area, and present observations suggest it is not especially rich in animal life. As far as can be determined, even the wetlands have no substantial populations of waterbirds. The presence of Brown Bandicoot is of interest, but this species is very common and widespread throughout the southwest. It is also tolerant to disturbance, despite its current Gazettal as Rare.

In summary, the value of the Lexia wetlands lies purely in the fact that they are relatively pristine, unlike nearly all other wetlands of the Swan Coastal Plain.

To preserve their pristine nature in the long-term, even if the Ellenbrook Project did not proceed, will become increasingly difficult. Dieback disease introduced by recreation activities, feral animals (cats and dogs were observed in the area) foxes and weed encroachment will gradually degrade the area over time. Nonetheless, the same factors affect all other wetlands on the coastal plain so that in the future, all other things being equal, the Lexia wetlands may still be in better condition than other areas.

If the natural attributes of the area are to be retained active management will be essential. These activities must include feral animal control, fire control, dieback management and management of people.

The principles of management will need to be established to ensure that, if some of the area is to be preserved, that this is carried out as cost-effectively as possible and in an ecologically sensitive manner. A subsequent report addresses these management issues in some detail and proposes a preferred management scenario.

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CONSERVATION ASSESSMENT
ELLENBROOK DEVELOPMENT

1.0 INTRODUCTION

The Ellenbrook Development is seen as providing up to 10% of Perth's metropolitan urban growth over the next fifteen years. The project comprises approximately 1,800ha and is located about 20km northeast of Perth Central Business District.

Dames & Moore has undertaken two preliminary environmental assessments of the area. These assessments included studies on several wetland complexes in the northwestern portion of the project area (Dames & Moore, 1988; 1990). These reports identified the wetlands as being significant for conservation of natural heritage and put forward recommendations for protection and further research. In particular, the following recommendation is relevant:

- Recommendation 5 (Dames & Moore, 1990)
  The *Banksia* woodlands and seasonal swamps in the north-western section should be further assessed with a view to developing appropriate management to preserve part or all of them in their present condition.

This current report seeks to undertake more detailed ecological studies on the northwest wetlands to better determine long-term management options. It also examines, in less detail, the wetlands in the eastern portion of the area, and the woodlands.

For brevity, and to avoid confusion as to what wetlands are referred to during this discussion, the wetlands in the northwestern portion of the Study Area (Figures 1 and 2) will be referred to as the "Lexia" wetlands and the area as the Lexia Area. This term is taken from Middle (1991). The eastern portion of the Study Area (Figures 1 and 3) contains Sawpit Gully drainage line and will therefore be referred to the Sawpit Area.

Preliminary planning and design of the site for urban development commenced in August 1990 and it is anticipated that construction works will commence in 1993. During this period, Environmental Impact Assessment, under the Environmental Protection Act 1986, will be undertaken and a report prepared for presentation to the Environmental Protection Authority. A more detailed analysis of constraints and opportunities related to the wetlands is required for evaluation as part of the EIA process.

Ellenbrook Management Pty Ltd (EM) was formed to manage the project on behalf of the owners. EM is responsible for planning, public relations, project feasibility and the management of all subconsultants and contractors.

2.0 SCOPE OF WORK

The scope of work for the conservation assessment in the Ellenbrook area is based on the project brief supplied to Dames & Moore by Ellenbrook Management Pty Ltd and on modifications outlined in a letter dated 3 September 1990. The following scope of work was undertaken:

- review and assessment of available data, including previous work carried out by Dames & Moore and hydrological information from GRC-Dames & Moore;
- a field study to provide ecological information on the wetlands;
- interpretation of the data and an evaluation of the implications for short-term and long-term conservation and management of the resource;
- provision of an interim report on findings;
- ongoing liaison during the review and evaluation process; and
- preparation of a final report suitable for presentation to the Environmental Protection Authority.

In addition, in November 1991, the Environmental Protection Authority (EPA) and Department of Conservation and Land Management requested further work. This additional work involved:

- examination of the woodlands for *Dryandra mimica,* as this species had been added to the Gazetted Rare Flora list since the earlier Dames & Moore surveys;
- examination of wetlands and woodlands for the Gazetted Rare plant *Caladenia huegelii* as this had since been found in the area but was not located during earlier Dames & Moore surveys;
- re-examination of the wetlands for rare aquatic species of plants, as the area had experienced a particularly wet winter;
- collection of some information on the wetlands and woodlands which lie in the eastern sector of the possible area of impact, and evaluation of all wetland using the methodology presented in EPA (1991);

- o an evaluation of the basic ecological relationships between the woodlands and the wetlands. This did not require a statistical approach of the type used to evaluate the wetlands, but should compare the woodlands with other, similar areas;
- o a desk-top evaluation of fauna of the area; and
- o an assessment of utilisation of the area by the Brown Bandicoot *(Isoodon obesulus)*. This species was added to the list of Gazetted Rare Fauna since the earlier work was undertaken by Dames & Moore.

This report contains the combined information from all the above requirements.

3.0 METHODOLOGY

The environmental assessment project was undertaken in four stages:

- o pre-survey collation of available data;
- o field studies;
- o analysis of the field data ; and
- o report preparation.

3.1 PRE-SURVEY COLLATION OF AVAILABLE DATA

The pre-survey component evaluated the existing relevant environmental data, including that collected as part of earlier Dames & Moore studies. The data were reviewed, particularly information on topography, soils, hydrology and vegetation structure and floristics. These data were used to estimate the ecological relationships between the various factors. Hydrological and climatic parameters were also reviewed and placed into an ecological context.

3.2 FIELD STUDIES

3.2.1 The Lexia Wetlands

The field studies aimed to provide on-site data to form a basis for statistical and ecological evaluation of the Lexia wetlands. These analyses clarified the following points:

- o soil structure, soil origin and hydrology in the ecotones around the swamp edges. These factors were largely determined by digging holes (with a spade) in the centre (wettest part) and outer bands of the wetland until either groundwater was reached or digging became too difficult. In some transects where the water table was close to or above the ground surface level, the water table depth was also estimated in the same way for an outer band. These data will help to provide an understanding of the hydrological factors controlling wetland water levels and associated soil conditions and profiles;
- o chemical analyses of water quality including pH, total dissolved solids, total N, NH_3-N, NO_3-N, total P and total Kjeldhal N, to undertake a hydrological assessment from a chemical/ecological rather than an engineering point of view;
- o physiognomic similarities were studied in the ecotonal bands to determine whether there are any important structural assemblages, and to find whether there are any particular hydrological dependencies;
- o floristic similarity between ecotones and between wetlands to evaluate the most unique habitats. This was only undertaken for structural or abundance-dominant species; and
- o searches for rare or significant flora.

From these data and analyses, guidelines were developed to maximise long-term conservation values. EPA (1990b) methodology was also used to evaluate conservation aspects.

3.2.2 Wetlands of Sawpit Area

Wetlands of the eastern portion (Sawpit Area) of the Ellenbrook Study Area were not surveyed to the level of complexity applied to those in the northwest portion. This was because:

- o they were much less well defined and many were more like damp woodlands than true wetlands; and
- o none contained free water, even at the end of winter (except for the drainage line known as Sawpit Gully in the extreme northeast portion of the Study Area).

The procedure employed in the Sawpit Area was to examine the area in detail and record structural and floristic information similar to that collected in the Lexia wetland. Precisely located transects and statistically precise data analyses were not used.

3.2.3 Woodlands of the Lexia and Sawpit Areas

Transects were located so as to sample the main types of woodlands as determined from inspection of aerial photographs. At each transect a traverse of approximately 250m long by 50-60m wide was undertaken (paced, not measured) and vegetation structure and floristic dominance recorded. The methodology follows Muir (1977).

3.2.4 Rare and Significant Flora

Searches for rare or significant flora have been carried out in various parts of the area on the following dates:

- December 1982;
- December 1987;
- August 1990; and
- December 1991.

Rare and significant flora were searched for in the following manner:

- a list was prepared of all Declared Rare Flora and Priority Flora known from the region. This was compiled using the Dames & Moore Rare Flora Database and information from the Rare Flora Database held by the Department of Conservation and Land Management (CALM) including the latest (21 November 1991) list;
- species which could not occur in the area because the habitat was completely absent (e.g. granite outcrops) were deleted from the list;
- Dames & Moore botanists then examined the selected species in the Western Australian Herbarium and became familiar with their appearance, life-form, identifying characteristics and habitat. Black and white photocopies were made of relevant herbarium sheets to provide in-field reference material;
- in the field two people familiar with the species walked a transect about 250m long by about 60m wide, or along the length of ecotone habitats, searching for the selected species; and
- a small specimen was taken from any plant which could have been a significant species, or which was not readily recognised in the field. This material was then identified by reference to literature and comparison with specimens held in the Western Australian Herbarium.

3.2.5 Fauna

A regional review of the fauna was derived from information prepared for the Gnangara Mound Groundwater Resources ERMP (Dames & Moore, 1986). The relevant section of that report has been reproduced with modifications in Section 4.6. The Western Australian Museum has contributed to updating the information contained in that section.

CALM also requested a specific search for Brown Bandicoot *(Isoodon obesulus)* as the species is believed to be becoming scarce in the metropolitan area although it is very common elsewhere. Previous work on recording abundance of Brown Bandicoot (Sanders, pers. comm.) has used the number of diggings as an indication of the abundance of the species. Bandicoot diggings are of a characteristic size and shape and usually distinguishable from rabbit diggings. The latter also usually have droppings associated with them, whereas Bandicoot diggings do not. The methodology for Bandicoot estimation is in its infancy and fraught with problems. Nonetheless, in the absence of any better method it is of some value.

In the present study the search area of each transect was about 1.25ha, i.e. about 250m long by about 50m wide. The transect was searched by three people, and was well covered. The relative abundance of diggings was recorded. Any diggings doubtful as to whether or not they were rabbit or bandicoot, were ignored.

3.3 ANALYSIS OF FIELD DATA

3.3.1 Classification of the Lexia Wetlands

An important step in evaluating the wetlands of the Ellenbrook Study Area is classification. The discussion below outlines the methodology and philosophy used.

Two methods were considered for classifying the wetlands:

- Qualitative Classification
  This form of classification allows the consideration of large amounts of disparate information or data. Its principal disadvantage is that it is difficult to cognitively evaluate these data due to their complexity; and

- Quantitative Classification
  Quantitative evaluation of data using a computer facilitates the development of relationships that qualitative evaluation may miss. It can also manipulate complex mathematical data with ease. However, it can only model relatively simple data sets (simple in the sense that the data cannot be disparate or unrelated) and thus the "big picture" may not be seen.

It is felt that there is merit in using both methods and in comparing the results.

Developing a classification **within** a wetland is difficult because the vegetation ranges from simple to complex in several ways:

- in size - it may range from small scale to regionally extensive units;
- in structure - it may contain a mix of woodlands, heaths, sedgelands, etc.; and
- in organisation - it may be simple or zoned, or composed of mosaics.

Mosaic vegetation may reflect variation in community history, or variation and gradients in topography, soils, water availability, and other edaphic factors. Alternatively, extensive "simple" (structurally and compositionally homogeneous) wetland vegetation may reflect underlying uniform environmental conditions.

The objectives for wetland classification at Ellenbrook are:

- to present a simplified view of the structure and organisation of wetland vegetation. The use of physiognomic categories are considered of most benefit, particularly density and height of plant cover, and dominant life forms;

- o to relate suites of vegetation communities or physiognomic types to either a given type of wetland or to habitats and edaphic features, such as geomorphology and hydrology within wetlands;
- o to use data from within wetlands to compare the type and extent of patterns between different wetland areas;
- o to place wetlands at a stage in their successional development; and
- o to convey information on the size and extent of the wetland vegetation complex.

3.3.2 Qualitative Evaluation

The qualitative classification system chosen for this project is that of Semeniuk *et al.* (1990) and is outlined below. Semeniuk *et al.* (*ibid.*) proposed a classification system for the wetlands of the Darling System based on the scale of vegetation complexes, the extent of vegetation cover over the wetland, internal organisation of vegetation when viewed in plan, vegetation structure, and details of the floristic/structural components. Vegetation cover is divided into three classes - homogeneous, zoned and heterogeneous. The combination of cover and internal organisation results in the recognition of nine basic wetland vegetation categories: periform, paniform, latiform, zoniform, gradiform, concentriform, bacataform, heteroform, and maculiform. These terms form the primary part of a binary terminology which forms the core of the classification. Established structural terms are adopted to describe the structure of wetland vegetation, and this forms the second part of the binary terminology. Scale terms are added as adjectival qualifiers, and details of floristics and structure in combination may be added as an adjunct to the main binary system. Thus, this approach provides a systematic way to describe and compile an inventory of wetland vegetation units. The classification provides a conceptual picture of the wetland vegetation, and the diversity and complexity of vegetation of specific wetlands then becomes more obvious. It also allows for wetlands to be classified and thereby easily compared.

The table below sets out and defines the terms used by Semeniuk *et al.* (1990). The term seepage has been added to accommodate part of the Ellenbrook wetlands.

TABLE 1

DEFINITION OF CLASSIFICATION TERMS

Scale		*Vegetation Organisation*	*Vegetation Cover*			*Type*	
			Peripheral	*Mosaic*	*Complete (>90%)*		
MEGA	Wetland complex larger than a frame of reference 10km x 10km	HOMOGENEOUS	Periform	Paniform	Latiform	LAKE	Permanently inundated
MACRO	Wetland complex encompassed by a frame of reference 1000m x 1000m to 10km x 10km	ZONED	Zoniform	Gradiform	Concentriform	SUMPLAND	Seasonally inundated
MESO	Wetland complex encompassed by a frame of reference 500m x 500m to 1000m x 1000m	HETEROGENEOUS	Bacataform	Heteroform	Maculiform	DAMPLAND	Seasonally waterlogged
MICRO	Wetland complex encompassed by a frame of reference 100m x 100m to 500m x 500m					SEEPAGE[1]	Dampland which is geomorphologically controlled
LEPTO	Wetland complex smaller than a frame of reference 100m x 100m						

Note: 1. The term seepage does not appear in Semeniuk *et al.*'s classification and is a modification proposed for this study. Seepages occur at the base of dunal systems of permeable sands which rest unconformably upon impermeable clays.

3.3.3 Quantitative Evaluation

One of the most widely used quantitative measures which allows for the classification of communities is the similarity coefficient. Similarity measures are peculiar because they are mainly descriptive coefficients, not estimators of some statistical parameter. Of the broad classes of similarity measures it is proposed to use a binary similarity coefficient for this study. The reasons for this are twofold:

- o binary similarity coefficients are simple to use and will provide a measurement of vegetation association at the Ellenbrook wetlands; and
- o the usual drawback to binary similarity coefficients, *viz.* that they do not provide information on the relative abundance of species, does not wholly apply in this case. The data for Ellenbrook record dominants and thus provide a built-in abundance estimate.

Binary similarity coefficients deal only with presence-absence data. The basic data for calculating binary (or association) coefficients is a 2 x 2 table as set out below:

		Sample A	
		No. of Species Present	*No. of Species Absent*
Sample B	No. of species present	a	b
	No. of species absent	c	d

where: a = Number of species in Sample A and Sample B (joint occurrence).
b = Number of species in Sample B but not in Sample A.
c = Number of species in Sample A but not in Sample B.
d = Number of species absent in both samples (zero-zero matches).

The range of similarity coefficients for binary data is usually between 0 (no similarity) and 1 (complete similarity). However, sample size and species richness affect the maximum value that can be obtained with coefficients. Thus, it is the relative values of the similarity coefficients that should be considered, not its relationship to the theoretical value of 1.

Both Sorensen and Baroni-Urbani and Buser Coefficients were used in this study (Krebs, 1989).

The Coefficient of Sorensen is calculated as:

$$S_s = \frac{2a}{2a + b + c} \qquad (1)$$

where: S_s = Sorensen's Similarity Coefficient.

This coefficient weights matches in species composition between the two samples more heavily than mismatches. This is advantageous for the Ellenbrook data because the Ellenbrook community contains many species which are present in the community but not necessarily present in the sample from the community.

The Baroni-Urbani and Buser Binary Similarity Coefficient is a more complex similarity coefficient that makes use of *negative* as well as positive matches.

$$S_B = \frac{\sqrt{ad} + a}{a + b + c + \sqrt{ad}} \qquad (2)$$

Where: S_b = Baroni-Urbani and Buser Similarity Coefficient

The values of both similarity coefficients will be compared.

Following the development of a similarity matrix, a technique known as cluster analysis was used. Clustering methods achieve a classification of a series of samples. Average linkage clustering or the unweighted pair-group method, using arithmetic averages, was the method employed for the Ellenbrook data. This clustering strategy uses the following definition:

For arithmetic average clustering by the unweighted pair-group method

(Similarity between a sample)	=	(Arithmetic mean of similarities)
(and an existing cluster)		(between the sample and all)
		(the members of the cluster)

Steps used to undertake this calculation are:

1. Find the most similar pair(s) of samples - this is defined as the first cluster.
2. The entire similarity matrix is then recomputed for the remaining communities and cluster 1 using the definition in equation (3) below.
3. This procedure is repeated until all the samples are in one big cluster.

$$S_{J(K)} = \frac{1}{t_J\, t_K} \left(\sum S_{SJ}\right) \qquad (3)$$

where: $S_{J(K)}$ = Similarity between clusters J and K

t_J = Number of samples in cluster J (>=1)

t_K = Number of samples in cluster K (>=2)

3.3.4 Evaluation of Conservation Aspects

The procedure outlined in the document "A Guide to Wetland Management in Perth" (EPA, 1990b) was used to analyse available data on the wetlands. Some assumptions had to be applied in order to use the procedure. These were as follows:

- the wetlands in the Lexia Area were considered to be seasonal and with well defined boundaries. They were thus distinguishable from the poorly defined "damp woodlands" found elsewhere in the Ellenbrook area;
- as the wetlands were all in close vicinity to one-another the characteristic of nearness to other wetlands was redundant and was not scored;
- although vegetation types varied between wetlands none were considered to be significantly different, e.g. saline versus fresh or bullrush-covered versus native sedges;
- drought refuge is not relevant as all the wetlands are seasonally dry;
- habitat types present were scored on the side of more value rather than less if there was any uncertainty;
- the "reserve area" was taken to be all the area shown on Figure 2 as the "Lexia wetlands"; and
- in the active recreation section of the EPA questionnaire horse riding and trail bike riding was scored as a plus, in accordance with the procedure. However, field studies identified numerous locations where dieback disease is believed to have been spread by these agencies.

In addition, since this work was carried out, the Environmental Protection Authority has examined all the wetlands to determine whether or not they should be included under the Draft Environmental Protection (Swan Coastal Plain Wetlands) Policy (EPA, 1991).

3.3.5 Fauna Study

A general review of the fauna abundance and diversity likely to occur in the Ellenbrook area was compiled primarily from data collected for the nearby Gnangara Mound study (Dames & Moore, 1986). The information was then updated by consultation with the Western Australian Museum and Wildlife Research Branch of CALM.

The only fauna specifically searched for in the Study Area was the Gazetted Rare species Brown Bandicoot *(Isoodon obesulus)* as agreed by CALM and the EPA . This species makes characteristic scratchings and diggings which, with experience, are easily distinguished from rabbit and other diggings. These were searched for at the same time as the rare flora examination of the transects in November 1991.

3.4 REPORT PREPARATION

This report contains the methodologies used, presents results and draws conclusions, where appropriate. The report is presented in a format suitable for direct inclusion as an appendix to an EPA assessment document.

4.0 RESULTS

4.1 CLASSIFICATION OF LEXIA WETLANDS

4.1.1 Qualitative Evaluation

The vegetation classification system of Semeniuk *et al.* (1990) was applied in sequence as follows:

- the scale of the wetland complex was determined;
- the extent of vegetation cover was assessed as either peripheral, mosaic or complete;
- the internal organisation of the wetland was determined as either homogeneous, zoned or heterogeneous;
- the structure of the vegetation zone was determined; and
- the floristics of the vegetation zone was assessed.

The classifiers follow those previously outlined in Table 1.

Generalised descriptions of the hydrology, soils and floristics of the Lexia wetlands are contained in Appendix A.

Lexia Wetlands

Table 2 below outlines the classification of vegetation and form of the Lexia wetlands of the Ellenbrook Study Area. Figure 1 provides a general locality plan of the wetland system. Figure 2 is a vegetation map of the various Lexia wetlands and shows the location of the transects surveyed. The letter descriptor used in Table 2 corresponds to those found on Figure 2. It facilitates an appreciation of the scale and diversity of the wetlands.

goes with fig 2.

TABLE 2

CLASSIFICATION OF THE VEGETATION OF THE LEXIA WETLANDS OF THE ELLENBROOK STUDY AREA

Transect	*Type*	*Classification of Wetland After Semeniuk et al., 1990*	*Inventory of Assemblages*[1,2]
A1	sumpland	micro concentriform open forest/closed heath/closed sedgeland	*Melaleuca preissiana/Astartea fascicularis/Baumea articulata*
A2	dampland	meso maculiform open forest/closed heath/closed sedgeland	*Melaleuca preissiana/Hypocalymma angustifolium/Astartea fascicularis-Baumea articulata*
A3	sumpland	micro maculiform open forest/closed heath/closed sedgeland	*Melaleuca preissiana/Pericalymma ellipticum/Astartea fascicularis/Baumea articulata*
A4	sumpland	micro zoniform closed heath/closed sedgeland	*Astartea fascicularis/Baumea articulata*
A5	dampland	macro maculiform forest/closed heath	*Melaleuca rhaphiophylla/Pericalymma ellipticum/Astartea fascicularis/Eucalyptus spp.-Banksia spp.*[3]
B1	sumpland	micro concentriform forest/closed heath/low woodland/closed sedgeland	*Hypocalymma angustifolium/ Banksia littoralis/M. preissiana/Baumea acuta/Astartea fascicularis-Pericalymma ellipticum/Baumea articulata*
C1	seepage	lepto maculiform open woodland/closed heath	*M. preissiana/A. fascicularis-Lepidosperma sp.*
D1	seepage	meso maculiform woodland/open woodland	*B. littoralis-M. preissiana/E. rudis*
E1	dampland	lepto latiform closed heath	*Eremaea pauciflora*[3]
F1	sumpland	micro concentriform forest/closed woodland/closed heath/closed sedgeland	*Melaleuca preissiana/Banksia littoralis-Lepidosperma gladiatum/ A. fascicularis/ Baumea acuta/B. articulata*
G1	sumpland	lepto concentriform open forest/closed heath/closed sedgeland	*Melaleuca preissiana-Hypocalymma angustifolium/Baumea acuta/Astartea fascicularis/B. articulata*
H1	sumpland	micro concentriform forest/closed heath/closed sedgeland	*Melaleuca preissiana/Hypocalymma angustifolium/Astartea fascicularis/Baumea articulata*
I1	sumpland	lepto concentriform open woodland/closed scrub/closed sedgeland	*Banksia littoralis/Astartea fascicularis/ Pericalymma ellipticum/Baumea acuta/B. articulata*
J1	dampland	micro heteroform closed low forest/closed sedgeland/closed heath	*Banksia littoralis/Baumea acuta/Pericalymma ellipticum*
K1	dampland	micro concentriform open forest/closed heath/closed sedgeland	*Melaleuca preissiana-Banksia littoralis/Calothamnus lateralis-Astartea fascicularis*
L1	dampland	lepto maculiform closed low forest/closed scrub	*Banksia littoralis/Melaleuca teretifolia-M. polygaloides*
M1	sumpland	micro gradiform closed sedgeland/closed scrub	*Baumea acuta/Lepidosperma longitudinale/Melaleuca teretifolia-Astartea fascicularis/Baumea articulata*
N1	sumpland	lepto concentriform closed woodland/closed heath/closed sedgeland	*M. preissiana-Banksia littoralis/Astartea fascicularis/Baumea acuta/Melaleuca lateritia/Baumea articulata*

Notes:
1. The various assemblages are separated by a slash (/):
Different species which occur within the same assemblage are separated by a dash (-).
2. For descriptions of the floristics of the wetlands see Appendix A.
3. This assemblage contains a mixture of woodland and wetland species.

The Ellenbrook Lexia wetlands do not contain any wetland type which is classified as a lake (i.e. permanently inundated). However, an additional "type" classification to those proposed by Semeniuk *et al.* can be recognised at Ellenbrook - the seepage. Seepages appear to be controlled by geomorphology rather than by topography, whereas the latter factor is largely the controller of sumplands and damplands which are "windows into the water table".

All scale classifications except the largest (mega) are present at Ellenbrook. There is a diversity of sizes present, with no particular size classification dominating.

Vegetation cover tends mainly to be complete and heterogeneous or zoned. However, mosaic and peripheral vegetation organisation also occur, but to a lesser extent.

Woodlands, heaths, scrubs and sedgelands all occur at Ellenbrook in a diverse structure and floristic composition depending primarily on topographic location.

Swan Coastal Plain Wetlands

In order to evaluate the Ellenbrook Lexia wetlands in a regional context, it was necessary to collate some data on other wetlands of the Swan Coastal Plain.

Table 3 below outlines the classification of vegetation of some typical wetlands of the Swan Coastal Plain as determined by Semeniuk *et al.* (*ibid*).

Comparison of the classification of these Swan Coastal Plain wetlands with the Ellenbrook Lexia wetlands reinforces the diversity of the Lexia wetlands. The Swan Coastal Plain wetlands, which are very widely spatially distributed throughout the Perth area, have simpler vegetation structure and assemblage diversity than the closely distributed Lexia wetlands. There is also a greater variety of introduced flora (e.g. *Typha orientalis*), alienated wetland or woodland and introduced structures such as grasslands in the wetlands of the Swan Coastal Plain.

TABLE 3

CLASSIFICATION OF THE VEGETATION OF SOME TYPICAL WETLANDS OF THE SWAN COASTAL PLAIN

Wetland	*Type*	*Classification of Wetland*	*Inventory of Assemblages*[1]
Lake Mungala	sumpland	micro zoniform woodland/low forest /shrubland	*Melaleuca preissiana/M. rhaphiophylla /M. teretifolia*
Bindiar Lake	dampland	meso concentriform forest/sedgeland	*M. preissiana-Banksia littoralis /Eucalyptus rudis/?Leptocarpus*
Lake Pinjar	sumpland	mega maculiform closed low forest/heath /sedgeland	*M. rhaphiophylla/E. rudis/M. preissiana /M. teretifolia/Lepidosperma sp. /Baumea articulata*
Lake Joondalup	lake	macro zoniform closed low forest/sedgeland	*M. rhaphiophylla-E. rudis/B. articulata-Typha orientalis*
Lake Jandabup	lake	macro bacataform open woodland/sedgeland	*M. preissiana/B. articulata/Baumea-Juncus-Lepidosperma-Leptocarpus-Typha*
Lake Gnangara	sumpland	macro zoniform open woodland/open forest	*M. preissiana/M. rhaphiophylla Baumea-Juncus-Lepidosperma-Leptocarpus-Typha*
Lake Carabooda	sumpland	macro maculiform open low forest/tall scrub /sedgeland	*M. rhaphiophylla/E. rudis-B. littoralis /T. orientalis*
Lake Booragoon	sumpland	micro periform closed low forest	*M. rhaphiophylla*
Roe Swamp	sumpland	micro maculiform woodland-closed forest /scrub/sedgeland	*M. preissiana/M. preissiana-E. rudis /Kunzea ericifolia/M. rhaphiophylla /M. teretifolia/T. orientalis*
Lake Coogee	sumpland	meso zoniform closed low forest/scrub /herbland	*M. rhaphiophylla/M. cuticularis-Halosarcia halocnemoides*
Lake Thompson	lake	macro zoniform closed low forest/closed scrub/grassland/sedgeland	*M. preissiana/M. preissiana-E. rudis/E. rudis /Acacia saligna/B. articulata-T. orientalis*
Forrestdale Lake	sumpland	macro zoniform low forest/sedgeland	*M. rhaphiophylla-E. rudis/T. orientalis-Juncus kraussii*
Brownman Swamps	sumplands	macro latiform open low forest	*M. rhaphiophylla*
The Spectacles	sumplands	macro maculiform open woodland/closed scrub/closed heath/closed low forest	*M. preissiana/E. rudis/mixed Melaleuca /M. rhaphiophylla*
Stable Swamp	sumpland	macro bacataform closed low forest/closed scrub/sedgeland	*M. rhaphiophylla/M. teretifolia/B. articulata /Baumea juncea*
Pt Becher Wetlands	sumplands	lepto concentriform sedgeland	*Lepidosperma gladiatum/L. angustifolium /Isopogon nodosus*

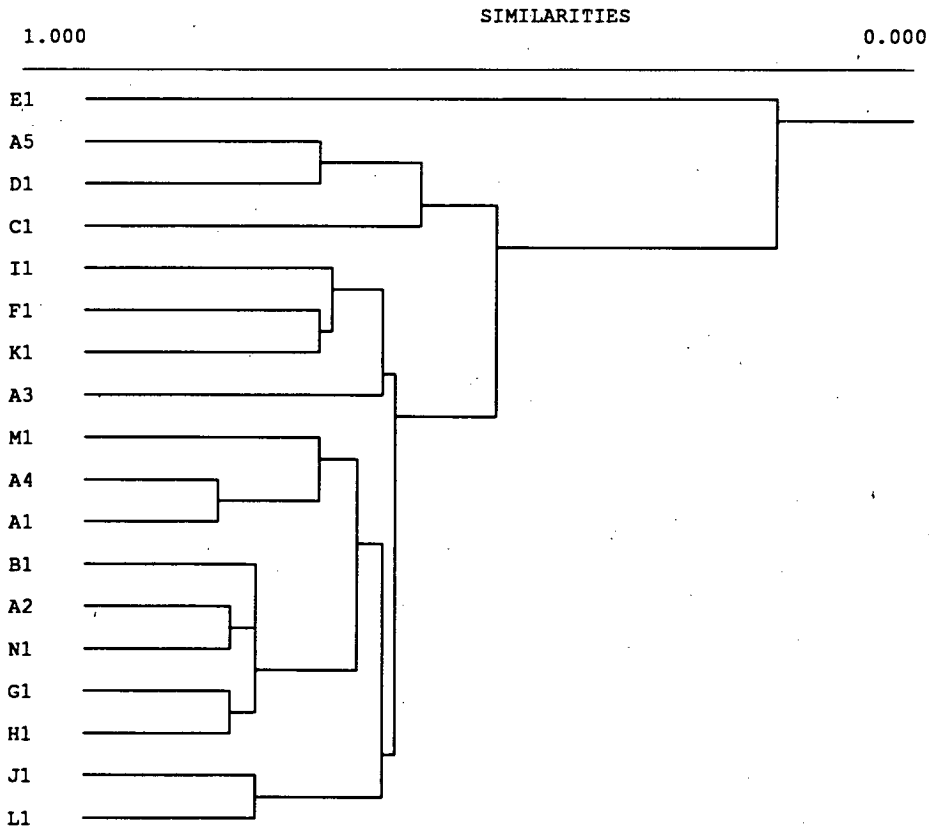
From Semeniuk *et al.* (1990).

Notes: 1. The various assemblages are separated by a slash (/):
Different species which occur within the same assemblage are separated by a dash (-).
2. Some of the species of sedge identified in the inventory of assemblages are provisional, because of the difficulty of identifying sedge taxa.

4.1.2 Quantitative Evaluation

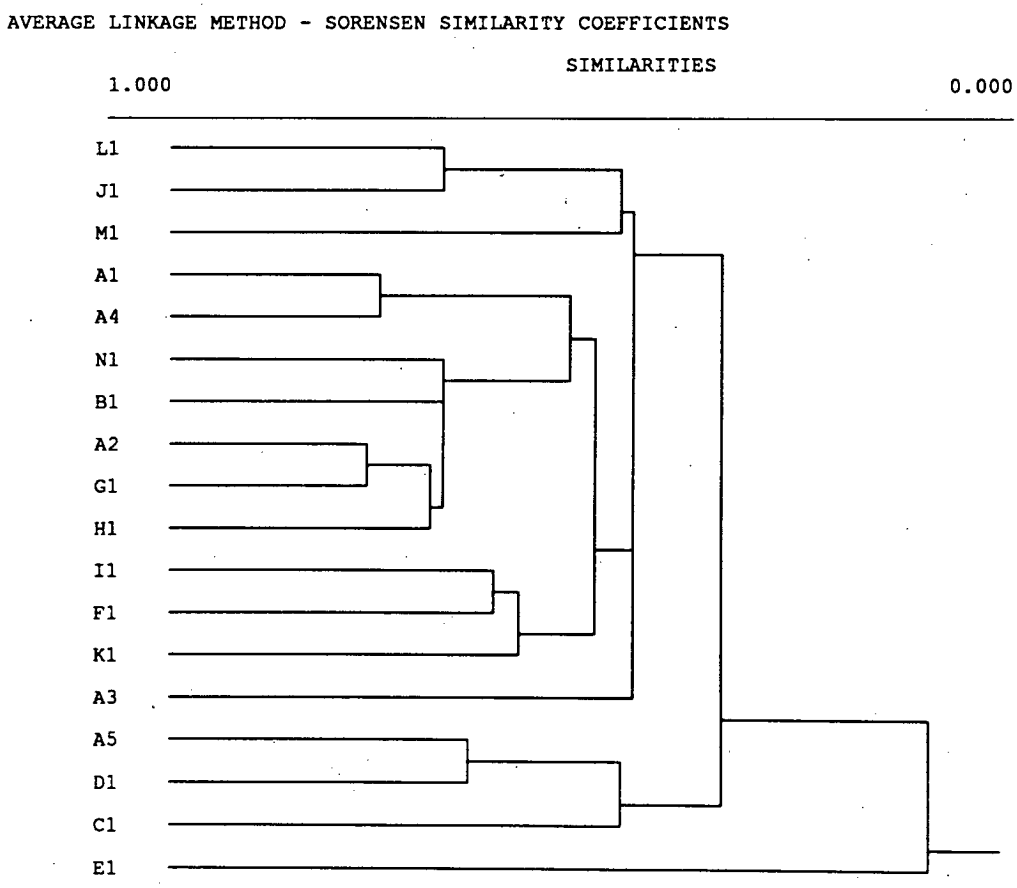
Appendix B contains floristic associations between the Lexia wetland transects and the results of analyses of contingency tables of the dominant floristics of the Lexia wetlands. The cluster dendrogram below outlines the results for Lexia wetlands using Baroni-Urbani and Buser Similarity Coefficients for the initial similarity matrix. It should be noted that this similarity technique, and the average linkage method of cluster analysis, both tend to agglomerate wetlands and emphasise the similarity/relationships between them rather than the differences. The use of Baroni-Urbani and Buser Similarity Coefficient assumes that the Lexia wetlands can be regarded as a "super-community" and that every plant species recorded for all the Lexia wetlands is likely to occur in any one wetland. This is probably not a reasonable assumption and thus the use of this coefficient is unrealistic, giving greater estimates of similarity than actually occur. Nonetheless, the results of this analysis are presented below.

AVERAGE LINKAGE METHOD - BARONI-URBANI AND BUSER SIMILARITY COEFFICIENT



Despite the possibly fallacious premise on which this dendogram is constructed, and the fact that it emphasises similarities between the wetlands, there are still considerable differences between the wetlands in terms of their species composition. However, it is not considered beneficial to conduct more detailed analyses using the methods above. All following discussions will be limited to the dendrogram constructed using a Sorensen Similarity Matrix.

Appendix B tabulates floristic associations between the Lexia wetland transects and the results of analyses of contingency tables of the dominant floristics of the Lexia wetlands. The cluster dendrogram below outlines the results for Lexia wetlands using Sorensen Similarity Coefficients for the initial similarity matrix. Like the Baroni-Urbani and Buser dendrogram above, similarity/relationships between wetlands are emphasised. Unlike the Baroni-Urbani and Buser method, the Sorensen Similarity Coefficient weights matches in species composition more heavily than mismatches. However, as outlined above, it is considered that this approach is more realistic than the use of the Baroni-Urbani and Buser coefficient described above as it does not consider the Lexia wetlands as a "super-community". It considers only the species which actually occur in the two wetland areas being compared.



This cluster dendogram emphasises the wide variety of different species composition patterns that occur at Ellenbrook to an even greater degree than the dendogram created using Baroni-Urbani and Buser Similarity Coefficients. Despite the close proximity, similar soils, climate and other physical factors of the Lexia wetlands at Ellenbrook, significant differences do occur. It is possible to classify certain groups of wetlands as having natural affinity in species composition. These are, however, less striking than might be expected from wetlands occurring in the same geographic location. Several factors may be responsible for this, including microscale differences in soils and climate, different fire patterns and different hydrological dependencies. These are discussed further in Section 5.1.

4.1.3 Structural Analysis

The following table outlines the numbers of vegetation bands, strata and structure-modifying perennials that occur within each transect. Structure-modifying perennials (SMP) are defined as those which alter the physiognomy of the association, although they may or may not be defined as dominants and their canopy cover may be greater or less than 2%.

This table suggests that the wetlands of the western sector (E1 to N1) of the Lexia wetlands have higher numbers of bands than the eastern-sector wetlands (A1 to D1). However, the eastern sector wetlands have higher average number of strata per band and higher numbers of SMPs.

The seasonal wetlands have an average of 4.6 bands per wetland transect compared to 2.7 bands per wetland transect for damplands and 3.0 bands per wetland transect for seepages. The number of strata per band averages 1.6 for sumplands, 2.3 for damplands and 3.3 for seepages.

The average number of SMP per band for sumplands ranges from 1.5 (M1) to 4.67 (A1). The overall average number of SRP for sumplands is 2.85. The average number of SMP per band for damplands ranges from 3.33 (K1) to 15 (E1). The overall average for damplands is 5.75. The average number of SMP per band for seepages ranges from 5.0 (C1) and 10.5 (D1). The average for both these seepages is 6.83.

TABLE 4

STRUCTURAL DATA FOR ELLENBROOK LEXIA WETLANDS

Transect	*Band Identifier*	*Number of Strata in Band*	*Number of Structure-Modifying Perennials*
A1	Centre	1	1
	1	2	3
	2	4	10
A2	Centre	2	4
	1	3	8
A3	Centre	1	1
	1	2	5
	2	2	5
	3	3	3
A4	Centre	1	1
	1	2	3
	2	2	3
A5	Centre	3	7
	1	2	6
	2	2	6
	3	4	21
B1	Centre	1	2
	1	1	2
	2	1	1
	3	3	6
C1	Source	1	3
	1	1	2
	2	3	8
	3	3	7
D1	Source	3	9
	1	4	12
E1	Centre	3	15
F1	Centre	1	4
	1	2	3
	2	2	5
	3	3	6

Transect	*Band Identifier*	*Number of Strata in Band*	*Number of Structure-Modifying Perennials*
G1	Centre	2	3
	1	1	4
	2	1	2
	3	1	2
	4	3	3
H1	Centre	1	1
	1	1	1
	2	1	1
	3	2	2
	4	1	1
	5	2	4
	6	1	2
I1	Centre	1	1
	1	1	2
	2	1	2
	3	2	2
	4	2	2
	5	1	3
	6	3	9
J1	Centre	1	1
	1	2	5
	2	2	5
	3	3	3
K1	Centre	2	4
	1	2	3
	2	2	3
L1	Centre	2	5
	1	2	2
M1	Centre	1	1
	1	2	3
	2	1	1
	3	1	1
N1	Centre	1	1
	1	2	5
	2	1	2
	3	2	2
	4	2	4

Most of the seasonal wetlands (sumplands) are simplest in or near their centre where often a monoculture of *Baumea articulata* exists. They tend to become more complex near the interface between wetland and woodland. This is because the woodland vegetation usually has a higher diversity.

The damplands show a higher average number of SMP per band and tend to be more varied in their structure and species composition than the seasonal wetlands. Similarly, the seepages (C1 and D1) show high average numbers of SMP, higher even than those occurring in the damplands, and are heterogeneous in structure and composition.

4.2 WATER QUALITY

Results of water analyses conducted by Analabs are presented in Appendix C.

The plots and table below compare results for water quality parameters in the seasonal Lexia wetlands with those obtained at urban wetlands on the Swan Coastal Plain during biological monitoring in 1985/86 (Davis and Rolls, 1987). There have been no surface waters recorded in the Sawpit Area.

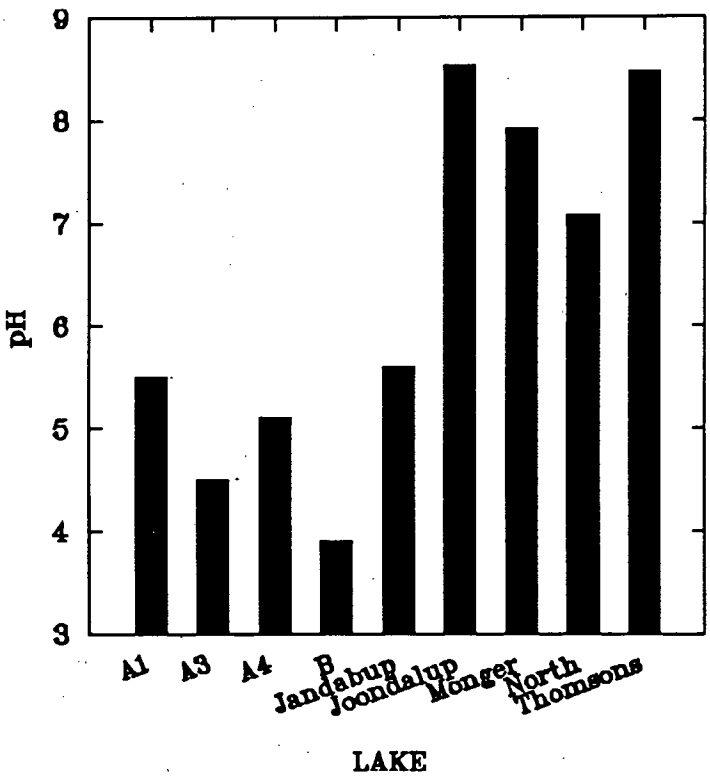
The lakes and swamps of Perth's wetlands are connected via an unconfined aquifer, and water levels vary with the height of the water table. Urbanisation has resulted in an increased demand for water from the unconfined aquifer, even in areas not directly affected by housing. With increased groundwater extraction, water levels in wetlands may drop or, in shallow wetlands, dry out completely. Conversely, urbanisation has also resulted in an increase in water levels in some wetlands because urban development has resulted in increased runoff. Local wetlands often act as compensating basins for storm water, and most lakes in developed areas have at least one, and often several, drains discharging into them.

Urbanisation has led to elevated nutrient levels in many of the urban lakes. Nutrient enrichment results in the occurrence of algal blooms in nuisance proportions whilst the use of pesticides to control water-breeding populations of insects is an additional stressor in some urban wetlands. Thus, it is considered that a comparison between urbanised wetlands and the comparatively pristine Lexia wetlands at Ellenbrook will give an estimation of the magnitude of change that could be expected for the Lexia wetlands should urbanisation take place without adequate drainage water quality control.

4.2.1 pH

Plot 1 presents a comparison of pH levels from analyses conducted in August 1990 at Ellenbrook with those found in urban wetlands on the Swan Coastal Plain during the study of Davis and Rolls (1987).

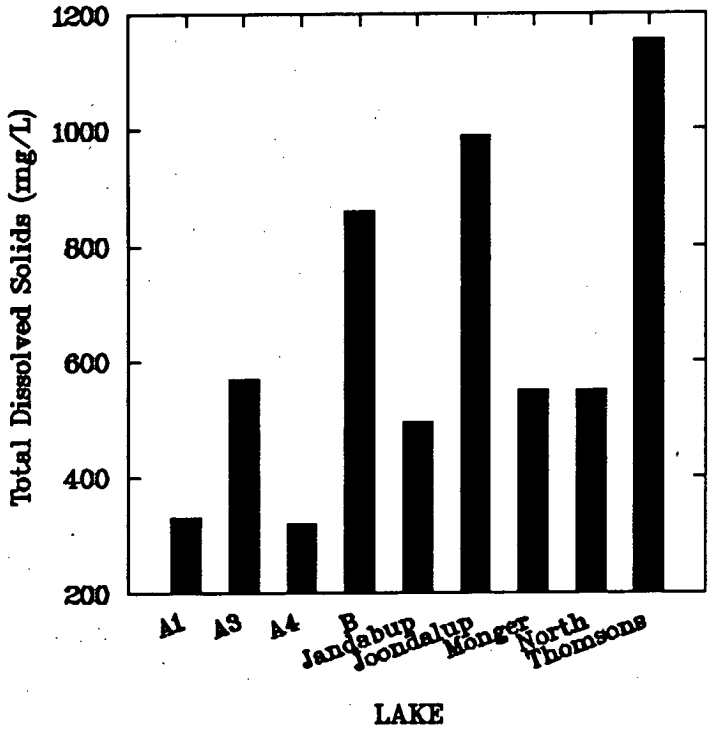
The plot shows that pH levels in the Ellenbrook Lexia wetlands (A1, A3, A4, B) tend to be acidic, while typical pH levels in the urbanised wetlands, with the exception of Lake Jandabup, are neutral to alkaline.



Plot 1
pH of urbanised wetlands compared with Ellenbrook Lexia wetlands

4.2.2 Total Dissolved Solids

Plot 2 compares winter values for total dissolved solids (determined from conductivity) recorded at the Ellenbrook Lexia wetlands and the urban wetlands of the Swan Coastal Plain (Davis and Rolls, 1987).



Plot 2
Comparison of Winter Total Dissolved Solids (determined from conductivity) between Urbanised Wetlands and Ellenbrook Lexia Wetlands

Results indicate that winter TDS levels are lower on average for the Ellenbrook Lexia wetlands than for the urban wetlands, although Ellenbrook "B" showed elevated levels which were higher than all wetlands except Lake Joondalup and Thompsons Lake.

4.2.3 Nutrients

Table 5 below sets out the concentration of nutrients in some typical urban wetlands and the Ellenbrook Lexia wetlands. Samples for the urban wetlands were taken during the winter/spring period (June to November 1985) (Davis and Rolls, 1987). The 1990 winter was comparatively dry, and in August when the Ellenbrook Lexia wetlands were sampled, only a few wetlands had surface water.

TABLE 5

WINTER CONCENTRATIONS OF NUTRIENTS
URBAN AND ELLENBROOK LEXIA WETLANDS

Lake	*Total Phosphorus (ug/L)*	*Ortho Phosphorus (ug/L)*	*Total N (Kjeldahl) (ug/L)*	*NO_3 (ug/L)*	*NH_3/NH_4 (ug/L)*	*N:P Ratio*
Jandabup	19.8 (± 2)	5.8 (± 0.7)	870 (± 77.9)	131 (± 44)	230.4 (± 98)	35:1
Joondalup	36 (± 38.9)	24.7 (± 4.9)	1675 (± 122)	13.4 (± 2.9)	23.3 (± 3.2)	39:1
Monger	186 (± 39)	46 (± 8)	3321 (± 510)	41 (± 17)	546 (± 242)	10:1
North	211 (± 12)	194 (± 9)	2069 (± 295)	259 (± 65)	501 (± 159)	8:1
Thompsons	54.4 (± 6.8)	14.5 (± 1.2)	2103 (± 173)	6.1 (± 1.2)	21.2 (± 0.8)	35:1
Ellenbrook	162 (± 85.4) 50-250	50 (± 0) 50	6125 (± 2973) 3900-10500	<50 (± 0) <50	1125 (± 1918.6) 50-4000	45:1 21:1-78:1

Note: The figures in brackets are the standard error of the mean.

Comparison of the range of concentrations of nutrients in the urban and Ellenbrook Lexia wetlands with Wetzel's (1975) classification of lake productivity (after Vollenweider, 1968) (Table 6) reveals that only Jandabup of the urban wetlands could be classified as oligo-mesotrophic with Joondalup and Thompsons Lakes being assessed as eutrophic and North Lake and Lake Monger exceeding the criterion for hyper-eutrophic. The Ellenbrook Lexia wetlands are all classified as eutrophic to hyper-eutrophic according to Wetzel's classification.

TABLE 6

CLASSIFICATION OF LAKE TROPHIC STATUS
BASED ON NUTRIENT CONCENTRATION

	(ug/L)		
Category	*Total P/Ortho P*	*Total N*	*Inorganic N*
Ultra-oligotrophic	0-5	0-250	0-200
Oligo-mesotrophic	5-10	250-600	200-400
Meso-eutrophic	10-30	300-1,100	300-650
Eutrophic	30-100	500-15,000	500-1,500
Hyper Eutrophic	>100	>15,000	>1,500

4.2.4 Water Table Levels

Table 7 shows water table levels recorded in August 1990 for the Ellenbrook Lexia wetlands.

TABLE 7

WATER TABLE LEVELS
ELLENBROOK LEXIA WETLANDS

Ellenbrook Transect	*Water Table Level from Ground Surface (cm)*
A1	-0.60 to -0.10
A2	not measured - ground surface dry
A3	-0.20 to +0.05
A4	-0.75 to +0.10
A5	not measured - ground surface dry
B	+0.02
C	not measured - ground surface dry
D	not measured - ground surface dry
E	not measured - ground surface dry
F	+0.30
G	+0.10
H	+0.10
I	-0.25 to -0.10
J	not measured - ground surface dry
K	not measured - ground surface dry
L	not measured - ground surface dry
M	+0.15
N	not measured - dry surface dry

These results show that the Ellenbrook Lexia wetlands are seasonal, and that they are particularly reliant on good rainfall to maintain water table levels above the ground surface. Little rain had fallen in the few weeks preceding the field survey of the area and this was reflected in the lowered water table levels in the wetlands.

4.2.5 Conclusions

The Lexia wetlands can be considered to be almost pristine, primarily as a direct consequence of their isolation. Their chemical parameters are more or less as expected and the amount of water they contain appears to be directly dependant on water table height and thus, indirectly, rainfall.

4.3 WETLANDS OF THE SAWPIT AREA

4.3.1 Introduction

As stated in Section 3.2.2, the "wetlands" of the eastern portion of the Study Area (Figure 3) differed from those in the Lexia Area. None (with the exception of Sawpit Gully) had free water, even at the end of the wet winter in 1991, and did not contain areas of *Baumea, Typha* or other typical wetland vegetation.

The areas examined would fall close to the Semeniuk *et al.* (1990) classification of heteroform damplands, although there was no evidence that they become seasonally waterlogged. They are believed to primarily represent a transition stage between a "wetland" in the accepted sense e.g. Lexia wetlands, and woodland of the type found in the Bassendean Dune formations of the Swan Coastal Plain.

Because the Sawpit Area "wetlands" did not lend themselves to the statistical methods used in the Lexia Area they are discussed separately.

4.3.2 The "Wetlands"

The damp woodland forms of wetland examined in the eastern portion of the Ellenbrook Study Area were:

- transects 4, 10 and 18;
- the eastern portion of Transect 20; and
- the eastern portion of Transect 21.

Descriptions of these transects are presented in Appendix D. Table 9 compares the structure and dominant floristics of these transects with similar habitats recorded by Morris and Muir at Mussel Pool (Jackson *et al.*, 1975) and at Melaleuca Park (Muir, 1983). Mussel Pool is now known as Whiteman Park, and is located on Bassendean Dune system about 5km southwest of Ellenbrook. Melaleuca Park is also on Bassendean Dunes and is located about 3km north-west of Ellenbrook. The geology, geomorphology and groundwater characteristics of the three sites are very similar.

TABLE 9

COMPARISON OF CHARACTERISTICS
WHITEMAN PARK/MELALEUCA PARK AND
ELLENBROOK SAWPIT AREA "WETLANDS"

Mussel Pool/Melaleuca Park		*Ellenbrook*	
STRATUM 1			
Upper stratum dominant *Melaleuca preissiana* sometimes with *Banksia* spp. or *Eucalyptus marginata.*		Upper stratum dominant *Melaleuca preissiana* sometimes with *Banksia littoralis* and *Eucalyptus marginata.*	
Height of stratum	2-15m	Height of stratum	2-16m
Canopy cover	2-10%	Canopy cover	2-30% (occasionally denser)
STRATUM 2			
Stratum 2 dominant *Xanthorrhoea preissii*		Stratum 2 dominant *Xanthorrhoea preissii* with occasional *Macrozamia reidlei, Hypocalymma angustifolium*, etc.	
Height of stratum	0-1.5m	Height of stratum	1-3m
Canopy cover	2-30%	Canopy cover	2-80%
STRATUM 3			
Stratum 3 dominated by mixed shrubs, sometimes with *Adenanthos obovatus* and/or *Regelia inops.*		Stratum 3 dominated by mixed shrubs, commonly with *Hypocalymma angustifolium, Xanthorrhoea preissii, Patersonia occidentalis* or *Melaleuca lateritia.*	
Height of stratum	0-1m	Height of stratum	0-1m
Canopy cover	30-80%	Canopy cover	5-90%

It is felt that the Ellenbrook Sawpit Area of wetlands are both structurally and floristically very similar to those found at Whiteman Park and Melaleuca Park. The wider variation in structural characteristics at Ellenbrook are a consequence of some areas having been long-unburned and other areas fairly recently burned. By contrast, the study areas at Whiteman Park and Melaleuca Park had, at the time these surveys were conducted, all been burned within the previous few years. Further, the Whiteman Park sites had been disturbed and grazed.

4.3.3 Sawpit Gully

The Sawpit Gully wetlands differ considerably from those described earlier in this report. The main differences are:

- they are part of a linear drainage system rather than lentic wetlands; and
- they primarily overlie Guildford Clay at depth, whereas the lentic wetlands are windows into the water table amongst Bassendean Dunes.

The Sawpit Gully wetlands are described in Appendix D under Transects 5, 11 and 12. Transects 11 and 12 were dominated by *Acacia saligna* woodland, with sedgey understoreys. *Eucalyptus rudis* (Flooded Gum) may also be present, and dominated in Transect 5.

Transect 11 represented the "headwater" region of the drainage line, and was sandy and with no clearly defined channel. Further downstream at Transect 12 a distinct channel had developed. Transect 5 also had a distinct channel, but in this case the headwaters of the gully lie in farmland north of the Ellenbrook Study Area.

A significant feature of the Sawpit Gully wetlands was the abundance of weeds compared to other areas examined. This is believed to be a result of:

- greater levels of disturbance compared to less accessible areas;
- severe encroachment of weeds from farmland to the north of Ellenbrook; and
- the higher clay content of the soils providing better moisture-holding capacity for weed establishment.

A further feature of significance, perhaps related to the more clayey soils along the drainage line, was the presence of the Gazetted Rare plant *Caladenia huegelii* in the three Sawpit Gully transects but not elsewhere.

4.4 WOODLANDS

4.4.1 Introduction

As stated in Section 4.3.1 the "wetland" habitats of the eastern portion of Ellenbrook are transitional between true wetlands and the dry Bassendean Dune system woodlands. A number of transects were chosen, for the purpose of this study, as being "damp" woodlands, and were discussed in Section 4.3. The remaining "dry" woodlands are discussed hereunder.

4.4.2 The Dry Woodlands

Dry woodlands were examined at the following locations:

- Transects 1 to 3;
- Transects 6 to 9 (east and west);
- Transects 13 to 17;
- Transect 19 (east and west);
- Transect 20 (west); and
- Transect 21 (west).

Descriptions of these transects are presented in Appendix D.

An examination of the structural and floristic composition of the transect data shows only minor variations between locations. These variations can be related to topographic position. Dune top vegetation is generally less dense, shorter and less floristically diverse, with these characteristics changing progressively as availability of moisture increases. At low topographic positions the vegetation merges imperceptibly into the "damp" woodland types described in Section 4.3 or into distinctive lentic wetlands as described in Section 4.1

4.4.3 Comparison with Other Areas

The dry woodlands at Ellenbrook have been compared structurally and floristically with those in nearby, similar, areas. Comparison was made to Mussel Pool (Whiteman Park) using data from Jackson *et al.* (1975) and to Melaleuca Park (Muir, 1983).

Results are summarised in Table 10.

There are considerable floristic composition variations. For example, *Banksia menzeisi* tends to favour dry sites and *B. ilicifolia* damper sites, *Eucalyptus todtiana* dry sites and *E. marginata* damper sites, etc., but these variations are considered minor. Likewise, the structure of the vegetation in the three sites is similar. The Ellenbrook woodlands tend to be a little denser in Strata 1 and 3 because they are older (longer since they were burned) than either Whiteman Park or Melaleuca Park were at the time of the latter surveys. Otherwise, they are very similar.

TABLE 10

COMPARISON OF CHARACTERISTICS
WHITEMAN PARK/MELALEUCA PARK AND
ELLENBROOK "DRY" WOODLANDS

Whiteman/Melaleuca Park		*Ellenbrook*	
STRATUM 1			
Dominants in Stratum 1 *Eucalyptus calophylla* and *E. marginata* and *Banksia menziesii, B. attenuata* or *B. ilicifolia.*		Dominants in Stratum 1 *Eucalyptus calophylla, E. marginata* or *E. todtiana. Banksia menziesii, B. attenuata* or *B. ilicifolia.*	
Height of stratum	2-15m	Height of stratum	2-15m
Canopy cover	2-10%	Canopy cover	10-30%
STRATUM 2			
Dominants in Stratum 2 *Xanthorrhoea preissii,* sometimes *Jacksonia furcellata.*		Dominants in Stratum 2 *Xanthorrhoea preissii, Macrozamia reidlei* or several other species including *Jacksonia furcellata.*	
Height of stratum	0-1.5m	Height of stratum	0-2m
Canopy cover	2-10%	Canopy cover	2-80%
STRATUM 3			
Dominants mixed shrubs.		Dominants mixed shrubs.	
Height of stratum	0-1m	Height of stratum	0-0.5m
Canopy cover	30-70%	Canopy cover	30-70%

4.5 RARE FLORA

The searches for Gazetted Rare or Priority flora resulted in locating three species of interest. The Gazetted Rare orchid *Caladenia huegelii* was located at Transects 5, 11 and 12 on Sawpit Gully. These locations are all part of a linear drainage line dominated by woodland (as opposed to the other wetlands which had limited overstorey development). A possible associated factor was the presence of grey, organic, loamy sand to sandy loam in the areas where it was located. This soil type was not observed elsewhere in the other wetlands or woodlands but appears to occur primarily along Sawpit Gully. *Caladenia huegelii* may occur elsewhere but was not found perhaps because flowering was earlier in the drier locations.

The Priority Three species *Conostephium minus* was recorded in Transect 6. Priority Three is described as "Taxa which are known from several populations, at least some of which are not believed to be under immediate threat" (CALM, 1991). *Conostephium minus* was also recorded at Melaleuca Park (B.G. Muir, pers. comm.).

The Priority Three species *Cartonema philydroides* was recorded in Transects 5 and 20. In both areas it was in large numbers in highly disturbed or dieback-affected vegetation.

A fourth species which was searched for on the request of CALM, was *Dryandra mimica*. This species was not found anywhere on Ellenbrook. Interestingly, it's well-known look-alike species *Dryandra nivea*, usually very common on the Swan Coastal Plain, was found to be very scarce, being only recorded near Sawpit Gully.

4.6 FAUNA

4.6.1 Introduction

The vertebrate fauna of the Ellenbrook area were not studied specifically as:

- information on fauna of the area is readily available, there would be little benefit in extensive further work;
- it is not believed that such a survey would add substantially to the current knowledge base;
- it would impose considerable cost on government and the developers; and
- to do so in a comprehensive manner would unnecessarily delay the project for several years, with consequent impacts on employment and housing.

The reasoning behind these latter statements is that biological survey work always has a point of diminishing returns. This means that once a certain level of knowledge is reached, the amount of effort required to gain additional information becomes far out of proportion to the information gained. The corollary of this is that additional research will almost invariably produce new data. The questions are whether the benefit warrants the cost, and whether management of the environment is enhanced by having available the new information.

It is the experience of most land-management ecologists that sensitive, practical management decisions can be made on good quality basic data, and that vast amounts of additional detail does not greatly enhance management.

Based on the issues raised above, the available information on fauna of the Ellenbrook region has been reviewed. It is concluded that the information which has been summarised for other projects provides an adequate database for management. Consequently, the Gnangara Mound Groundwater Resources Environmental Review and Management Programme (Dames & Moore, 1986) is used as a basis for the following discussion. Most of the following text is reproduced unaltered from that source, with additional comments added where necessary. This discussion has also been examined by staff of the Western Australian Museum and corrections and alterations have been made in accordance with their information.

4.6.2 Mammals

After a search of the Western Australian Museum records and relevant literature, Kitchener *et al.* (1978) concluded that 33 native mammal species have been recorded with certainty from the Northern Swan Coastal Plain. An additional four are also listed, though these are considered to be of doubtful validity due to vague locality data on the original specimens. An annotated list (including history, past and present distributions, abundance and habitat preferences) of all mammals listed for the region can be found in the above reference.

The Northern Swan Coastal Plain was extensively surveyed for mammals during 1977-78 by the Western Australian Museum. Prior to this, the only other organised mammal collecting was undertaken by Shortridge (undertaken from 1904 to 1907) (Shortridge, 1909) and the Western Australian Museum at Mussel Pool in 1975. The 1977-78 survey included Melaleuca Park (3km to the northwest of Ellenbrook) and in very similar habitat, and Twin Swamps Reserve (2km to the northeast of Ellenbrook) and in habitat similar to that found at the Vines Estate. Their survey also examined five other areas, including Moore River, Yanchep and Neerabup National Parks, Results as discussed here assume that the Ellenbrook woodland and wetland could contain any of the fauna.

The Museum's 1977-1978 survey confirmed the presence of 12 native mammal species. They are:

- Short-beaked Echidna *(Tachyglossus aculeatus)*;
- Southern Brown Bandicoot *(Isoodon obesulus)*;
- Common Brushtail Possum *(Trichosurus vulpecula)*;
- Honey Possum *(Tarsipes rostratus)*;
- Western Brush Wallaby *(Macropus irma)*;
- Western Grey Kangaroo *(Macropus fuliginosus)*;
- Lesser Long-eared Bat *(Nyctophilus geoffroyi)*;
- Goulds Wattled Bat *(Chalinolobus gouldii)*;
- King River Eptesicus *(Eptesicus regulus)*;
- Water Rat *(Hydromys chrysogaster)*;
- Ashey Grey Mouse *(Pseudomys albocinereus)*; and
- Bush Rat *(Rattus fuscipes)*.

Furthermore, another three were also considered to be possibly still extant in the region:

- Western Quoll *(Dasyurus geoffroii)* - last collected in 1972;
- Western Pygmy Possum *(Cercartetus concinnus)* - last collected in 1966; and
- Chocolate Wattled Bat *(Chalinolobus morio)* - last collected in 1951.

More recent information (J. Dell pers. comm.) has added the following:

- o White-striped Mastiff Bat *(Tadarida australis);*
- o Greater Long-eared Bat *(Nyctophilus major);* and
- o Gould's Long-eared Bat *(Nyctophilus gouldi).*

All of the above 18 species inhabit heath, shrubland or woodland habitats with the exceptions of the Southern Brown Bandicoot, Water Rat and Bush Rat, which prefer swamps and lakes.

The Honey Possum *(Tarsipes rostratus)*, is known to occur in Yanchep National Park and at Mindarie, east of Burns Beach, where it depends on a year round supply of flowering plants.

4.6.3 Reptiles and Amphibians

The Northern Swan Coastal Plain supports a relatively rich herpetofauna (Table 11) with 42 genera and 70 species distributed amongst 11 families (Storr *et al.*, 1978a).

TABLE 11

HERPETOFAUNA OF THE NORTHERN SWAN COASTAL PLAIN

Group	*Family*	*Number of Genera*	*Number of Species*
Ground Frogs	Leptodactylidae	7	11
Tree Frogs	Hylidae	1	2
Side-necked Turtles	Cheluidae	2	2
Geckos	Gekkonidae	4	6
Legless Lizards	Pygopodidae	6	8
Dragon Lizards	Agamidae	1	2
Skink Lizards	Scincidae	10	19
Monitor Lizards	Varanidae	1	3
Blind Snakes	Typhlopidae	1	2
Pythons	Boidae	2	2
Front-fanged Snakes	Elapidae	7	13

In the Museum study the Northern Coastal Plan was divided longitudinally into three zones corresponding approximately to the Spearwood/Safety Bay sands (western zone), Bassendean Dune System (central zone including Ellenbrook), and the Guildford Formation (eastern zone including the Vines and a small part of Ellenbrook). The western zone, primarily due to the presence of outcropping limestone, possessed a greater diversity of geckos (Gekkonidae) than the eastern zone which was noted to be much richer in ground frogs (Leptodactylidae) and poorer in skink lizards (Scincidae) than the other zones. Otherwise, the zones only differed marginally.

The importance to the amphibian fauna of unpolluted surface water is illustrated by the fact that all but one species (The Turtle Frog - *Myobatrachus gouldii*) use swamps, lakes and streams etc., for lavae development. Additionally, a number of reptiles prefer surface water or moist places, namely the Long-necked Tortoise *(Chelodina oblonga)*, Short-necked Tortoise *(Pseudemydura umbrina)*, the skink lizards *Egernia luctuosa* and *Leiolopisma trilineatum* and the Western Tiger Snake *(Notechis scutatus occidentalis)*.

Seventeen of the above species and sub-species listed in Storr *et al.* (1978a) are considered to be scarce or rare, primarily due to a lack of suitable habitat on the coastal plain though they are more common elsewhere in the south west. Four of the seventeen are believed to be at the respective limits of their distributions. A further twelve species are endemic or nearly endemic to the west coast and coastal plains from North West Cape to Geographe Bay, though none are restricted to the Northern Swan Coastal Plain.

4.6.4 Birds

The avifauna of the region was documented by Storr *et al.* (1978b) who compiled an annotated list which included local distribution, relative abundance, faunal status (i.e. visitor, resident etc.), habitat preferences and breeding season. Data were derived from the literature, WA Museum catalogues, journals of local naturalists and survey work undertaken by WA Museum staff during 1977-78. A summary is reproduced below (Table 12). Figures in brackets refer to species which formerly occurred on the Swan Coastal Plain but for which no definite records exist.

TABLE 12

BIRD STATUS OF THE NORTHERN SWAN COASTAL PLAIN

	Non-passerines	*Passerines*	*Total*
Residents	52 (3)	48 (7)	100 (10)
Breeding Visitors	14	5	19
Non-breeding Visitors	73	10	83
Vagrants	12	2	14
Established Exotics	5	2	7
TOTAL	156 (3)	67 (7)	223 (10)

Of the birds that have declined or become locally extinct, Storr *et al.* (1978b) noted that most were either wetland or forest inhabiting species.

Of the woodlands on the coastal plain, the best have been felled for timber and cleared for various agricultural activities. Consequently, birds such as the Scarlet Robin (as a breeding species), Yellow Robin, Crested Shrike-tit, Rufous Tree Creeper, Yellow-plumed Honeyeater, White-naped Honeyeater, Dusky Wood-swallow and Grey Currawong are either no longer found in the region or are rare. The increasing rarity of the Western Rosella and more recently the Regent Parrot have probably been caused by the increase in numbers of the Ringnecked Parrot. The Bush Stone Curlew has declined since the introduction of the Red Fox and the Brown Falcon became scarce due to the use of DDT in the south west of the State.

A number of species have benefited by man's clearing practices and growing of exotic trees. This has enabled some species to colonise the Perth area, e.g. the Great Egret, Straw-necked Ibis, Sacred Ibis, Wood Duck, Banded Plover, Crested Pigeon, Regent Parrot and the Galah. Also, open-country birds have been favoured, including White-faced Heron, Richards Pipit, Magpie Lark, Black-faced Wood-swallow, Magpie and Australian Raven. Others such as Silver Gull and Grey-breasted White-eye have benefited from an increased food supply and consequently become much more common. The additional food sources include pine plantations, rubbish disposal areas and cultivated fruit trees.

Part of the WA Museum survey of 1977-78 concentrated on the lakes of the region and Storr *et al.* (1978b) note that the waterfowl most threatened by a lowering of the water table are the inhabitants of deeper waters, i.e. the Musk Duck, Blue-billed Duck, Freckled Duck and Blue-winged Shoveller. Most of the wetland species that have declined depend greatly on the fringing swamp and lake vegetation. The combined effects of drainage and land fill, fire, cutting for fence posts and clearing for summer grazing would have eliminated shelter and nest sites for many species over large areas of the coastal plain. Some species, e.g. the Great Crested grebe, were rare in the 1960s, but have become common since the development of deep-water wetlands as landscaping features. Birds greatly affected by the deterioration of the wetlands included the above mentioned species plus Black Bittern, Brown Bittern, Barking Owl, Red-winged Fairy Wren, Golden Whistler, Restless Flycatcher, Red-eared Firetail, Marsh Harrier, Painted Snipe and Whiskered Tern. To this list can be added the Ground Parrot and Bristlebird, which are today locally extinct and are not represented in Museum collections, but were reported by local naturalists in earlier days. Both relied upon dense swamp vegetation.

Some other birds, e.g. the Southern Emu Wren, Splendid Fairy Wren, Broad-tailed Thornbill, Western Thornbill and White-browed Scrub-wren have also declined, but as a consequence of loss of dense, low, heath habitat rather than loss of wetland.

Unlike some of the southern metropolitan lakes, those north of the Swan River do not provide a major habitat for wading birds (Storr pers. comm., Johnstone pers. comm.). This appears to be for two main reasons. The western linear lakes have steep sides and rarely dry out sufficiently to allow waders to feed. The lakes of the shallow eastern chain (e.g. Ellenbrook) do dry out, but still do not support large wader populations, probably because the sandy lake substrates do not support the organisms on which the waders feed.

4.6.5 The Brown Bandicoot

Results of the search for Brown Bandicoot are summarised in Table 13. Each search area or transect covered approximately 1.25ha, as described in Section 3.2.5.

The results suggest that Brown Bandicoot may occur in at least 11 locations within the Ellenbrook Study Area. They appear to be absent from the dry woodland areas, and this would correspond with their known preference for wetland and dampland habitats. Further, they were either not particularly abundant or may be absent in the central portions of wetlands and damplands, but appeared to favour the ecotone between the wetland and the adjacent woodland. Diggings of Brown Bandicoot appear to be particularly abundant in damp woodland at Transects 9 and 10, but were also present on the edge of wetland A5, where they presumably would potentially occupy all of the wetland A1-A5 complex, and possibly also into the associated H1 and nearby wetlands.

They were also present in Transects 4 and 5 on the linear drainage of Sawpit Gully. It is concluded that the Brown Bandicoot probably occurs throughout the area, mainly utilising the edges of the many wetlands and damplands.

The Brown Bandicoot is a very common species, occurring from near Geraldton to east of Esperance, and from the coast inland to the wheatbelt. There is considerable evidence that it has been added to the list of Gazetted Rare Fauna in error. The addition to the list is accounted for by the increasing scarcity of the species in the metropolitan region but fails to account for its abundance elsewhere.

The Brown Bandicoot is also not very habitat-specific, is not greatly affected by disturbance and lives and breeds quite well adjacent to human activities.

TABLE 13

TRANSECTS SURVEYED FOR DIGGINGS POSSIBLY ATTRIBUTABLE TO RABBITS OR BANDICOOTS

Transect	*Rabbit Diggings**	*Bandicoot Diggings**
1	0	0
2	0	0
3	0	0
4	0	Few
5	0	0
6	Few	0
7	0	Few
8	0	0
9	Few	Many
10	Few	Many
11	Abundant	Few
12	0	Few
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	Few
19	Abundant	Few
20	Few	0
21	Abundant	Few
A5	0	Few
A4	0	Few

* See comments Section 4.6.5.

5.0 DISCUSSION

5.1 WETLAND ORGANISATION

5.1.1 Hydrological Classification of the Lexia Wetlands

Three principal hydrological/geomorphological classifications of wetland occur in the Lexia Area at Ellenbrook. These were listed in Table 2.

- Seepages

  These are geomorphically controlled wetlands and occur at the bottom of dunal rises, probably at the interface between the overlying sand and the underlying Guildford Formation. These have a markedly different structure and species composition to other wetland components at Ellenbrook.

- Damplands

  These are topographically controlled and occur in depressions where the water table lies near, but not above, ground surface level. These are structurally and compositionally very variable and no discernible pattern exists between them. Damplands are vulnerable to minor changes in water table levels.

- Sumplands

  These are "windows into the watertable" and are seasonally inundated during the wet season when the water table rises. Like the damplands, sumplands are potentially very vulnerable to changes in water table levels. In addition, because free-standing water exists, they may also be affected by changes to water quality.

5.1.2 Soils

In all sumplands examined, the soils were peat in the centre and sand over peat on the edges. Some evidence of peat below sand in the ecotones outside the main part of the sumpland suggests that the sumplands were once slightly larger and that the surrounding sands are gradually encroaching. The damplands and seepages have organic sands rather than peat-based soils. The amount of organic material present is quite variable depending on topographic position (organic material tends to accumulate in depressions) and the type of vegetation present.

5.1.3 Species Composition and Species Richness

Although some natural groupings of wetlands do appear from the data analysis (e.g. I1, F1, K1: A5, D1: A2, G1, H1, N1, B1: A1, A4: L1, J1), overall there is a low level of similarity between the wetlands in terms of species composition. This is apparent when measured by Sorensen's Similarity Coefficients and an average linkage cluster dendogram. The groupings tend to suggest that there are large scale differences between the wetlands of the eastern half (A1 to D1) of the Lexia Area and those of the western half (E1 to N1) although some overlap does occur.

It should be noted that the dendogram measures only species associations, and other factors such as hydrological dependencies and structure are ignored. This creates some groupings which do not appear to be logical (e.g. D1 - a seepage - and A5 - a dampland). However, the level of similarity is quite low, so the grouping need not be emphasised too greatly.

Species richness tends to be highest in the damplands and seepages and near the wetland/woodland interface. Pure stands of species such as *Baumea articulata* and *Astartea fascicularis* commonly appeared in the sumplands. However, species richness is characteristically low in wetland systems compared to that found in woodlands and heaths.

Surveys indicate that variation in species composition and structure is not due to differences in fire regimes.

5.1.4 Semeniuk Classification

Semeniuk's classification suggests the following natural groupings:

- A1, B1, F1, G1, H1, I1, N1;
- A2, A5, L1; and
- C1, D1.

The remainder of the Lexia wetlands are the sole members of a group and thus cannot be properly associated in a group using this classification. Nonetheless, this emphasises the variety of wetland types which are present.

It is noted that Sorensen's Coefficients and Semeniuk's classification give quite different results. This is principally because the two methods are measuring different aspects of the wetland. Sorensen's Coefficient measures species composition and association while Semeniuk's classification emphasises hydrological origins, vegetation organisation and vegetation cover.

The two classifications should therefore be used in conjunction and discretion exercised in analysing the results obtained with each. It is clear from these results that the Lexia wetlands differ considerably from each other, otherwise the methods of classification would result in similar groupings.

5.1.5 Structural Analyses

Results of data collected on structure at Ellenbrook Lexia wetlands show that, as with species richness, the damplands and seepages are most structurally complex and the sumplands least complex. In general, the wetlands of the eastern section of the Lexia Area tend to have fewer bands but more strata than those of the western section.

5.1.6 Stage in Successional Development

The presence of sand over peat on the sumpland edges suggests that the sumplands were once slightly larger and are gradually being encroached on by movement of sand particles from the sides.

As the peat does not extend very far outside the present peaty surface of the sumplands (only 2-3 metres), it is assumed that:

- the sumplands and damplands have been stable for a fairly long time; and
- the sumplands were originally larger, probably during a wetter phase of the local climate.

The Lexia wetlands are, therefore, probably stable in terms of a geological time-scale, but may vary slightly as a result of different climatic phases in the short-term.

They may be perceived as occupying depressions in a sloping landscape and where the height above water table is the critical factor in determining the type of wetland (Figure 4). Thus, it can be expected that, over time, sand from adjacent high ground will encroach on the wetlands, reducing their size and burying the margins.

5.2 WATER QUALITY

The results of the limited (one sample from each of four locations) chemical monitoring programme indicate that nutrient levels are naturally high in the Ellenbrook Lexia wetland chain. This is not as a result of urban runoff or any other form of environmental degradation. It is believed that the high nutrient levels are a result of concentration of organic material in the water at the end of the wet season. At the time of this study, the Lexia wetlands were almost dry, and all salts and nutrients would have been at maximum concentration.

Values for pH at Ellenbrook tend to be acidic compared to the urbanised wetlands. It is considered that pH values are related to:

- the type of geological substrate present. Both Joondalup and Monger lie within the Spearwood Dune system in which alkaline calcareous sands overlie aeolianite. The lower values at Ellenbrook and Jandabup may reflect the more acidic siliceous nature of the sands of the Bassendean Dune system in which they lie; and

- the amount of bioproductivity. The type of geological substrate (even with peaty soils) cannot wholly explain the differences in pH values. North Lake is anomalous and, on the whole, Ellenbrook shows more acidic values than even Jandabup. The level of bioproductivity is a likely explanation for such variations. High bioproductivity, as would be expected at the near-pristine wetlands at Ellenbrook, may be reflected in more acidic conditions (i.e. a lower pH value). This possible explanation is reinforced by the fact that of two hydrogeologically equivalent urban wetlands North and Jandabup (Davis & Rolls, 1987) the less disturbed wetland (Jandabup) was more acidic and has the lower pH value.

The nutrient data indicate that phosphorus and nitrogen levels are also high in the Lexia wetlands. Dames & Moore believes that this is primarily a consequence of the time of year at which the sampling was carried out. Surface waters were concentrated and have given anomalously high results.

The mechanism for concentration of salts and nutrients is probably as follows:

1. When winter rains commence and the water table rises, the fresh, clean rainwater lies on top of the previous season's water table. When the water table reaches the surface, the quality is therefore quite good.

2. Once exposed, sunlight and oxygen encourage the growth of primary organisms, such as algae. These provide food for secondary organisms, such as microfauna, and the annual successional cycle begins.

3. During the winter period, the succession continues and bioproductivity reaches a peak. At this time nutrient input from outside the swamps is greatest as debris and salts wash in. Biological conversion is also maximised as the now prolific fauna and flora reach maximum productivity.

4. Towards the end of winter, as the water table drops, biological conditions in the water become overloaded or even toxic. Many of the plants and animals die and pH drops as a result. Phosphorus and nitrogen levels rise dramatically.

5. When only a trace of surface water remains, as was the case at the Ellenbrook Lexia wetlands when surveys were carried out, the nutrient levels are maximised. In addition, salts have been concentrated by evaporation and salinity is also at a maximum. It should be noted, however, that total dissolved salts at Ellenbrook, although at a maximum, were still considerably less that in the disturbed wetlands of the region.

6. During the summer when the water table is below the surface, some nutrients are taken out by absorption to peat, clays or bog-ironstone in certain areas. Dispersion and mixing occurs and water quality improves.

7. This natural cycle then restarts when winter rains commence.

5.3 STATUS AND CONSERVATION VALUE OF LEXIA WETLANDS

An examination of the Ellenbrook Lexia wetlands is not complete without consideration of current EPA and Government wetland protection policy. The following discussion aims to put the Ellenbrook Lexia wetlands into context in regard to these policies.

The EPA has released a document (EPA, 1990b) to facilitate identification of wetland attributes and management possibilities. Results of a conservation value assessment of the Lexia wetlands, based on the EPA (1990b) procedure, do not distinguish clearly between the individual wetlands (Table 8). The only wetland which scored significantly higher in the evaluation was wetland A which gained primarily because it was larger than all the others. Using the numeric attributes of questionnaires in the EPA report, the Ellenbrook wetlands are identified, both collectively and individually, as Category C - wetlands which possess a high degree of naturalness. The management objective for wetlands belonging to this classification is to maintain and enhance natural attributes and functions.

Middle (1991), in a report prepared for the Water Authority of Western Australia and the Shire of Swan, evaluated lentic wetlands in the Shire of Swan, including the Ellenbrook wetlands. In Middle's report the Ellenbrook wetlands are referred to as the "Lexia" wetlands, a name we adopted for this study. Middle also identifies the Ellenbrook Lexia wetlands as Category C. In Middle's view, the group of wetlands are probably a linked system, both hydrogeologically and as a wildlife habitat, and, as such, may well be unique as a largely intact wetland/dryland system. Middle recommends that the "system" nature of the area be studied in more detail and that any development would need to be carried out in a way that maintains the important natural values of the wetlands.

The Environmental Protection Authority has also released a draft discussion paper for an Environmental Protection Policy (EPP) to protect groundwater, wetlands and associated ecosystems of the Swan Coastal Plain (EPA, 1990a) and a draft EPP (EPA, 1991). Certain beneficial uses are also recognised including:

- protection and maintenance of the quality and quantity of the groundwater resources of the Swan Coastal Plain;
- maintenance and management of the wetlands of the Swan Coastal Plain; and
- protection and management of ecosystems that are dependent on the groundwater or wetlands of the Swan Coastal Plain.

TABLE 8

LEXIA WETLAND CONSERVATION ASSESSMENT BASED ON EPA (1990b)

EPA Question	*Character*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
	PERMANENT AND SEASONAL WETLANDS WITH WELL DEFINED BOUNDARIES													
I	Environmental geology classification	1	1	1	1	1	1	1	1	1	1	1	1	1
II	Adjacent wetlands within 2km													
III	Habitat diversity	2	2	2	2	2	2	2	2	2	2	2	2	2
IV	Drought refuge	0	0	0	0	0	0	0	0	0	0	0	0	0
V	Area of wetland	4	1	1	1	1	1	1	1	1	2	2	1	2
VI	Habitat types present	7	6	4	6	4	6	5	7	6	5	4	3	4
VII	Emergent vegetation	5	3	2	3	2	3	2	1	1	3	2	2	3
VIII	Adverse water quality	5	5	5	5	5	5	5	5	5	5	5	5	5
IX	Drainage	5	5	5	5	5	5	5	5	5	5	5	5	5
X	Adjacent nutrient sources	5	5	5	5	5	5	5	5	5	5	5	5	5
XI	Area of wetland modified	5	5	5	5	5	5	5	5	5	5	5	5	5
XII	Reserve area	2	2	2	2	2	2	2	2	2	2	2	2	2
XIII	Native vegetation buffer	10	10	10	10	10	10	10	10	10	10	10	10	10
	TOTAL OF NATURAL ATTRIBUTES	51	45	42	45	42	45	43	44	43	45	43	41	44
	HUMAN USE													
I	Aesthetics	7	7	7	7	7	7	7	7	7	7	7	7	7
11	History and archaeology	0	0	0	0	0	0	0	0	0	0	0	0	0
III	Security of wetland	1	1	1	1	1	1	1	1	1	1	1	1	1
IV	Protection groups	5	5	5	5	5	5	5	5	5	5	5	5	5
V	Passive recreation	0	0	0	0	0	0	0	0	0	0	0	0	0
VI	Active recreation	2	2	2	2	2	2	2	2	2	2	2	2	2
VII	Other human uses	1	1	1	1	1	1	1	1	1	1	1	1	1
	TOTAL OF HUMAN USE	16	16	16	16	16	16	16	16	16	16	16	16	16
	SUPPLEMENTARY QUESTIONS													
I	Species rarity	N	N	N	N	N	N	N	N	N	N	N	N	N
II	Effect on land values	N	N	N	N	N	N	N	N	N	N	N	N	N
III	Human use	N	N	N	N	N	N	N	N	N	N	N	N	N
	MANAGEMENT CATEGORY	C	C	C	C	C	C	C	C	C	C	C	C	C

The draft EPP is relevant to the wetlands at Ellenbrook as they are located in the Gnangara Water Reserve in the Water Authority of Western Australia's Lexia Groundwater Source area (Dames & Moore, 1986). The Gnangara Water Reserve is one of several areas given specific protection within the EPA discussion paper (EPA, 1990a) as a designated "Groundwater, Wetland and Ecosystem Protection Area". Within these protection areas, only the following land use activities are considered compatible with beneficial uses and thus will be permitted in the groundwater protection areas:

- native vegetation retention;
- wetland retention; and
- passive recreation.

All other land use activities within groundwater protection areas shall not be permitted unless and until it has been subject to consideration under Part IV or V of the Environmental Protection Act 1986 or a policy specifying it as compatible has been prepared.

The EPA inspected the Lexia wetlands in November - December 1991 and arrived at the following conclusions:

- the small wetlands at the end of Transect 1 (Figure 2) are both included in the EPP;
- wetland G1 is included in the EPP but wetlands F1 is not;
- wetlands H1 and A1 to A5 are considered as part of a single large wetland complex, all of which is included in the EPP;
- wetland B1 is included in the EPP;
- the small circular wetland lying 150m west of wetland I1 and just below the eastern end of Transect 7 (Figure 2) is included in the EPP but not part of the complex which lies to the southeast of it; and
- wetlands I1, J1, K1, L1, M1 and N1 are considered part of a single large wetland complex, all of which are included in the EPP.

Thus, in summary, all the Lexia wetlands with the exception of F1, C1 and D1 and illustrated on Figure 2, are in the EPP.

None of the damplands shown on Figure 3 are considered under the EPP.

In addition, the EPA identified four wetlands north of Maralla Road (Figure 2) as part of the Lexia complex. One of these was cleared, and is therefore of limited value. The southernmost wetland, nearest to Maralla Road, was considered by the EPA as meeting EPP requirements and has therefore been included.

Based on the EPP, it is clear that the Ellenbrook Lexia wetlands (and the wetland north of Maralla Road) cannot be greatly altered without prior assessment and approval by the EPA. At the time of preparation of this document, the final EPP incorporating public comments has not been released.

5.4 WETLANDS OF THE SAWPIT AREA

5.4.1 Damp Woodlands

Studies by Muir (1983) identified the structure and floristic composition of the Bassendean Dune woodlands at Melaleuca Park as changing gradually as the height in the landscape decreased. Muir felt that this could be explained by soil moisture level, which, in turn, was a result of capillary rise in moisture above the water table. The same mechanism is believed to be operating on the Bassendean Dunes at Ellenbrook.

Thus, although the "damp woodlands" contain characteristics of wetlands, e.g. scattered *Melaleuca preissiana* trees, they are clearly intermediate between the true wetlands (concentric ecotones, surface water for a month or so each year, sedges, etc.) and the drier woodlands.

The damp woodlands themselves do not hold any intrinsic special value, but they are clearly a significant part of the transitional ecosystem.

5.4.2 Sawpit Gully

Sawpit Gully is the only wetland of its type in the Ellenbrook Study Area. It carries a vegetation structure and floristic composition not found in the other wetlands and contains several species of interest such as *Eucalyptus rudis, Acacia saligna* woodland and *Caladenia huegelii,* a Gazetted Rare species.

Unfortunately, however, it has suffered badly from the influence of adjacent farmland and disturbance. Weed infestations are widespread. Most of the weed species are fairly harmless, although they have the potential to displace the native plants, increase fire hazard, etc. Transect 5 had Watsonia established, and this species will probably take over the drainage channel unless it is controlled.

5.5 DRY WOODLANDS

These represent the drier habitats within the transitory stages between very dry upland conditions and the lower-lying damp woodlands. The structural and floristic analysis showed that the woodlands examined were all basically similar, were comparable with woodlands in nearby conservation areas, and their characteristics could be explained by Muir's (1983) soil moisture hypothesis.

The most significant feature of the dry woodlands was the widespread presence of dieback disease. The disease is visually apparent in Transects 1, 6, 9, 20 and 21. Transect 20, in particular, had an area of several hectares in which almost everything was dead. The disease appears to have been introduced by timber cutting, off-road vehicles or horse riders.

Small groups of dead and dying *Banksia, Xanthorrhoea* and *Macrozamia* were seen in numerous locations adjacent to almost every track in the area. Where these patches were observed away from tracks they were, in every case, on a horse trail.

It must be concluded that the whole area is probably affected or potentially affected with dieback disease and will, eventually, be altered by it. It is not reasonable, however, to assume that prevention of development in the Lexia wetlands area will prevent dieback spread. The very obvious association with horse riding trails suggests that recreation activities which have already occurred will probably ultimately lead to loss of most of the woodland. This process would now continue even if all human activities were excluded.

5.6 RARE FLORA

One Gazetted Rare species and two Priority Three species were found. The Gazetted Rare *Caladenia huegellii* (Spider Orchid) was recorded at three locations, all part of Sawpit Gully. It was not observed anywhere else in the area. It may be that *C. huegellii* is restricted to the loamy soils of the drainage line. Alternatively, it may flower later in the season in these damp locations than it does in the drier habitats around the Lexia wetlands. The usual flowering time for *C. huegellii* is around August to October.

The Priority Three species *Cartonema philydroides* was found at two locations:

- an area devastated by dieback disease on Transect 20. Here it is very abundant and several hundred plants are present. It is almost the only species surviving the dieback infection; and
- a very disturbed, weed infested area on Transect 5. The area has been partly cleared, burned and possibly grazed. Several tens of plants were observed.

Considering the tolerance of this species to disturbance, and the fact that it is dieback resistant, it is felt that it is probably much more widespread than currently believed.

The second Priority Three species, *Conostephium minus,* was recorded in Transect 6. This species is widespread but not common. It probably occurs in patches throughout the dry woodland.

5.7 FAUNA

5.7.1 General

As the Lexia wetlands, and to a lesser extent the remainder of the area, is relatively undisturbed, it is believed the fauna of the area may be fairly rich in species. There are, however, no data to support that opinion.

The Western Australian Museum indicated that unpolluted wetlands may be particularly significant for frogs. The wetlands at Ellenbrook are certainly unpolluted, but frogs seemed neither abundant nor diverse in species based on casual observations during the field studies.

Storr *et al.* (1978b) indicated that deep-water waterfowl were those most likely to be affected by changes in the water table. There are no deep waters at Ellenbrook (and in fact no permanent water) so there is unlikely to be any dependence on the areas for this resource.

As indicated by the W.A. Museum studies, the sandy substrates of the lakes in the eastern part of the Swan Coastal Plain do not support abundant small organisms, consequently they are not used very much by wading birds.

5.7.2 Brown Bandicoot

There are indications that Brown Bandicoot exists in the area, and that it may be common in some localities. The species prefers the ecotones between the wetlands and the adjacent forest.

5.7.3 Short-necked Tortoise

Searches by the Wildlife Research Division of CALM failed to find Short-necked Tortoise in the area, and the habitat, in their opinion, is not suitable.

6.0 CONCLUSIONS

Results indicate that the Lexia wetlands at Ellenbrook are quite heterogeneous. Qualitative analyses using Semeniuk *et al.*'s classification indicate a wide variety of wetland types which can be compared in scope with wetlands occurring regionally across the Swan Coastal Plain. Similarly, quantitative analyses using cluster dendrograms show a low level of similarity between the wetlands and again emphasise the heterogeneity of the Ellenbrook Lexia wetland system. Both of these methods were able to detect differences which were not apparent to observers in the field, yet differed from each other and from intuitive variations observed during field studies.

Structural comparison of the Lexia wetlands and the quantitative analysis both suggest some basic differences between the wetlands of the eastern and western sectors of the Lexia Area. The classification of Semeniuk *et al.* tends to aggregate wetlands according to hydrology (e.g. sumplands versus damplands versus seepages) and vegetation organisation and pattern. It fails to clearly discriminate between the eastern and western section of the Lexia wetlands because it is not concerned with floristics except at a superficial level.

Water analyses show that the Ellenbrook Lexia wetlands tend to have acidic pH levels, naturally high nutrient levels and low total dissolved solids. As the Lexia wetlands can be considered to be almost pristine, it is considered that these parameters reflect a high level of bioproductivity compared to the urbanised wetlands of the Swan Coastal Plain. At the same time, the low level of natural salts reflects the lack of input from polluted waters containing sodium chloride and other minerals.

In the Sawpit Area there are no wetlands of the type found in the Lexia Area. Rather, the low-lying ground is represented by "damp woodlands" which grade into dry woodlands as the topographic altitude increases. The structure and floristics of these woodlands is similar to that recorded at Whiteman Park and Melaleuca Park, two conservation reserves in the same area. The northeastern corner of the Sawpit Area contains Sawpit Gully, a drainage line which overlies Guildford Clay soils. This gully is very degraded and weed infested at its eastern end, but improves in its conservation value towards the west. The gully contains the Gazetted Rare orchid *Caladenia huegellii* and the Priority Three species *Cartonema philydroides*.

Woodlands associated with the Lexia wetlands were found to contain areas where the Priority Three species *Cartonema philydroides* and *Conostephium minus* occurred.

In terms of conservation value the most significant part of the Ellenbrook Project Area is the Lexia wetlands. The damp woodlands and Sawpit Gully also have some importance, as do the dry woodlands, although the damp and dry woodlands are well represented in other conservation reserves. Sawpit Gully, because of its weed infestations, probably has limited long-term conservation value.

There is no evidence that any truly rare fauna occur in the area, and present observations suggest it is not especially rich in animal life. As far as can be determined, even the wetlands have no substantial populations of waterbirds. The presence of Brown Bandicoot is of interest, but this species is very common, widespread and tolerant to disturbance, despite its current Gazettal.

In summary, the value of the Lexia wetlands lies purely in the fact that they are relatively pristine, unlike nearly all other wetlands of the Swan Coastal Plain.

To preserve their pristine nature in the long-term, even if the Ellenbrook Project did not proceed, will become increasingly difficult. Dieback disease introduced by recreation activities, feral animals (cats and dogs were observed in the area) foxes and weed encroachment will gradually degrade the area over time. Nonetheless, the same factors affect all other wetlands on the coastal plain so that in the future, all other things being equal, the Lexia wetlands may still be in better condition than other areas.

If the natural attributes of the area are to be retained active management will be essential. These activities will include feral animal control, fire control, dieback management and management of people.

The principles of management will need to be established to ensure that, if some of the area is to be preserved, that this is carried out as cost-effectively as possible and in an ecologically sensitive manner.

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Respectfully submitted
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Figures

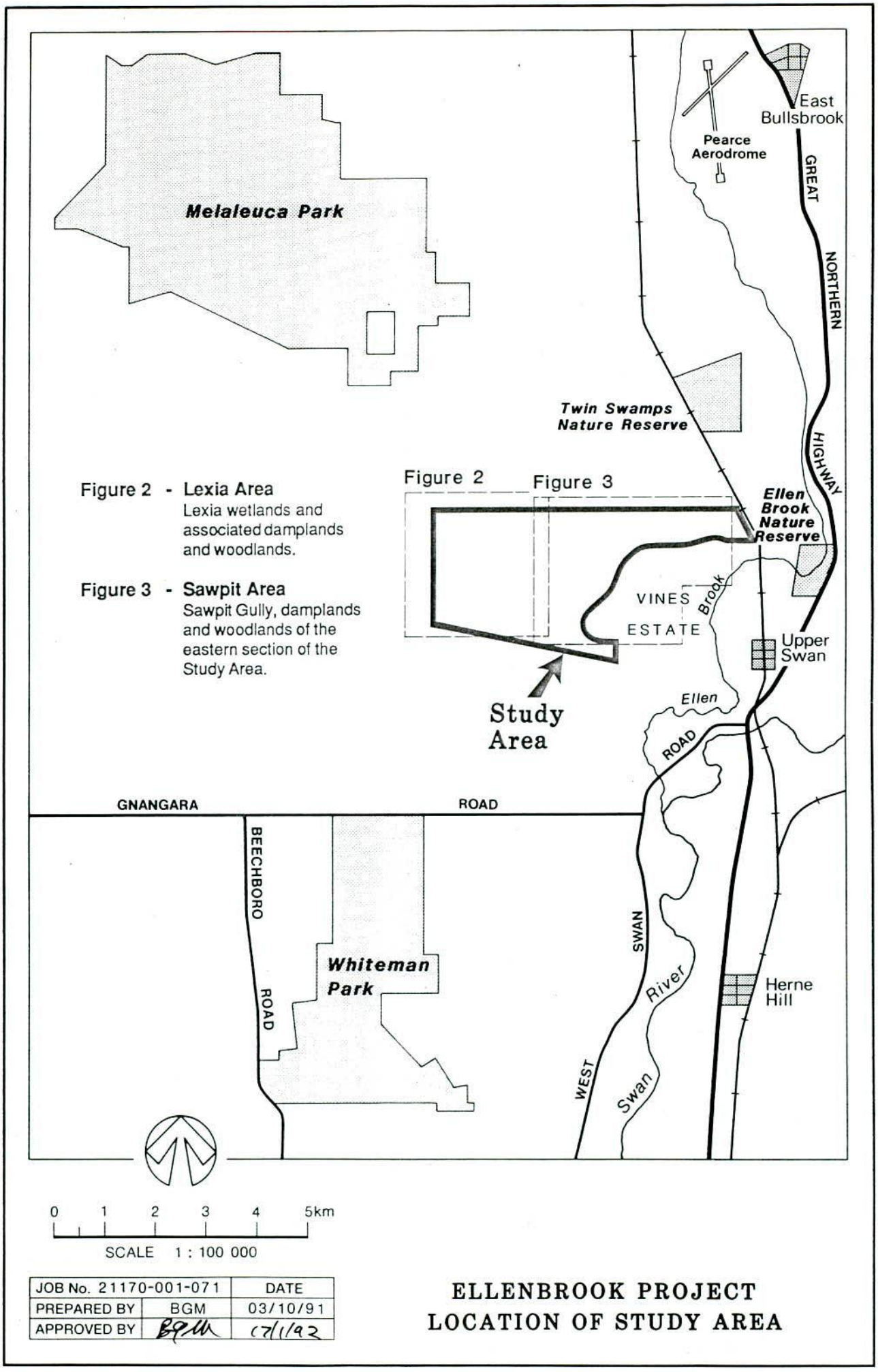

FIGURE 1
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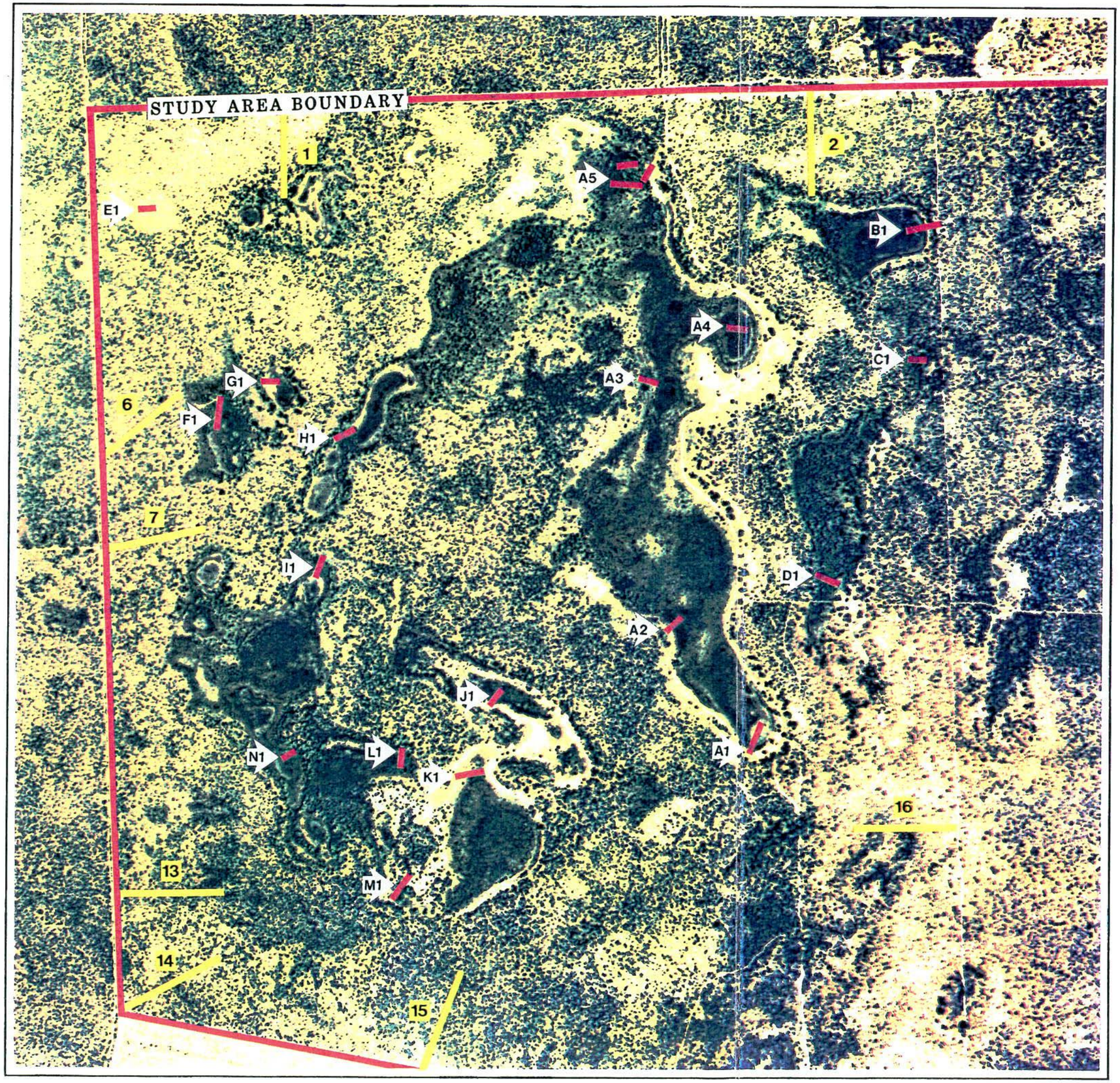


0 100 200 300 400 500m

Woodland Transects

Wetland Transects

TRANSECT LOCATIONS
LEXIA AREA

FIGURE 2
DAMES & MOORE

STUDY AREA BOUNDARY

3

4

5

SAWPIT GULLY

12

9

10

11

8

18

19

20

17

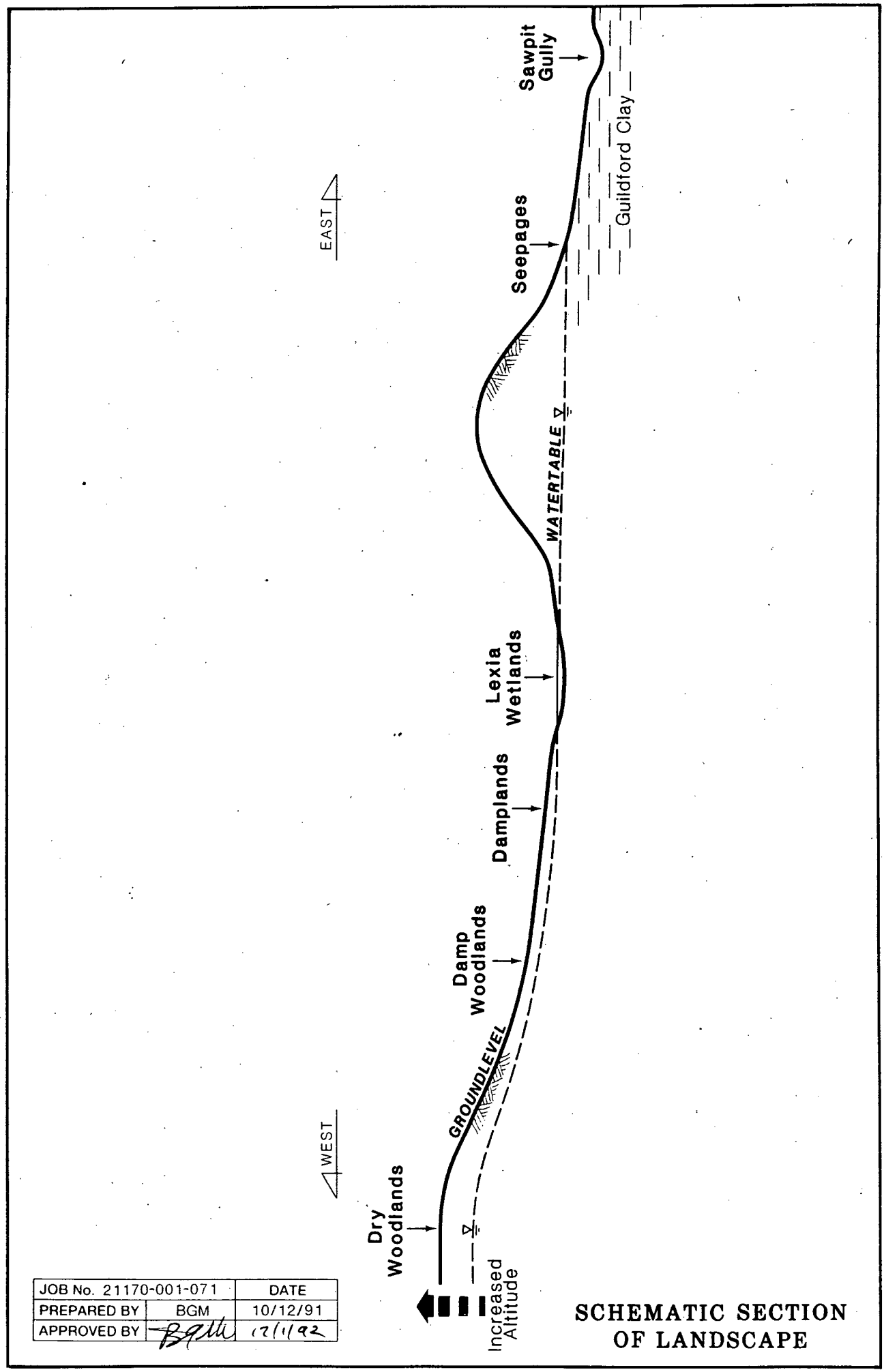
21

0 100 200 300 400 500m

Woodland Transects

TRANSECT LOCATIONS
SAWPIT AREA

FIGURE 3
DAMES & MOORE



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PREPARED BY	BGM	10/12/91
APPROVED BY		12/1/92

FIGURE 4
DAMES & MOORE

Appendix A

APPENDIX A

VEGETATION DESCRIPTIONS
ELLENBROOK LEXIA WETLANDS

APPENDIX A

VEGETATION DESCRIPTIONS

ELLENBROOK LEXIA WETLANDS

The Eastern Sector Wetlands

o Transect A1

Centre: Stratum 1 - *Baumea articulata*, 1.0m tall, 50% canopy cover. Soil is peat over sand. Kangaroo grazing was noted in this centre section. Burning had occurred recently; probably <1 year ago. Winter wet

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.5m tall, 80% canopy cover. Stratum 2 - *Restio* spp. to 0.5m tall, 15% canopy cover. Soil is typical of the sands of the Bassendean Dune system.

Band No. 2: Stratum 1 - *Melaleuca preissiana*, 3-7m tall, 2% canopy cover; also occasional *Eucalyptus rudis* and *Banksia littoralis*. Stratum 2 - *Jacksonia furcellata*, 0.5-2.0m tall, 1% canopy cover. Stratum 3 - *Astartea fascicularis*, 0.5-1.5m tall, 2% canopy cover. Stratum 3 - sedge and heath understorey comprising *Darwinia, Hibbertia, Schoenus, Lepidosperma gladiatum*, 0.25-0.5m, 5% canopy cover. Emu tracks were noted in this area. Band No. 2 passes into a narrow band of *M. preissiana* and then into *Banksia spp.* Soil is comprised of dunal aeolianite sands. This band appears to be white sand on the aerial photograph.

o Transect A2

Centre: Stratum 1 - *Astartea fascicularis-Melaleuca lateritia*, 0.5-1.0m, 70% canopy cover. Stratum 2 - *Restio* sp.-*Baumea articulata*, to 0.5m tall, 50% canopy cover. Soil is peat over sand (presumed).

Band No. 1: - Stratum 1 - *Melaleuca preissiana*, 2-4m tall, 1% canopy cover. *Astartea fascicularis*, 0.5-1.0m tall, 70% canopy cover. Stratum 3 - *Restio* spp. and *Baumea ? acuta*, 0-0.5m tall, 50% canopy cover. Soil is as for centre.

Band No. 2: - Stratum 1 - *Hypocalymma angustifolium-Jacksonia furcellata* 0.5-2.0m tall, 80% canopy cover. Soil is comprised of dunal aeolianite sands. This band corresponds to Band No. 2 in Transect A1 and appears to be white sand on the aerial photograph.

o Transect A3

Centre: Stratum 1 - *Baumea articulata* to 1.0m tall, 90% canopy cover. Soil is peat grading to aeolian sand at 30-40cm. Winter wet.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.0m tall, 50% canopy cover. Stratum 2 - *Pericalymma ellipticum*, 0.2-0.5m tall, 30% canopy cover. Soil is sand with organic matter and roots grading into coarse sand without organic matter.

Band No. 2: Stratum 1 - *Melaleuca preissiana*, 2-6m tall, 2% canopy cover. Stratum 2 - *Astartea fascicularis*, 0.2-1.0m tall, 70% canopy cover. Fire had killed much of the *Astartea fascicularis*. Soil is as for Band No. 1.

Band No. 3: Stratum 1 - *Pericalymma ellipticum*, 0.5-1.5m tall, 80% canopy cover. Ocasional *Adenanthos obovatus* (1-3m tall) and *Calothamnus lateralis* (0.2-0.5m tall) occurred as occasional plants. Soil is sand with organic matter grading to pure sand.

o Transect A4

Centre: Stratum 1 - *Baumea articulata* to 1m, 90% canopy cover. Vegetation grades into *Astartea fascicularis*. Soil is peat grading to sand at 10cm. Winter wet.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.5m tall, 90% canopy cover. Stratum 2 - *Lepidosperma gladiatum*, 0.2-0.5%, 2% canopy cover. Soil is organic material and sand to 40cm grading to sand (no organics). Evidence of kangaroo grazing was noted.

Band No. 2: Stratum 1 - *Astartea fascicularis*, 0.5-1.0m, 50% canopy cover. Stratum 2 - *Restio* sp-*Lepidosperma gladiatum*, 0.2-0.5m, 10% canopy cover. Soil is organic sand to 50cm grading to pure sand. Lycosid tunnels were noted on the outer edge of this transect.

o Transect A5

Centre: Stratum 1 - *Melaleuca rhaphiophylla*, 3-10m, 50% canopy cover. Stratum 2 - *Astartea fascicularis-Baumea ? acuta*, 0.5-1.0m tall, 90% canopy cover. Stratum 3 - *Lepidosperma gladiatum*, 0.2-0.5m tall, 80% canopy cover. Soil is peat and peaty sand with organic material. This area is a localised depression and appears to have been wetter previously than is now the case.

Band No. 1: Stratum 1 - *Melaleuca preissiana*, 3-8m tall, 10% canopy cover. Stratum 2 - *Pericalymma ellipticum*, 0.2-0.5m tall, 80% canopy cover. Soil is organic material to 10cm grading into sand.

Band No. 2: Stratum 1 - *Jacksonia furcellata*, 0.5-1.5m tall, 2% canopy cover. Stratum 2 - *Astartea fascicularis-Pericalymma ellipticum*, 0.2-0.5m tall, 70% canopy cover. Soil is as for Transect A1, Band No. 2.

Band No. 3: Stratum 1 - *Melalauca preissiana-Eucalyptus marginata*, 3-18m tall, 1% canopy cover. Stratum 2 - *Melaleuca preissiana-Banksia attenuata-Banksia ilicifolia*, 2-10m tall, 30% canopy cover. Stratum 3 - *Xanthorrhoea preissii-Jacksonia furcellata*, 0.5-1.0m tall, 30% canopy cover. Stratum 4 - Mixed heath dominated by *Isopgon dubius* and *Lepidosperma* sp., 0.2-0.5m tall, 30% canopy cover. Soil is dunal aeolian sand.

o Transect B1

Centre: Stratum 1 - *Baumea articulata*, 0.5-1.0m tall, 90% canopy cover. Soil is peat to 1m grading to sand. Winter wet.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.0m, 90% canopy cover. *Hypocalymma angustifolium* occurs in a band adjacent to the *Astartea*.

Band No. 2: Stratum 1 - *Baumea ? acuta*, 0.2-0.5m tall, 70% canopy cover.

Band No 3: Stratum 1 - *Melaleuca preissiana-Banksia littoralis*, 3-16m tall, 30% canopy cover. Stratum 2 - *Jacksonia furcellata*, 0.5-1.5m tall, 1% canopy cover. Stratum 3 - *Baumea ? acuta-Hovea*, 0.2-0.5m tall, 70% canopy cover.

o Transect C1

Centre: Stratum 1 - *Astartea fascicularis-Lepidosperma gladiatum*, 0.5-1.0m tall, 2% canopy cover. Soil is very leached white sand at surface over organic sand.

Band No. 1: Stratum 1 - *Adenanthos cygnorum-Jacksonia furcellata*, 0.5-3m tall, 100% canopy cover. Soil is as for Centre.

Band No. 2: Stratum 1 - *Melaleuca preissiana*, 8-22m tall, 5% canopy cover. Stratum 2 - *Melaleuca preissiana*, 2-5m tall, 30% canopy cover. Stratum 3 - *Agonis linearifolia-Astartea fascicularis-Styphelia tenuiflora*, 0.2-1m tall, 70% canopy cover.

Band No. 3: Stratum 1 - *Melaleuca preissiana*, 3-6m tall, 5% canopy cover. Stratum 2 - *Eutaxia virgata-Xanthorrhoea preissii*, 1-2m tall, 70% canopy cover. Stratum 3 - *Hypocalymma angustifolium-Astartea fascicularis*, 0-1m tall, 70% canopy cover.

o Transect D1

Centre: Stratum 1 - *Melaleuca preissiana-Banksia littoralis-Eucalyptus marginata-Eucalyptus calophylla*, 2-8m tall, 30% canopy cover. Stratum 2 - *Xanthorrhoea preissii*, 0.5-2m tall, 50% canopy cover. Stratum 3 - *Hypocalymma angustifolium-Astartea fascicularis*, 0.5-1.0m tall, 50% canopy cover. Soil is organic sand to 30cm grading to pure sand.

Band No. 1: Stratum 1 - *Eucalyptus rudis*, 2-10m tall, 10% canopy cover. Stratum 2 - *Banksia ilicifolia-Banksia attenuata-Banksia littoralis*, 1.5-3m tall, 20% canopy cover. Stratum 3 - *Jacksonia furcellata*, 0.5-1.5m tall, 15% canopy cover. Stratum 4 - *Verticordia* sp., 0.2-0.5m tall, 50% canopy cover. Soil is as for the Centre.

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o Transect E1

Centre: Stratum 1 - Emergent *Banksia ilicifolia*, 1-5m tall, <1% canopy cover. Stratum 2 - *Eremaea pauciflora-Xanthorrhoea preissii*, 0.24-1.0m tall, 60% canopy cover. Stratum 3 - *Restio* spp.-*Dasypogon bromeliifolius-Patersonia occidentalis*, 0-0.25m tall, 35% canopy cover. Soil is sand with a little organic material.

o Transect F1

Centre: Stratum 1 - *Baumea articulata-Astartea fascicularis-Restio* sp., 0.5-1.5m tall, 80% canopy cover. Soil is peat with almost no sand to 30cm in depth.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-2.0m tall, 90% canopy cover. Stratum 2 - *Baumea ? acuta*, to 1m tall, 90% canopy cover. Soil is peat with almost no sandPeat

Band No. 2: Stratum 1 - *Banksia littoralis*, 2-8m tall, 70% canopy cover. Stratum 2 - *Lepidosperma gladiatum*, 0.5-2m tall, 100% canopy cover.

Band No. 3: Stratum 1 - *Melaleuca preissiana*, 3-10m tall, 30% canopy cover (clumped 70% canopy cover). Stratum 2 - *Xanthorrhoea preissia-Banksia littorralis-Banskia ilicifolia-Banksia attenuata*, 1.0-2.5m tall, 30% canopy cover. Stratum 3 - *Lepidosperma ? glabra*, 0.5-1m tall, 2% canopy cover. Soil is peat to 10cm depth grading into sand with some organic matter.

o Transect G1

Centre: Stratum 1 - *Baumea articulata*, 1.0-1.5m tall, 90% canopy cover. Stratum 2 - *Baumea ? acuta*, 0.5-1.0m tall, 80% canopy cover.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.5m tall, 90% canopy cover.

Band No. 2: Stratum 1 - *Baumea ? juncea*, 0.2-0.5m tall, 30% canopy cover (clumped 100% canopy cover).

Band No. 3: Stratum 2 - *Calothamnus lateralis-Astartea fascicularis*, 0.2-0.5m tall, 2% canopy cover.

Band No. 4: Stratum 1 - *Melaleuca preissiana*, 1-6m tall, 10% canopy cover. Stratum 2 - *Hypocalymma angustifolium*, 0.5-1m tall, 80% canopy cover. Stratum 3 - ? *Loxycarya* sp., 0.2-1m tall, 80% canopy cover.

o Transect H1

Centre: Stratum 1 - *Baumea articulata*, 1.0-1.5m tall, 90% canopy cover. Soil is peat with minor sand.

Band No. 1: Stratum 1 - *Baumea ? acuta*, 1.0m tall, 100% canopy cover.

Band No. 2: Stratum 1 - *Melaleuca lateritia*, 0.5-1.5m tall, 80% canopy cover. Stratum 2 - *Baumea ? acuta*, 1.0m tall, 100% canopy cover.

Band No. 3: Stratum 1 - *Astartea fascicularis*, 1.5-2m tall, 90% canopy cover. Soil is organic sand.

Band No. 4: Stratum 1 - *Melaleuca preissiana-Banksia littoralis*, 2-8m tall, 30% canopy cover. Stratum 2 - *Xanthorrhoea preissii-Astartea fascicularis*, 1.5-2m tall, 90% canopy cover.

Band No. 5: Stratum 1 - *Hypocalymma angustifolium*, 0.5-1.0m tall, 90% canopy cover.

o Transect I1

Centre: Band No. 1 - *Baumea articulata*, 1.5m tall, 70% canopy cover. Soil is peat.

Band No. 1: Stratum 1 - *Baumea ? acuta-Restio* sp., 0.5-0.75m tall, 100% canopy cover.

Band No. 2: Stratum 1 - *Astartea fascicularis-Baumea ? acuta*, 0.5-1.5m tall, 50% canopy cover.

Band No. 3: Stratum 1 - *Astartea fascicularis*, 0.5-1m tall, 80% canopy cover. Stratum 2 - *Baumea ? acuta*, 0.2-0.5m tall, 70% canopy cover.

Band No. 4: Stratum 1 - *Astartea fasicicularis*, 1-2m tall, 70% canopy cover, with occasional *Melaleuca preissiana* and *Calothamnus lateralis*.

Band No. 5: Stratum 1 - *Banksia littoralis-Banksia ilicifolia-Melaleuca preissiana*, 2-10m tall, 10% canopy cover. Stratum 2 - *Hypocalymma angustifolium-Isopogon linearis*, 0.5-1m tall, 50% canopy cover. Stratum 3 - *Hibbertia sp.-Dasypogon bromellifolius-Eucholopsis linearis-Phlebocarya ciliata*, 0.2-0.4m tall, 30% canoy cover.

o Transect J1

Centre: Stratum 1 - *Banksia littoralis*, 2-10m tall, localised 90% canopy cover. Stratum 2 - *Baumea articulata*, 1.0-1.5m tall, 90% canopy cover. Stratum 3 - *Baumea ? acuta*, to 0.5m tall, 90% canopy cover. Soil is sand, very organic, to 30cm grading into grey sand.

Band No. 1: Stratum 1 - *Astartea fascicularis-Hypocalymma angustifolium-Melaleuca lateritia*, 0.5-1m tall, 10% canopy cover. Stratum 2 - *Baumea ? acuta*, to 0.5m tall, 100% canopy cover.

Band No. 2: Stratum 1 - *Pericalymma ellipticum-Calothamnus lateralis*, 1.0-1.5m tall, 80% canopy cover. Stratum 2 - *Restio* spp., 0.5m tall, 5% canopy cover.

o Transect K1

Centre: Stratum 1 - *Pericalymma ellipticum-Astartea fascicularis*, 0.5-1.0m tall, 90% canopy cover. Stratum 2 - *Baumea ? acuta-Restio* sp., 0.5m tall, 90% canopy cover.

Band No. 1: Stratum 1 - *Astartea fascicularis*, 0.5-1.0m tall, 70% canopy cover. Stratum 2 - *Calothamnus lateralis-Baumea ? acuta*, 0.5m tall, 90% canopy cover.

Band No. 2: Stratum 1 - *Melaleuca preissiana-Banksia ilicifolia*, 1-4m tall, 10% canopy cover. Stratum 2 - *Baumea ? acuta*, 0.5m tall, 80% canopy cover.

o Transect L1

Centre: Stratum 1 - *Meleleuca teretifolia-Melaleuca polygaloides-Astartea fascicularis*, 1.5-4m tall, 100% canopy cover. Stratum 2 - *Baumea articulata*, 1.0-2.5m tall, 80% canopy cover.

Band No. 1: Stratum 1 - *Banksia littoralis*, 2-10m tall, 90% canopy cover. Stratum 2 - *Baumea articulata*, 1-2m tall, 100% canopy cover. Soil is root material to 10cm gradint to sandy peat then sand with organic material to 50cm.

o Transect M1

Centre: Stratum 1 - *Baumea articulata*, 1.5-2.5m tall, 100% canopy cover. Soil is peaty sand.

Band No. 1: Stratum 1 - *Astartea fascicularis-Melaleuca teretifolia*, 1.5-2.5m tall, 95% canopy cover. Stratum 2 - *Baumea articulata*, 1.0m tall, 30% canopy cover.

Band No. 2: Stratum 1 - *Lepidpsperma longifolia*, 1m tall, 90% canopy cover. Soils are sands.

Band No. 3: Stratum 1 - *Baumea ? acuta*, 1m tall, 100% canopy cover.

o Transect N1

Centre: Stratum 1 - *Baumea articulata*, 1-2m tall, 90% canopy cover. Soil is peat.

Band No. 1: Stratum 1 - *Astartea fascicularis-Melaleuca lateritia*, 1.5-2.5m tall, 80% canopy cover. Stratum 2 - *Baumea articulata-Baumea ? acuta*, 0.5m tall, 70% canopy cover.

Band No. 2: Stratum 1 - *Baumea ? acuta*, 1m tall, 100% canopy cover.

Band No. 3: Stratum 1 - *Astartea fascicularis*, 0.5-1.5m tall, 80% canopy cover. Stratum 2 - *Baumea ? acuta*, 0.5m tall, 100% canopy cover.

Appendix B

APPENDIX B

FLORISTIC ASSOCIATION, 2 x 2 CONTINGENCY TABLES AND BARONI-URBANI AND BUSER AND SORENSEN SIMILARITY COEFFICIENTS

APPENDIX B
FLORISTIC ASSOCIATION, 2 X 2 CONTINGENCY TABLES AND BARONI-URBANI AND BUSER AND SORENSEN SIMILARITY COEFFICIENTS

TABLE B1
FLORISTIC ASSOCIATION
ELLENBROOK WETLANDS

SPECIES	PRESENCE																	
Baumea articulata	A1	A2	A3	A4		B1				F1	G1	H1	I1	J1		L1	M1	N1
Astartea fascicularis	A1	A2	A3	A4	A5	B1	C1	D1		F1	G1	H1	I1	J1	K1	L1	M1	N1
Restio sp.	A1	A2		A4									I1	J1	K1			
Melaleuca preissiana	A1	A2	A3		A5	B1	C1	D1		F1	G1	H1	I1		K1			N1
Jacksonia furcellata	A1	A2			A5	B1	C1	D1										
Darwinia sp.	A1																	
Hibbertia hypericoides	A1												I1					
Lepidosperma gladiatum	A1			A4	A5		C1			F1								
Schoenus sp.	A1																	
Melaleuca lateritia		A2										H1		J1				N1
Eucalyptus calophylla					A5			D1										
Eucalyptus marginata					A5			D1										
Hypocalymma angustifolium		A2				B1	C1	D1			G1	H1	I1	J1				
Adenanthos sp.			A3															
Adenanthos cygnorum							C1											
Pericalymma ellipticum			A3		A5								I1	J1				
Calothamnus lateralis			A3							F1			I1	J1	K1			
Melaleuca rhaphiophylla					A5													
Isopogon dubius					A5								I1					
Eucalyptus rudis						B1		D1										
Banksia littoralis						B1		D1		F1		H1	I1	J1		L1		N1
Hovea trisperma						B1												
Agonis linearifolia							C1											
Styphelia tenuiflora							C1											
Eutaxia ? obovata							C1											
Xanthorrhoea preissii					A5		C1	D1	E1	F1		H1						
Banksia ilicifolia					A5			D1	E1	F1			I1		K1			
Banksia attenuata					A5			D1		F1								
Verticordia plumosa								D1										
Eremaea pauciflora									E1									
Phlebocarya ciliata									E1				I1					
Patersonia ? occidentalis									E1									
Dasypogon bromeliifolius									E1				I1					
Eriostemon spicatum									E1									
Calytrix sp.									E1									
Acacia pulchella									E1									
Burchardia ? umbellata									E1									
Tricoryne elatior									E1									
Dampiera ? linearis									E1									
Bossiaea eriocarpa									E1									
Baumea ? acuta	A1	A2		A4	A5	B1				F1	G1	H1	I1	J1	K1		M1	N1
Lepidosperma sp.										F1								
Pultenaea reticulata												H1						
Euchilopsis linearis													I1					
? Loxycarya											G1							
Melaleuca teretifolia														J1		L1	M1	
Melaleuca polygaloides																L1		
Lepidosperma longitudinale																	M1	
	A1	A2	A3	A4	A5	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1
No of species present	10	8	6	5	13	9	10	12	13	11	6	9	15	10	6	5	5	6

TABLE B2
2 X 2 CONTINGENCY TABLES
BARONI-URBANI AND BUSER AND SORENSEN SIMILARITY COEFFICIENTS

BU = 20.7/26.7 =.775

S = 12/18 = 0.667

		A1 pr.	A1 ab.
A2	pr.	6	2
	ab.	4	36

BU = 13.392/22.39 = 0.598

S = 6/15 = 0.4

		A1 pr.	A1 ab.
A3	pr.	3	3
	ab.	6	36

BU = 21.1/25.1 = 0.841

S = 12/16 = 0.75

		A1 pr.	A1 ab.
A4	pr.	6	0
	ab.	4	38

BU = 17.247/30.247 = 0.57

S = 10/23 = 0.434

		A1 pr.	A1 ab.
A5	pr.	5	8
	ab.	5	30

BU = 18.038/27.038 = 0.667

S = 10/19 = 0.526

		A1 pr.	A1 ab.
B1	pr.	5	4
	ab.	5	34

BU = 15.135/28.135 = 0.538

S = 8/21 = 0.381

		A1 pr.	A1 ab.
C1	pr.	4	6
	ab.	7	31

BU = 12.327/28.327 = 0.435

S = 6/22 = 0.272

		A1 pr.	A1 ab.
D1	pr.	3	9
	ab.	7	29

BU = 0/23 = 0

S = 0/23 = 0

		A1 pr.	A1 ab.
E1	pr.	0	13
	ab.	10	25

BU = 17.649/28.491 = 0.619

S = 10/21 = 0.476

		A1 pr.	A1 ab.
F1	pr.	5	6
	ab.	5	32

BU = 16/24 = 0.667

S = 8/16 = 0.50

		A1	
		pr.	ab.
	pr.	4	2
G1	ab.	6	36

BU = 15.314/26.314 = 0.582

S = 8/19 = 0.421

		A1	
		pr.	ab.
	pr.	4	5
H1	ab.	6	32

BU = 18.961/25.961 = 0.730

S = 12/25 = 0.48

		A1	
		pr.	ab.
	pr.	6	9
I1	ab.	4	28

BU = 15.313/27.313 = 0.561

S = 8/20 = 0.4

		A1	
		pr.	ab.
	pr.	4	6
J1	ab.	6	32

BU = 16.329/24.329 = 0.671

S = 8/16 = 0.5

		A1	
		pr.	ab.
	pr.	4	2
K1	ab.	6	38

BU = 10.367/21.357 = 0.485

S = 4/15 = 0.267

		A1	
		pr.	ab.
	pr.	2	3
L1	ab.	8	35

BU = 13.392/22.392 = 0.598

S = 6/15 = 0.4

		A1	
		pr.	ab.
	pr.	3	2
M	ab.	7	36

BU = 16/24 = 0.667

S = 8/16 = 0.5

		A1	
		pr.	ab.
	pr.	4	2
N1	ab.	6	36

BU = 13.356/21.356 = 0.634

S = 6/14 = 0.428

		A2	
		pr.	ab.
	pr.	3	3
A3	ab.	5	37

BU = 16.490/21.490 = 0.767

S = 8/12 = 0.667

		A2	
		pr.	ab.
	pr.	4	1
A4	ab.	4	39

BU = 15.135/28.135 = 0.538

S = 8/21 = 0.381

		A2 pr.	A2 ab.
	pr.	4	9
A5	ab.	4	31

BU = 20.9/25.9 = 0.807

S = 12/17 = 0.706

		A2 pr.	A2 ab.
	pr.	6	3
B1	ab.	2	37

BU = 15.662/25.662 = 0.61

S = 8/18 = 0.444

		A2 pr.	A2 ab.
C1	pr.	4	6
	ab.	4	34

BU = 15.314/27.314 = 0.561

S = 8/20 = 0.4

		A2 pr.	A2 ab.
	pr.	4	8
D1	ab.	4	32

BU = 0/21 = 0

S = 0/21 = 0

		A2 pr.	A2 ab.
	pr.	0	13
E1	ab.	8	27

BU = 14.954/28.954 = 0.516

S = 8/22 = 0.364

		A2 pr.	A2 ab.
	pr.	4	7
F1	ab.	7	30

BU = 18.964/22.964 = 0.826

S = 10/13 = 0.769

		A2 pr.	A2 ab.
	pr.	5	1
G1	ab.	3	39

BU = 20.900/26.900 = 0.777

S = 12/18 = 0.667

		A2 pr.	A2 ab.
	pr.	6	3
H1	ab.	3	37

BU = 19.638/30.638 = 0.641

S = 12/23 = 0.522

		A2 pr.	A2 ab.
	pr.	6	9
I1	ab.	2	31

BU = 20.697/26.697 = 0.775

S = 12/16 = 0.75

		A2 pr.	A2 ab.
	pr.	6	4
J1	ab.	2	36

BU = 16.329/22.329 = 0.731

S = 8/14 = 0.571

		A2	
		pr.	ab.
K1	pr.	4	2
	ab.	4	38

BU = 10.602/19.602 = 0.541

S = 4/13 = 0.308

		A2	
		pr.	ab.
L1	pr.	2	3
	ab.	6	37

BU = 13.677/20.677 = 0.661

S = 6/13 = 0.461

		A2	
		pr.	ab.
M1	pr.	3	2
	ab.	5	38

BU = 18.964/22.964 = 0.826

S = 10/14 = 0.714

		A2	
		pr.	ab.
N1	pr.	5	1
	ab.	3	39

BU = 10.832/17.832 = 0.607

S = 4/11 = 0.364

		A3	
		pr.	ab.
A4	pr.	2	3
	ab.	4	39

BU = 12.798/25.798 = 0.496

S = 6/19 = 0.316

		A3	
		pr.	ab.
A5	pr.	3	10
	ab.	3	32

BU = 13.392/19.392 = 0.690

S = 6/15 = 0.4

		A3	
		pr.	ab.
B1	pr.	3	6
	ab.	3	36

BU = 10.246/22.246 = 0.460

S = 4/16 = 0.25

		A3	
		pr.	ab.
C1	pr.	2	8
	ab.	4	34

BU = 10/24 = 0.417

S = 4/18 = 0.222

		A3	
		pr.	ab.
D1	pr.	2	10
	ab.	4	32

BU = 0/19 = 0

S = 0/19 = 0

		A3	
		pr.	ab.
E1	pr.	0	13
	ab.	6	29

BU = 15.832/24.832 = 0.637

S = 8/17 = 0.47

		A3	
		pr.	ab.
F1	pr.	4	7
	ab.	2	35

BU = 13.817/19.817 = 0.697

S = 6/12 = 0.5

		A3	
		pr.	ab.
G1	pr.	3	3
	ab.	3	39

BU = 13.536/22.536 = 0.601

S = 6/16 = 0.400

		A3	
		pr.	ab.
H1	pr.	3	7
	ab.	3	37

BU = 17.64928/28.649 = 0.616

S = 10/21 = 0.476

		A3	
		pr.	ab.
I1	pr.	5	10
	ab.	1	32

BU = 16/24 = 0.667

S = 8/16 = 0.5

		A3	
		pr.	ab.
J1	pr.	4	6
	ab.	2	36

BU = 13.817/19.817 = 0.697

S = 6/12 = 0.5

		A3	
		pr.	ab.
K1	pr.	3	3
	ab.	3	39

BU = 10.832/17.832 = 0.607

S = 4/11 = 0.364

		A3	
		pr.	ab.
L1	pr.	2	3
	ab.	4	39

BU = 10.832/17.832 = 0.607

S = 4/11 = 0.364

		A3	
		pr.	ab.
M1	pr.	2	3
	ab.	4	39

BU = 13.817/19.817 = 0.697

S = 6/12 = 0.50

		A3	
		pr.	ab.
N1	pr.	3	3
	ab.	3	39

BU = 12.950/24.950 = 0.519

S = 6/18 = 0.333

		A4	
		pr.	ab.
A5	pr.	3	10
	ab.	2	33

BU = 13.536/21.536 = 0.628

S = 6/14 = 0.428

		A4	
		pr.	ab.
B1	pr.	3	6
	ab.	2	37

BU = 10.367/21.367 = 0.485

S = 4/15 = 0.267

		A4	
		pr.	ab.
C1	pr.	2	8
	ab.	3	35

BU = 6.657/21.657 = 0.307

S = 2/17 = 0.118

		A4	
		pr.	ab.
D1	pr.	1	11
	ab.	4	32

BU = 6.568/22.568 = 0.291

S = 2/18 = 0.111

		A4	
		pr.	ab.
E1	pr.	1	12
	ab.	4	31

BU = 16/24 = 0.667

S = 8/16 = 0.5

		A4	
		pr.	ab.
F1	pr.	4	7
	ab.	1	36

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		A4	
		pr.	ab.
G1	pr.	3	3
	ab.	2	40

BU = 13.677/21.677 = 0.631

S = 6/14 = 0.428

		A4	
		pr.	ab.
H1	pr.	3	6
	ab.	2	38

BU = 12/24 = 0.5

S = 8/20 = 0.4

		A4	
		pr.	ab.
I1	pr.	4	11
	ab.	1	32

BU = 16.165/23.165 = 0.698

S = 8/15 = 0.533

		A4	
		pr.	ab.
J1	pr.	4	6
	ab.	1	37

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		A4	
		pr.	ab.
K1	pr.	3	3
	ab.	2	40

BU = 10.944/16.944 = 0.646

S = 4/10 = 0.4

		A4	
		pr.	ab.
L1	pr.	2	3
	ab.	3	40

BU = 14.09/18.09 = 0.834

S = 6/10 = 0.6

		A4	
		pr.	ab.
M1	pr.	3	2
	ab.	2	41

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		A4	
		pr.	ab.
N1	pr.	3	3
	ab.	2	40

BU = 14.954/28.954 = 0.516

S = 8/22 = 0.364

		A5	
		pr.	ab.
B1	pr.	4	5
	ab.	9	30

BU = 17.247/30.247 = 0.570

S = 10/23 = 0.435

		A5	
		pr.	ab.
C1	pr.	5	5
	ab.	8	30

BU = 23.748/32.748 = 0.725

S = 16/25 = 0.64

		A5	
		pr.	ab.
D1	pr.	8	4
	ab.	5	31

BU = 8.928/30.928 = 0.289

S = 4/26 = 0.154

		A5	
		pr.	ab.
E1	pr.	2	11
	ab.	11	24

BU = 21.731/31.731 = 0.685

S = 14/24 = 0.583

		A5	
		pr.	ab.
F1	pr.	7	4
	ab.	6	31

BU = 12.798/25.798 = 0.496

S = 6/19 = 0.316

		A5	
		pr.	ab.
G1	pr.	3	3
	ab.	10	32

BU = 15.136/29.136 = 0.519

S = 8/22 = 0.364

		A5	
		pr.	ab.
H1	pr.	4	5
	ab.	9	31

BU = 18.49/34.49 = 0.536

S = 12/28 = 0.428

		A5	
		pr.	ab.
	pr.	6	9
I1	ab.	7	26

BU = 12.165/29.165 = 0.417

S = 6/23 = 0.261

		A5	
		pr.	ab.
	pr.	3	7
J1	ab.	10	28

BU = 15.489/26.489 = 0.585

S = 8/19 = 0.421

		A5	
		pr.	ab.
	pr.	4	2
K1	ab.	9	33

BU = 6.568/22.568 = 0.291

S = 2/18 = 0.111

		A5	
		pr.	ab.
	pr.	1	4
L1	ab.	12	31

BU = 10/24 = 0.417

S = 4/18 = 0.222

		A5	
		pr.	ab.
	pr.	2	3
M1	ab.	11	32

BU = 12.798/25.798 = 0.496

S = 6/19 = 0.316

		A5	
		pr.	ab.
	pr.	3	3
N1	ab.	10	32

BU = 15.489/26.489 = 0.585

S = 8/19 = 0.421

		B1	
		pr.	ab.
	pr.	4	6
C1	ab.	5	33

BU = 20.071/29.071 = 0.69

S = 12/21 = 0.571

		B1	
		pr.	ab.
	pr.	6	6
D1	ab.	3	33

BU = 0/22 = 0

S = 0/22 = 0

		B1	
		pr.	ab.
	pr.	0	13
E1	ab.	9	26

BU = 17.845/27.845 = 0.641

S = 10/20 = 0.5

		B1	
		pr.	ab.
	pr.	5	6
F1	ab.	4	33

BU = 18.784/23.784 = 0.79

S = 10/15 = 0.667

		B1 pr.	B1 ab.
G1	pr.	5	1
	ab.	4	38

BU = 20.9/26.9 = 0.777

S = 12/18 = 0.667

		B1 pr.	B1 ab.
H1	pr.	6	3
	ab.	3	37

BU = 19.416/31.416 = 0.618

S = 12/24 = 0.5

		B1 pr.	B1 ab.
I1	pr.	6	9
	ab.	3	30

BU = 18.038/27.038 = 0.667

S = 10/19 = 0.526

		B1 pr.	B1 ab.
J1	pr.	5	5
	ab.	4	34

BU = 17.697/26.697 = 0.663

S = 6/15 = 0.4

		B1 pr.	B1 ab.
K1	pr.	3	3
	ab.	6	36

BU = 13.536/21.536 = 0.628

S = 6/14 = 0.428

		B1 pr.	B1 ab.
L1	pr.	3	2
	ab.	6	37

BU = 13.536/21.536 = 0.628

S = 6/14 = 0.428

		B1 pr.	B1 ab.
M1	pr.	3	2
	ab.	6	37

BU = 18.784/23.784 = 0.79

S = 10/15 = 0.667

		B1 pr.	B1 ab.
N1	pr.	5	1
	ab.	4	38

BU = 17.845/27.845 = 0.641

S = 10/20 = 0.5

		C1 pr.	C1 ab.
D1	pr.	5	7
	ab.	3	33

BU = 6.291/25.2910.249

S = 2/21 = 0.095

		C1 pr.	C1 ab.
E1	pr.	1	12
	ab.	7	28

BU = 15.489/26.489 = 0.585

S = 8/19 = 0.421

		C1 pr.	C1 ab.
	pr.	4	7
F1	ab.	4	33

BU = 13.536/21.536 = 0.628

S = 6/14 = 0.428

		C1 pr.	C1 ab.
	pr.	3	3
G1	ab.	5	37

BU = 16/25 = 0.640

S = 8/17 = 0.470

		C1 pr.	C1 ab.
	pr.	4	5
H1	ab.	4	36

BU = 19.416/31.416 = 0.618

S = 12/24 = 0.5

		C1 pr.	C1 ab.
	pr.	6	9
I1	ab.	3	30

BU = 12.95/24.95 = 0.519

S = 6/18 = 0.333

		C1 pr.	C1 ab.
	pr.	3	7
J1	ab.	5	33

BU = 10.485/20.485 = 0.512

S = 4/14 = 0.286

		C1 pr.	C1 ab.
	pr.	2	4
K1	ab.	6	36

BU = 7/18 = 0.389

S = 2/13 = 0.154

		C1 pr.	C1 ab.
	pr.	1	4
L1	ab.	7	36

BU = 7/18 = 0.389

S = 2/13 = 0.154

		C1 pr.	C1 ab.
	pr.	1	4
M1	ab.	7	36

BU = 10.485/20.485 = 0.512

S = 4/14 = 0.286

		C1 pr.	C1 ab.
	pr.	2	4
N1	ab.	6	36

BU = 9.071/30.071 = 0.302

S = 4/25 = 0.16

		D1 pr.	D1 ab.
	pr.	2	11
E1	ab.	10	25

BU = 19.638/30.638 = 0.641

S = 12/23 = 0.522

		D1 pr.	D1 ab.
F1	pr.	6	5
	ab.	6	31

BU =12.95/24.95

S = 6/18 = 0.333

		D1 pr.	D1 ab.
G1	pr.	3	3
	ab.	9	33

BU = 17.845/28.845 = 0.619

S = 10/21 = 0.476

		D1 pr.	D1 ab.
H1	pr.	5	4
	ab.	7	33

BU = 16.402/33.402 = 0.491

S = 10/27 = 0.37

		D1 pr.	D1 ab.
I1	pr.	5	10
	ab.	7	26

BU = 12.327/28.327 = 0.435

S = 6/22 = 0.273

		D1 pr.	D1 ab.
J1	pr.	3	7
	ab.	9	29

BU = 12.95/24.95 = 0.519

S = 6/18 = 0.333

		D1 pr.	D1 ab.
K1	pr.	3	3
	ab.	9	33

BU = 10.124/23.124 = 0.438

S = 4/17 = 0.235

		D1 pr.	D1 ab.
L1	pr.	2	3
	ab.	10	33

BU = 6.657/21.657 = 0.307

S = 2/17 = 0.118

		D1 pr.	D1 ab.
M1	pr.	1	4
	ab.	11	32

BU = 10/24 = 0.417

S = 4/18 = 0.222

		D1 pr.	D1 ab.
N1	pr.	2	4
	ab.	10	32

BU = 9.211/29.211 = 0.315

S = 4/24 = 0.167

		E1 pr.	E1 ab.
F1	pr.	2	9
	ab.	11	26

BU = 12.95/24.95 = 0.519

S = 6/18 = 0.333

		E1	
		pr.	ab.
	pr.	3	3
G1	ab.	9	33

BU = 6.291/26.291 = 0.239

S = 2/22 = 0.091

		E1	
		pr.	ab.
	pr.	1	8
H1	ab.	12	28

BU = 11.307/33.307 = 0.339

S = 6/28 = 0.214

		E1	
		pr.	ab.
	pr.	3	12
I1	ab.	10	23

BU = 0/23 = 0

S = 0/23 = 0

		E1	
		pr.	ab.
	pr.	0	10
J1	ab.	13	25

BU = 0/19 = 0

S = 0/19 = 0

		E1	
		pr.	ab.
	pr.	0	6
K1	ab.	13	29

BU = 0/18 = 0

S = 0/18 = 0

		E1	
		pr.	ab.
	pr.	0	5
L1	ab.	13	30

BU = 0/18 = 0

S = 0/18 = 0

		E1	
		pr.	ab.
	pr.	0	5
M1	ab.	13	30

BU = 10/24 = 0.417

S = 4/18 = 0.222

		E1	
		pr.	ab.
	pr.	2	4
N1	ab.	10	32

BU = 15.832/22.832 = 0.693

S = 8/17 = 0.47

		F1	
		pr.	ab.
	pr.	4	2
G1	ab.	7	35

BU = 20.697/27.697 = 0.747

S = 12/19 = 0.631

		F1	
		pr.	ab.
	pr.	6	2
H1	ab.	5	36

BU = 21.967/30.967 = 0.709

S = 14/23 = 0.609

		F1	
		pr.	ab.
I1	pr.	7	5
	ab.	4	32

BU = 17.649/28.649 = 0.616

S = 10/21 = 0.476

		F1	
		pr.	ab.
J1	pr.	5	5
	ab.	6	32

BU = 18.416/25.416 = 0.724

S = 10/17 = 0.588

		F1	
		pr.	ab.
K1	pr.	5	1
	ab.	6	36

BU = 13.247/23.247 = 0.57

S = 6/16 = 0.375

		F1	
		pr.	ab.
L1	pr.	3	2
	ab.	8	35

BU = 13.247/23.247 = 0.57

S = 6/16 = 0.375

		F1	
		pr.	ab.
M1	pr.	3	2
	ab.	8	35

BU = 18.416/25.416 = 0.724

S = 10/17 = 0.588

		F1	
		pr.	ab.
N1	pr.	5	1
	ab.	6	36

BU = 19.142/23.142 = 0.827

S = 10/14 = 0.714

		G1	
		pr.	ab.
H1	pr.	5	2
	ab.	1	40

BU = 18.229/26.229 = 0.695

S = 10/19 = 0.555

		G1	
		pr.	ab.
I1	pr.	5	7
	ab.	1	35

BU = 16/24 = 0.667

S = 8/16 = 0.5

		G1	
		pr.	ab.
J1	pr.	4	6
	ab.	2	36

BU = 13.817/19.817 = 0.697

S = 6/12 = 0.5

		G1	
		pr.	ab.
K1	pr.	3	3
	ab.	3	39

BU = 10.832/17.832 = 0.607

S = 4/11 = 0.364

		G1	
		pr.	ab.
	pr.	2	3
L1	ab.	4	39

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		G1	
		pr.	ab.
	pr.	3	2
M1	ab.	3	40

BU = 16.649/20.649 = 0.806

S = 8/12 = 0.667

		G1	
		pr.	ab.
	pr.	4	2
N1	ab.	2	40

BU = 20.283/29.283 = 0.693

S = 12/21 = 0.571

		H1	
		pr.	ab.
	pr.	6	7
I1	ab.	2	34

BU = 20.491/28.491 = 0.719

S = 12/20 = 0.600

		H1	
		pr.	ab.
	pr.	6	5
J1	ab.	3	35

BU = 13.536/22.536 = 0.600

S = 6/15 = 0.400

		H1	
		pr.	ab.
	pr.	3	4
K1	ab.	5	37

BU = 13.677/21.677 = 0.631

S = 6/14 = 0.428

		H1	
		pr.	ab.
	pr.	3	3
L1	ab.	5	38

BU = 10.602/20.602 = 0.515

S = 4/14 = 0.286

		H1	
		pr.	ab.
	pr.	2	4
M1	ab.	6	37

BU = 18.784/24.784 = 0.758

S = 10/16 = 0.625

		H1	
		pr.	ab.
	pr.	5	2
N1	ab.	4	38

BU = 23.748/32.748 = 0.725

S = 16/25 = 0.64

		I1	
		pr.	ab.
	pr.	8	2
J1	ab.	7	31

BU = 20.071/29.071 = 0.69

S = 12/21 = 0.571

		I1	
		pr.	ab.
K1	pr.	6	0
	ab.	9	33

BU = 12.644/26.644 = 0.474

S = 6/20 = 0.3

		I1	
		pr.	ab.
L1	pr.	3	2
	ab.	12	31

BU = 12.644/26.644 = 0.474

S = 6/20 = 0.3

		I1	
		pr.	ab.
M1	pr.	3	2
	ab.	12	31

BU = 17.649/28.649 = 0.616

S = 10/21 = 0.476

		I1	
		pr.	ab.
N1	pr.	5	1
	ab.	10	32

BU = 13.247/23.247 = 0.57

S = 6/16 = 0.375

		J1	
		pr.	ab.
K1	pr.	3	3
	ab.	7	35

BU = 18.784/23.784 = 0.79

S = 10/15 = 0.667

		J1	
		pr.	ab.
L1	pr.	5	0
	ab.	5	38

BU = 17.601/24.601 = 0.715

S = 8/15 = 0.533

		J1	
		pr.	ab.
M1	pr.	4	1
	ab.	6	37

BU = 16/24 = 0.667

S = 8/16 = 0.5

		J1	
		pr.	ab.
N1	pr.	4	2
	ab.	6	36

BU = 7.245/15.245 = 0.475

S = 2/9 = 0.222

		K1	
		pr.	ab.
L1	pr.	1	4
	ab.	4	39

BU = 10.944/16.944 = 0.646

S = 4/10 = 0.4

		K1	
		pr.	ab.
M1	pr.	2	3
	ab.	3	40

BU = 13.817/19.817 = 0.697

S = 6/12 = 0.5

		K1	
		pr.	ab.
	pr.	3	3
N1	ab.	3	39

BU = 10.944/16.944 = 0.646

S = 4/10 = 0.4

		L1	
		pr.	ab.
	pr.	2	3
M1	ab.	3	40

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		L1	
		pr.	ab.
	pr.	3	3
N1	ab.	2	40

BU = 13.954/18.954 = 0.736

S = 6/11 = 0.545

		M1	
		pr.	ab.
	pr.	3	3
N1	ab.	2	40

Appendix C

APPENDIX C

WATER SAMPLE ANALYSES CONDUCTED BY ANALABS

ANALABS
Chartered Chemists

52 Murray Road
Welshpool
W.A.
Tel: (09) 458 7999

CERTIFICATE OF ANALYSIS

For : Dames & Moore
Attn. Sarah McEroy
26 Lyall Street
South Perth 6151

Our ref: 255.6.01.77693
Your ref:
Date :10.09.90

Sample description
Four water samples were received on the 04.09.90 for analysis.

Sample : A3

Chemical Data

pH		4.5u
Total Dissolved Solids dried @ 180°C (mg/l) (gravimetric)		57o

		(mg/l).
Nitrate	NO3	<0.05
Ammonia-Nitrogen	NH3-N	0.20
Total Kjeldahl Nitrogen		4.80
Ortho Phosphorus	p	0.05
Total Phosphorus	p	0.15

Analyst: P.W. BAMFORD B.Sc. Grad.Dip. E.I.A. M.E.I.A
Chemist

ANALABS
Chartered Chemists

52 Murray Road
Welshpool
W.A.
Tel: (09) 458 7999

CERTIFICATE OF ANALYSIS

For : Dames & Moore
Attn. Sarah McEroy
26 Lyall Street
South Perth 6151

Our ref: 255.6.01.7/69
Your ref:
Date :10.09.90

Sample description
Four water samples were received on the 04.09.90 for analysis.

Sample : A4

Chemical Data

pH		5.10
Total Dissolved Solids dried @ 180°C (mg/l) (gravimetric)		520
		(mg/l)
Nitrate	NO3	<0.05
Ammonia-Nitrogen	NH3-N	0.25
Total Kjeldahl Nitrogen		3.90
Ortho Phosphorus	p	0.05
Total Phosphorus	p	0.05

Analyst: P.W. BAMFORD B.Sc. Grad.Dip. E.I.A. M.E.I.A
Chemist

ANALABS
Chartered Chemists

52 Murray Road
Welshpool
W.A.
Tel: (09) 458 7999

CERTIFICATE OF ANALYSIS

For : Dames & Moore
Attn. Sarah McEroy
26 Lyall Street
South Perth 6151

Our ref: 255.6.01.77693
Your ref:
Date :10.09.90

Sample description

Four water samples were received on the 04.09.90 for analysis.

Sample : B

Chemical Data

pH		3.90
Total Dissolved Solids dried @ 180°C (mg/l) (gravimetric)		860
		(mg/l)
Nitrate	NO3	<0.05
Ammonia-Nitrogen	NH3-N	4.00
Total Kjeldahl Nitrogen		10.5
Ortho Phosphorus	p	0.05
Total Phosphorus	p	0.20

Analyst: P.W. BAMFORD B.Sc. Grad.Dip. E.I.A. M.E.I.A
Chemist

ANALABS
Chartered Chemists

52 Murray Road
Welshpool
W.A.
Tel: (09) 458 7999

CERTIFICATE OF ANALYSIS

For : Dames & Moore
Attn. Sarah McElroy
26 Lyall Street
South Perth 6151

Our ref: 255.6.01.77693
Your ref:
Date :10.09.90

Sample description
Four water samples were received on the 04.09.90 for analysis.

Sample : B1

Chemical Data

pH		5.50
Total Dissolved Solids dried @ 180°C (mg/l) (gravimetric)		330
		(mg/l)
Nitrate	NO3	<0.05
Ammonia-Nitrogen	NH3-N	0.05
Total Kjeldahl Nitrogen		5.3
Ortho Phosphorus	p	0.05
Total Phosphorus	p	0.25

Analyst: P.W. BAMFORD B.Sc. Grad.Dip. E.I.A. M.E.I.A
Chemist

Appendix D

APPENDIX D

TRANSECT DESCRIPTIONS OF NON-WETLANDS

APPENDIX D

TRANSECT DESCRIPTIONS OF NON-WETLANDS

Transect 1

Stratum 1 *Banksia menziesii, Banksia attenuata* trees, 2-10m tall, 20% canopy cover.

Stratum 2 *Banksia attenuata, Banksia menziesii, Jacksonia floribunda* trees and shrubs, 1-3m tall, 5% canopy cover.

Stratum 3 *Eremaea beaufortioides, Hibbertia hypericoides, Hibbertia subvaginata, Beaufortia* sp, *Patersonia occidentalis* 0-1m tall, 70% canopy cover.

The vegetation of Stratum 1 was slightly lower and less dense near the top of the dune, and the understorey slightly denser. *Banksia ilicifolia* was scattered in the upper canopy lower in the landscape.

Area is gently undulating white/grey sand, extremely well drained. There are 22 Structure-modifying Species. There is evidence of heavy fire damage and dieback disease is widespread.

The vegetation health ratings at the time of study were Stratum 1 - rating 3, Stratum 2 - rating 4, Stratum 3 - rating 5. No gazetted or priority flora were observed.

Transect 2

Stratum 1 *Banksia menziesii, Banksia ilicifolia* and *Eucalyptus todtiana* trees, 4-8m tall, 30% canopy cover.

Stratum 2 *Adenanthos cygnorum* and *Banksia ilicifolia* trees, 2-6m tall, 10% canopy cover.

Stratum 3 *Verticordia nitens, Regelia inops* and *Persoonia saccata* shrubs, 0.5-1.5m tall, 10% canopy cover.

Stratum 4 *Melaleuca scabra, Stirlingia latifolia* and *Patersonia occidentalis* shrubs, 0-0.5m tall, canopy cover 70%

There was a small area of *Melaleuca preissii* and *Banksia littoralis* trees 2-6m tall and 30% cover over *Hypocalymma angustifolium, Astartea fascicularis* shrubs, 1m tall and 80% canopy cover. These areas were generally floristically poorer, with 4 Structure-modifying Species. There were also occasional patches of *Regelia inops* and/ or *Hypocalymma angustifolium.*

Area is gently undulating white/grey sand, extremely well drained. There are 17 Structure-modifying Species. There is no evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 3

Stratum 1 *Banksia menziesii, Banksia attenuata* and *Banksia ilicifolia* trees, 4-8m tall, 60% canopy cover.

Stratum 2 *Adenanthos cygnorum* and *Banksia attenuata* shrubs, 1-4m tall, 10% canopy cover.

Stratum 3 *Macrozamia reidlei* and *Verticordia nitens* shrubs, 0.5-1.5m tall, 10% canopy cover.

Stratum 4 *Petrophile linearis, Hibbertia subvaginata* and *Stirlingia latifolia* shrubs, 0-1m tall, canopy cover 30%

Area is gently undulating white/grey sand, extremely well drained. There are 17 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 4

Stratum 1 *Eucalyptus calophylla* and *Melaleuca preissii* trees, 6-14m tall, 2% canopy cover.

Stratum 2 *Regelia inops, Jacksonia furcellata, Leptospermum erubescens* and *Jacksonia denudata* shrubs 0-2m tall, 5% canopy cover.

Stratum 3 *Dasypogon bromiliifolius, Hypocalymma angustifolium, Hibbertia hypericioides, Xanthorrhoea preissii, Dasypogon bromiliifolius* shrubs 0-0.5m tall, canopy cover 80%.

Open areas have *Leptospermum erubescens* and *Jacksonia furcellata* 1m tall and 90% canopy cover over sedges and *Dasypogon bromiliifolius* 0.3m tall and 20% canopy cover. There are occasional clumps of *Melaleuca scabra* and *Verticordia plumosa.*

Area is flat with grey slightly organic, sand, moderately to seasonally poorly drained. There are 18 Structure-modifying Species. There is no evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5, stratum 3 - rating 5.

Transect 5

Stratum 1 *Eucalyptus rudis* trees 8-16m tall, 90% canopy cover.

Stratum 2 *Melaleuca raphiophylla* and *Acacia saligna* trees 2-8m tall, locally up to 40% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and sedges with abundant weeds 1m tall and 90% canopy cover. Weeds included *Avena fatua* (Oat Grass), *Anagallis arvensis* (Pimpernel), *Arctotheca calendula* (Cape Daisy), *Briza maxima* (Shiver Grass), *Daucus carota* (Wild Carrot), *Erodium* spp (crane's Bill), *Homeria* sp (Cape Tulip), *Parentucella viscosa* (Sticky Bartsia), *Rumex* spp (Dock), *Solanum nigrum* (Nightshade) and *Trifolium* spp (clover).

The surrounding area is flat with grey sand, moderately to very well drained. It has remnant *Banksia attenuata* or *Acacia saligna* woodland, heavily disturbed and infested with weeds. *Cartonema phylidroides* was common in the disturbed area. The watercourse is in a depressed area some 50m wide and 1-2m lower than the surrounding landscape. In the middle of the watercourse is a narrow creekline 1m deeper than the surrounds and 2-4m wide but with sloping banks so that the creek itself is about 1m wide. There are 18 Structure-modifying Species. There is no evidence of recent fire, and the area appears not to have been burnt for some considerable time.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5.

Transect 6

Stratum 1 *Banksia menziesii, Banksia attenuata* and *Banksia ilicifolia* trees, 4-8m tall, 20% canopy cover.

Stratum 2 *Banksia attenuata, Banksia menziesii, Banksia ilicifolia* and *Casuarina fraseriana* trees, 2-4m tall, 10% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and scattered *Dasypogon bromiliifolius, Conostephium minus* and *Melaleuca scabra* shrubs, 0-0.5m tall, 80% canopy cover.

Area is flat white/grey sand, extremely well drained. There are 13 Structure-modifying Species. There is evidence of heavy fire damage and dieback disease is widespread.

The vegetation health ratings at the time of study were Stratum 1 - rating 3, Stratum 2 - rating 4, Stratum 3 - rating 5. *Conostephium minus,* a Priority 3 species, was observed in Transect 6.

Transect 7

Stratum 1 *Eucalyptus calophylla* and *Eucalyptus marginata* trees, 6-10m tall, 2% canopy cover.

Stratum 2 *Banksia menziesii, Banksia ilicifolia, Banksia attenuata* trees, 2-6m tall, 40% canopy cover.

Stratum 3 *Xanthorrhoea preissii* shrubs, 0-1m tall, 10% canopy cover.

Stratum 4 *Dasypogon bromiliifolius, Petrophile linearis, Hypocalymma angustifolium, Conostephium pendulum, Hibbertia subvaginata* shrubs, 0-0.5m tall, canopy cover 50%

Area is flat white sand, moderately well drained. There are 12 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 3, Stratum 2 - rating 4, stratum 3 - rating 5, Stratum 4 - rating 5. No Gazetted or Priority species were observed. There was an area about 20m in diameter which had been killed by dieback disease.

Transect 8

Stratum 1 *Banksia menziesii, Eucalyptus todtiana, Nuytsia floribunda* trees, 3-7m tall, 30% canopy cover.

Stratum 2 *Banksia attenuata* young trees, 2-5m tall, 20% canopy cover.

Stratum 3 *Macrozamia reidlei, Adenanthos cygnorum, Banksia attenuata* shrubs 0-1.5m tall, 3% canopy cover.

Stratum 4 *Eremaea pauciflora* and *Stirlingia latiflora* shrubs, 0-1m tall, 70% canopy cover.

Stratum 5 *Hibbertia hypericoides, Hibbertia subvaginata, Petrophile linearis* shrubs, 0-0.5m tall, 30% canopy cover.

Area is gently undulating white sand, extremely well drained. There are 18 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, Stratum 3 - rating 5, Stratum 4 - rating 5, Stratum 5 - rating 5. No gazetted or priority flora were observed.

Transect 9

The eastern end of Transect 9 was:

Stratum 1 *Melaleuca preissiana, Eucalyptus calophylla* and *Eucalyptus marginata* trees, 5-15m tall, 5% canopy cover.

Stratum 2 *Banksia menziesii, Banksia ilicifolia, Banksia littoralis, Nuytsia floribunda* trees, 3-6m tall, 10% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and *Hibbertia subvaginata, Dasypogon bromiliifolius, Hypocalymma angustifolium, Pericalymma elliptica* shrubs, 0-1m tall, 40% canopy cover.

Stratum 4 *Patersonia occidentalis* shrubs, 0-0.3m tall, canopy cover 10%

Area is flat grey sand, moderately to poorly drained. There are 16 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 4, Stratum 4 - rating 5. No gazetted or priority flora were observed. There were a few dead trees which may have been the result of dieback disease.

The western end of Transect 9 was:

Stratum 1 *Eucalyptus calophylla* and *Eucalyptus marginata* trees, 5-15m tall, 2% canopy cover.

Stratum 2 *Banksia menziesii, Banksia attenuata,* trees, 2-6m tall, 70% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and *Macrozamia reidlei* shrubs, 0.5-2m tall, 5% canopy cover.

Stratum 4 *Patersonia occidentalis, Dasypogon bromiliifolius, Conostephium pendulum* and numerous other shrubs, 0-0.5m tall, canopy cover 25%

Area is gently sloping grey sand, well drained. There are 13 Structure-modifying Species. There is evidence of recent fire, and possible dieback disease infection.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 10

Transect 10 crosses two habitat types. The eastern end is:

Stratum 1 *Melaleuca preissiana* and *Eucalyptus marginata* trees, 4-16m tall, 10% canopy cover.

Stratum 2 *Melaleuca preissiana, Banksia menziesii, Banksia ilicifolia, Nuytsia floribunda* trees, 3-10m tall, 10% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and *Hypocalymma angustifolium* shrubs, 0-1m tall, 80% canopy cover.

Stratum 4 *Patersonia occidentalis* and ?*Conostylis* sp, 0-0.5m tall, canopy cover 10%

Area is flat grey-black organic peaty sand, poorly drained. There are 16 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 4, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

The western end of Transect 10 is:

Stratum 1 *Melaleuca preissiana* trees, 2-8m tall, 2% canopy cover.

Stratum 2 *Melaleuca preissiana* trees, 3-5m tall, 2% canopy cover.

Stratum 3 *Xanthorrhoea preissii* shrubs, 0-1m tall, 80% canopy cover.

Stratum 4 *Leptospermum erubescens, Hypocalymma angustifolium* shrubs, *Dasypogon bromiliifolius,* and *Patersonia occidentalis,* 0-0.5m tall, canopy cover 90%

On the eastern margin of the area there are locations with dense clumps of *Regelia inops* 2m tall and locally 100% cover. There was also a patch of *Melaleuca preissiana* 4-12m tall and 70% canopy cover over *Acacia saligna* 4-12m tall and 30% canopy cover, over sedges 0.5m tall and 100% cover.

Area is flat grey-black organic peaty sand, poorly drained. There are 9 Structure-modifying Species in the main area described. There is of evidence of recent fire.

The vegetation health ratings in the main area at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 4, stratum 3 - rating 4, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 11

Stratum 1 *Acacia saligna* trees, 4-9m tall and locally up to 100% canopy cover. Occasional *Banksia littoralis* present.

Stratum 2 *Dryandra nivea, Petrophile linearis, Conostylis aculeata* and *Dasypogon bromiliifolius* shrubs, 0-0.3m tall, locally 90% canopy cover.

Some areas with scattered *Eucalyptus rudis* to 10m tall or Banksia littoralis to 10m tall. These areas had less *Dryandra nivea* and more *Conostylis aculeata.* These were also occasional patches of *Xanthorrhoea preissii, Stirlingia latifolia* or *Patersonia occidentalis.*

Weeds were common, and included *Avena fatua* (Oat Grass), *Anagallis arvensis* (Pimpernel), *Arctotheca calendula* (Cape Daisy), *Briza maxima* (Shiver Grass), *Daucus carota* (Wild Carrot), *Erodium* spp (crane's Bill), *Homeria* sp (Cape Tulip), *Hypochaeris glabrata* (Cat's Ear), *Parentucella viscosa* (Sticky Bartsia), *Rumex* spp (Dock), *Sonchus oleraceous* (Sow Thistle) and *Trifolium* spp (clover).

Area is flat cream coloured sand, well drained but seasonally damp or wet. There are 9 Structure-modifying Species. There is no evidence of fire for a considerable time.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5. *Caladenia huegelii* was found in several small clumps.

Transect 12

Stratum 1 *Acacia saligna* trees, 2-10m tall and locally up to 100% canopy cover.

Stratum 2 *Opercularia vaginata, Ranunculus colonorum* to 0.5m tall and sedges including *Mesomelaena stygia* 0-1m tall, locally 100% canopy cover. in drier areas *Dryandra nivea* may occur.

The edges of the stand with *Eucalyptus calophylla* to 24m tall and numerous saplings top 5m tall. There were also occasional patches of *Hakea prostrata.*

Weeds were common, and included *Avena fatua* (Oat Grass), *Anagallis arvensis* (Pimpernel), *Arctotheca calendula* (Cape Daisy), *Briza maxima* (Shiver Grass), *Cirsium vulgare* (Black Thistle), *Erodium* spp (Crane's Bill), *Homeria* sp (Cape Tulip), *Rumex* spp (Dock), and *Trifolium* spp (clover).

Area is surrounded by flat white sand, well drained but possibly seasonally damp. The watercourse is about 2m lower in the landscape than the surrounds. The creekline is poorly defined and about 0.5m deeper than the general watercourse depression. In very wet areas the canopy is absent and the sedges dominate. There are 9 Structure-modifying Species. There is no evidence of fire for a considerable time.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5. *Caladenia huegelii* was found in several small clumps.

Transect 13

Stratum 1 *Banksia menziesii, Banksia attenuata* and *Banksia ilicifolia* trees, 4-8m tall, 20% canopy cover.

Stratum 2 *Adenanthos cygnorum* shrubs, *Banksia attenuata, Banksia menziesii* and scattered *Regelia inops* shrubs, 1-4m tall, 20% canopy cover.

Stratum 3 *Verticordia nitens* and *Xanthorrhoea preissii* shrubs, 0.5-1m tall, 30% canopy cover.

Stratum 4 *Hypocalymma angustifolium, Dasypogon bromiliifolius, Baeckea* sp, *Patersonia occidentalis, Melaleuca scabra* shrubs, 0-0.5m tall, canopy cover 70%

Area is gently undulating white/grey sand, extremely well drained. There are 22 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 3, Stratum 2 - rating 4, Stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 14

Stratum 1 *Banksia menziesii, Banksia attenuata, Banksia ilicifolia* trees, 1-8m tall, 10% canopy cover.

Stratum 2 *Macrozamia reidlei, Adenanthos cygnorum, Nuytsia floribunda* shrubs 0-2m tall, 2% canopy cover.

Stratum 3 *Eremaea beaufortioides, Hibbertia hypericoides, Petrophile linearis, Jacksonia floribunda, Hibbertia subvaginata, Melaleuca scabra, Stirlingia latifolia* shrubs, 0-0.5m tall, 50% canopy cover.

Stratum 4 *Patersonia occidentalis, Lyginea barbata* 0-0.2m tall, 2% canopy cover.

Area is gently undulating flat white sand, well drained. There are 15 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 4, Stratum 3 - rating 4, Stratum 4 - rating 4. No gazetted or priority flora were observed.

Transect 15

Stratum 1 *Banksia menziesii, Banksia attenuata* and *Banksia ilicifolia* trees, 4-10m tall, 10% canopy cover.

Stratum 2 *Adenanthos cygnorum* shrubs, 1-4m tall, 20% canopy cover.

Stratum 3 *Verticordia nitens* and *Regelia inops* shrubs, 0.5-1.5m tall, 20% canopy cover.

Stratum 4 *Persoonia saccata, Hypocalymma angustifolium* and *Stirlingia latifolia* shrubs, 0-0.5m tall, canopy cover 30%

Area is flat white sand, extremely well drained. There are 19 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 3, Stratum 2 - rating 3, Stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 16

Stratum 1 *Banksia menziesii, Banksia menziesii, Eucalyptus todtiana, Nuytsia floribunda* trees, 2-6m tall, 10% canopy cover.

Stratum 2 *Macrozamia reidlei, Stirlingia latifolia* and *Xanthorrhoea preissii* shrubs 0-1.5m tall, 2% canopy cover.

Stratum 3 *Eremaea pauciflora, Acacia pulchella, Hibbertia hypericoides, Bossiaea eriocarpa, Scholtzia involucrata, Petrophile linearis* shrubs, 0-0.5m tall, 30% canopy cover.

Stratum 4 *Patersonia occidentalis, Stipa* sp. 0-0.3m tall, 5% canopy cover.

Area is flat white sand, well drained. There are 15 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 4, Stratum 3 - rating 4, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 17

Stratum 1 *Banksia attenuata, Eucalyptus todtiana* trees, 4-10m tall, 30% canopy cover.

Stratum 2 *Banksia attenuata* and *Eucalyptus todtiana* young trees, 1-3m tall, 20% canopy cover.

Stratum 3 *Stirlingia latifolia* and *Nuytsia floribunda* shrubs 0-1m tall, 2% canopy cover.

Stratum 4 *Eremaea pauciflora, Hibbertia hypericoides, Hibbertia subvaginata, Petrophile linearis* and *Jacksonia floribunda* shrubs, 0-0.5m tall, 60% canopy cover.

Area is flat white sand, extremely well drained. There are 18 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 4, Stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 18

Stratum 1 *Melaleuca preissii* and *Banksia littoralis* trees 4-12m tall, 30% canopy cover.

Stratum 2 *Banksia littoralis* and *Pultenaea reticulata* shrubs, 1-3m tall, 2% canopy cover.

Stratum 3 Sedges and *Melaleuca lateritia* shrubs, 0-0.5m tall, 50% canopy cover. In some areas Stratum 3 also contains *Xanthorrhoea preissii, Pericalymma ellipticum* 0-1m tall, 70% canopy cover. Also in some areas, a fourth stratum of *Patersonia occidentalis, Hibbertia subvaginata* and *Hypocalymma angustifolium* 0-0.5m tall, 30% canopy cover may be developed.

Most of the area is flat organic peaty grey sand, poorly drained. There is no evidence of recent fire, but the presence of *Banksia littoralis* in two strata suggests a period of post-fire regeneration.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5. No gazetted or priority flora were observed.

Transect 19

Transect 19 crosses two habitat types. The eastern end is:

Stratum 1 *Banksia attenuata, Banksia menziesii, Eucalyptus calophylla, Eucalyptus todtiana* and *Nuytsia floribunda* trees, 5-10m tall, 30% canopy cover.

Stratum 2 *Macrozamia reidlei, Stirlingia latifolia* and *Xanthorrhoea preissii* shrubs, 0-1.5m tall, 5% canopy cover.

Stratum 3 *Hibbertia hypericoides, Hibbertia subvaginata, Petrophile linearis* shrubs, *Patersonia occidentalis* shrubs, 0-0.5m tall, 60% canopy cover.

Area is flat white sand, well drained. There are 17 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5, Stratum 3 - rating 5. No gazetted or priority flora were observed. There were a few dead trees which may have been the result of dieback disease.

The western end of Transect 19 is essentially the same, but height and cover vary from the eastern end; as follows:

Stratum 1 *Banksia attenuata, Banksia menziesii, Eucalyptus calophylla, Eucalyptus todtiana* and *Nuytsia floribunda* trees, 5-8m tall, 5% canopy cover.

Stratum 2 *Macrozamia reidlei, Stirlingia latifolia* and *Xanthorrhoea preissii* shrubs, 0-0.5m tall, 10% canopy cover.

Stratum 3 *Hibbertia hypericoides, Hibbertia subvaginata, Petrophile linearis, Patersonia occidentalis* shrubs, 0-0.3m tall, 60% canopy cover.

Area is gently undulating white sand, extremely well drained. There are 17 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5, Stratum 3 - rating 5. No gazetted or priority flora were observed.

Transect 20

Transect 20 crosses two habitat types. The eastern end is:

Stratum 1 *Melaleuca preissii* and *Banksia littoralis* trees with scattered emergent *Eucalyptus marginata* trees (to 20m tall), 3-12m tall, 60% canopy cover.

Stratum 2 *Xanthorrhoea preissii* shrubs, 0-2.5m tall, 2% canopy cover.

Stratum 3 *Xanthorrhoea preissii* shrubs, 0-1m tall, 5% canopy cover.

Stratum 4 Unidentified sedges, 0-0.5m tall, canopy cover 70%

Area is flat white sand, very well drained. There are 12 Structure-modifying Species. There is no evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Adjacent to the eastern end of the transect was an open area severely affected by dieback disease (*Phytophthora cinnamomi).* This area contained *Banksia menziesii* and *Banksia attenuata,* all dead or dying. A *Eucalyptus marginata* tree was also dead.

Understorey comprised dying *Xanthorrhoea preissii* to 1m tall and 70% canopy cover.

Area is flat grey sand, very well drained. There are 3 Structure-modifying Species. There is no evidence of recent fire. The area is believed to have been heavily used by horses, as an adjacent track had many hoof prints. These is also a vehicle track and the area has been cut over for timber a long time ago. Any of these could have been the source of the disease.

The vegetation health ratings at the time of study were: Stratum 1 - rating 1, Stratum 2 - rating 3 The priority species *Cartonema phylidroides* was very abundant in the dieback affected area, but was not observed outside it.

The western end of Transect 20 is:

Stratum 1 *Eucalyptus calophylla* trees, 8-20m tall, 20% canopy cover.

Stratum 2 *Melaleuca preissiana* trees, 6-10m tall, 40% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and *Jacksonia furcellata* shrubs, 1-2.5m tall, 10% canopy cover.

Stratum 4 *Hypocalymma angustifolium* and *Xanthorrhoea preissii* shrubs, 0-0.5m tall, canopy cover 70%

Area is flat grey sand, moderately well drained. There are 16 Structure-modifying Species. There is no evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 4, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

Transect 21

Transect 21 crosses two habitat types. The eastern end is:

Stratum 1 *Melaleuca preissiana* and *Eucalyptus marginata* trees, 4-16m tall, 30% canopy cover.

Stratum 2 *Melaleuca preissiana, Eucalyptus marginata* trees, 2-8m tall, 10% canopy cover.

Stratum 3 *Xanthorrhoea preissii* and *Macrozamia riedlei* shrubs, 0-1.5m tall, 60% canopy cover.

Stratum 4 *Hypocalymma angustifolium* shrubs, 0-0.5m tall, canopy cover 10%

Area is flat grey sand, moderately well drained. There are 9 Structure-modifying Species. There is evidence of recent fire; much of the canopy growth is from epicormic shoots, and the presence of the same species dominating the upper two strata suggests that the strata represent two stages of regrowth, the lower ones probably representing post-fire saplings.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed. There were a few dead trees which may have been the result of dieback disease.

The western end of Transect 21 is:

Stratum 1	*Banksia menziesii* and *Banksia attenuata* trees, 4-8m tall, 10% canopy cover.
Stratum 2	*Macrozamia reidlei, Jacksonia sternbergiana* shrubs, 2-8m tall, 10% canopy cover.
Stratum 3	*Acacia pulchella* shrubs, *Banksia ilicifolia, Banksia attenuata* trees, 0-1m tall, 5% canopy cover.
Stratum 4	*Petrophile linearis, Hibbertia subvaginata* shrubs, 0-0.5m tall, canopy cover 30%

Area is gently undulating white sand, extremely well drained. There are 12 Structure-modifying Species. There is evidence of recent fire.

The vegetation health ratings at the time of study were Stratum 1 - rating 5, Stratum 2 - rating 5, Stratum 3 - rating 5, Stratum 4 - rating 5. No gazetted or priority flora were observed.

ELLENBROOK DEVELOPMENT
PUBLIC ENVIRONMENTAL REVIEW

APPENDIX A3

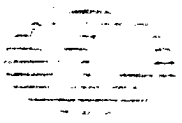
Management Options, Lexia Wetlands

MANAGEMENT SCENARIOS
LEXIA WETLANDS
ELLENBROOK DEVELOPMENT

for

Ellenbrook Management Pty Ltd

DAMES & MOORE



Dames & Moore Job No. 21170-001-071

February 1992

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1.0 INTRODUCTION

The Ellenbrook project area, comprising approximately 1,800ha and located about 20km northeast of Perth Central Business District, is seen as providing up to 10% of Perth's metropolitan urban growth over the next fifteen years.

Dames & Moore has undertaken several environmental assessments in the area. These include:

- o assessment of Western Swamp Tortoise habitat (Dames & Moore, 1988);
- o studies of the Lexia Wetlands[1] (in the northwest corner of the site), and a non-Lexia seasonal swamp near the Boral sand quarry (Dames & Moore, 1990; 1991a); and
- o a detailed conservation assessment and floristic analysis of the Lexia Wetlands (Dames & Moore, 1992).

These reports identified the wetlands in the northwest corner of the site as being significant for the conservation of natural heritage. The seasonal swamp near the Boral sand quarry is not considered to have the same conservation value as the Lexia Wetlands and is not part of this assessment.

This current report seeks to better determine long-term management scenarios for the Lexia Wetlands given their acknowledged conservation status and values, and Government policy on wetlands and planning issues.

Preliminary planning and evaluation of the site for urban development commenced in August 1990 and it is anticipated that construction works will begin in 1993. During this period an environmental assessment, under the Environmental Protection Act 1986, will be undertaken and a Public Environmental Review (PER) prepared for presentation to the Environmental Protection Authority. The objective of the current study is to evaluate a number of management scenarios for the Lexia wetlands. The results of this evaluation will, therefore, form an important part of the PER.

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[1] The term "Lexia Wetlands" was coined by Middle (1991). This name was not used in Dames & Moore reports prior to 1991.

2.0 SCOPE OF WORK

The scope of work for determination of management scenarios for the wetlands in the Ellenbrook area is based on discussions held between Dames & Moore, Feilman Planning Consultants and Ellenbrook Management Pty Ltd. The scope of work was to:

- outline the background to the proposal, especially in terms of Government environmental and planning policies;
- review and assess previous work carried out in the region by Dames & Moore, and to re-evaluate the work in terms of conservation of the Lexia wetlands;
- evaluate the implications for short-term and long-term conservation and management of the Lexia wetlands;
- provide a draft report on findings; and
- prepare a final report suitable for presentation to the Environmental Protection Authority.

3.0 BACKGROUND

During the housing boom of the late 1980's, there was Government and community concern over the availability of housing land within and adjacent to the Perth Metropolitan Region. A result of this concern was that the Department of Planning and Urban Development prepared a policy statement identifying available land for expansion of metropolitan Perth (DPUD, 1990) and a planning strategy known as "Metroplan" (DPUD, 1991). These reports form the basis of the Government's published policy on urbanisation. The Ellenbrook project area was identified as Category A (relatively unconstrained for development) (DPUD *ibid*). The DPUD reports do not deal with environmental factors in terms of specific issues such as the preservation of wetlands.

These planning policies have important implications in regard to the EPA's Draft Environmental Protection Policies (EPP) on wetlands and associated ecosystems (EPA, 1990; discussed in Dames & Moore, 1992). These policies attempt to arrest the pace of destruction and degradation of wetlands that has taken place on a large scale since European settlement. Based on these draft EPP's, it is clear that the Lexia Wetlands cannot be altered without consideration under Part IV or V of the Environmental Protection Act 1986.

4.0 MANAGEMENT OBJECTIVES

Previous studies have shown that the Lexia Wetlands have high conservation value. This is not because they have any great significance for flora or fauna, but simply because they represent near-pristine wetlands, unlike most others on the Swan Coastal Plain. Consequently, the Ellenbrook proponent's objective is to conserve as much of them as practical for the medium to long-term. However, there are several complexities which affect this aim, not the least of which is that not all of the wetlands are under the proponent's control. The objectives of the present evaluation are to:

- o present various management scenarios so that the Lexia Wetlands can be practically managed; and
- o if lack of funding or other constraints on management or acquisition dictate that only part of the wetlands be retained, to determine which part.

5.0 MANAGEMENT SCENARIOS

5.1 INTRODUCTION

The proponent's favoured scenario would be to protect all of the Lexia wetlands. Their total area, including immediate surrounds, is approximately 500ha. About 410ha of this is under the proponent's control. However, without intensive management, any reserve of this size is too small to be maintained in the long-term, especially when urbanisation is in close proximity. This is evidenced by areas such as Kings Park and Bold Park, which are about the same size. Fire, dieback disease, feral animals and weed encroachment have all had serious impacts on these reserves. Both of these areas have complex and expensive management programmes in place and the reserves are still considered to play an important role in the conservation of flora and fauna even though they have become degraded.

The Lexia Wetlands would also require intensive management. The most fundamental decision which would need to be made in order to retain the wetlands in their entirety is that of who would manage the reserve. No Government or other agency is currently committed to take responsibility for the long-term management of a conservation reserve at Ellenbrook, should one be established. The most appropriate agency would be CALM. However, CALM's financial resources are limited and it is probable that other conservation areas would have higher priority. CALM also recognises that management would need to be intense, but there is no guarantee of long-term viability of the wetlands. Another management agency might be the

Local Government Authority. That organisation has neither the resources nor the finances to put into such a labour and cost-intensive programme. Finally, the proponent could manage the wetlands. However, the proponent does not have the resources, the expertise or the finances.

In summary, there is a difficulty in that the area is too small to be managed as a significant long-term National Park or Nature Reserve, but too large to be effectively managed as Regional Open Space. The concept of a regional park, as discussed by the EPA in its Green and Red Book Recommendations (Department of Conservation and Environment, 1981; 1983), may have relevance, but these areas also require considerable and expensive management.

The lack of management options leads into the second component of this evaluation; if it is not possible to protect the whole wetland area, what part should be protected? This assumes that one of the management groups identified above would have the resources to manage a smaller area; either on their own or in combination with other agencies.

An attempt to resolve this question focuses around four possible management scenarios:

- Scenario 1 - conserve and manage the Lexia Wetland system as a whole, assuming that resources would be available to do so;
- Scenario 2 - conserve and manage only the EPP wetlands within the Lexia system;
- Scenario 3 - conserve and manage only the EPP wetlands which are within the Lexia system and within the proponents land; and
- Scenario 4 - define a smaller, more manageable but representative area and concentrate management activities to it.

These scenarios are shown on Figure 1.

Figure 1 shows that there are several single wetlands and two relatively discrete larger wetland assemblages within the proponent's control. The single wetland assemblages would be extremely difficult to manage in isolation if the aim was to retain medium to long-term conservation values. The influence of adjacent disturbances on such small areas would rapidly degrade their natural values. Identification of a smaller conservation area (i.e. Scenario 4) therefore considers two assemblages, that comprising areas A1 to A5 and the assemblage comprising area I1 to N1 (Figure 2). It was also felt that these areas had a conservation value as a "system" of various wetland types in contrast to smaller wetlands which were primarily of a single type.

5.2 SCENARIO 1 - THE WHOLE LEXIA SYSTEM

The whole Lexia system comprises all the wetlands shown on Figure 1. It includes all the EPP wetlands and the associated wetlands which are clearly part of the same system but which were considered by the EPA to not have EPP status.

The advantage of Scenario 1 is that it would conserve a representative sample of the northern Swan Coastal Plain wetlands. Only one of the wetlands is degraded (Figure 1), the others are surrounded by natural bushland and are relatively pristine.

If scenario one was to be considered, it must be appreciated that the proper management of the land affected extends beyond the boundary of the land which is the subject of this report (refer Figure 1) and sound management would dictate that the whole of the land should be the subject of a Comprehensive Management Plan which would consider the:

- desirability of including the total (500ha) land parcel in the proposed reserve to ensure the preservation of the full conservation value of the wetland system;
- incompatibility of existing residential activity on the site with conservation objectives; and
- opportunity to use the existing house as a rangers residence negating the need for further destruction of bushland to construct a new ranger's residence.

It is understood, on the advice of the Environmental Protection Authority, that this scenario cannot be considered as a viable option as it would include land which is not owned by the Ellenbrook Project proponents, and consequently is outside the scope of this PER. Efforts could be made by government agencies to secure the cooperation of the adjoining landowners in which case this scenario would become viable.

5.3 SCENARIO 2 - THE EPP WETLANDS

The wetlands considered by the EPA as being included under the Draft Environmental Protection (Swan Coastal Plain Wetlands) Policy (EPP) would be protected under this scenario. The impracticalities of managing nine separate areas, together with the impracticality of housing development under stringent controls in the small areas between them, would be major problems. It includes most, but not all, of the wetlands protected by Scenario 1, and is effectively the same as Scenario 1 in terms of management. It is also not a viable option as it includes land which is outside the proponent's control.

5.4 SCENARIO 3 - WETLANDS WITHIN ELLENBROOK

This scenario involves the protection of those wetlands which have been designated under the EPP and which are within the proponent's land. It includes a total area of approximately 410ha. It excludes one EPP wetland and three less significant wetlands. These are part of the Lexia system but are outside the scope of this PER. This scenario is feasible. However, while it does retain a large area of wetland it does not achieve a major conservation objective of conserving the full biological diversity of the Lexia wetland system, its attendant vegetation assemblages, flora and fauna.

5.5 SCENARIO 4 - A SMALLER WETLANDS ASSEMBLAGE

The attributes of the two wetland assemblages (A1 to A5 and I1 to N1 - Figure 2) were compared. In Dames & Moore (1992), two methods were used to classify the Lexia Wetlands:

- the classification of Semeniuk *et al.* (1990), which is based on the size of wetland vegetation complexes; the extent of vegetation cover over the wetland; internal organisation of vegetation in plan; vegetation structure and details of the floristic/structural components; and
- binary similarity coefficients were calculated and a similarity matrix developed. Following this, cluster analysis was undertaken. This technique classifies the sample wetlands according to their similarity.

In terms of Semeniuk *et al.*'s (1990) classification, the two assemblages both contain the basic types of wetland (e.g. dampland, sumpland). However, with the exception of one type of wetland (micro-concentriform), the wetland classifications represented were different for the two assemblages. Assemblage A1-A5 has two sumplands and three damplands. Assemblage I1-N1 has three sumplands and three damplands.

Dames & Moore (1992) refers to natural groups of wetland types. These are wetland groups which were considered to have similar vegetation organisation and structure. Both Assemblage I1-N1 and Assemblage A1-A5 include representatives from two of the three groupings. However, Assemblage I1-N1 contains these within a more compact area.

Using the Sorensen Similarity Coefficient dendrogram in Dames & Moore (1991b), it is found that:

- Assemblage A1-A5 contains four basically dissimilar types of wetlands and one (A1 and A4) moderately similar pair; and
- Assemblage I1-N1 contains three basically dissimilar types of wetlands and two sets (L1-J1, J1 and I1, K1) that are moderately similar but less similar than A1 and A4 in Assemblage A1-A5.

Dames & Moore (1992) also found that the wetlands of the western sector (E1-N1) have a higher number of bands of vegetation than the eastern sector wetlands (A1-D1). These ecotonal bands are considered to be significant in the overall structural diversity of the wetlands. The average number of bands in Assemblage A1-A5 is 3.2 whereas there is a mean of 4.2 bands in Assemblage I1-N1.

The total number of strata for all bands in Assemblage A1-A5 is 36 whereas in Assemblage I1-N1 it is 42.

Both wetland assemblages had at least one area of surface water exposure under the conditions prevailing at the time of the Dames & Moore (1991b) study. The I1-N1 Assemblage tends to be a little drier, undoubtedly a contributing factor to the higher structural diversity in this wetland assemblage. This slightly drier condition is not significant in terms of provision of an open water habitat type, as this habitat is still represented.

Based on these observations, the wetlands can be grouped as follows:

Assemblage A1-A5

This area is large compared to Assemblage I1-N1 and has too great a perimeter length to be practically managed as a discrete area in isolation from the whole of the Lexia Wetlands. It is also semi-linear, increasing the edge effect (weed encroachment and degradation would have greater impacts).

Wetlands B1, E1, F1, G1 and H1

These wetlands are very small and, managed in isolation, would have low viability in the long-term.

Assemblage I1-N1

This area is smaller than Assemblage A1-A5, has a shorter perimeter length and is almost circular, thereby reducing edge effects.

On the basis of these observations, it would appear that the area which is small enough and compact enough to be intensively managed with limited resources, yet still contain most of the significant habitat types, is Assemblage I1-N1.

6.0 COST OF MANAGEMENT

6.1 CAPITAL COST ESTIMATE

An approximate estimate of costs has been prepared for the management of the four scenarios described in Section 5.0. The largest reserve (for this exercise) is estimated to be approximately 500ha, the second and third scenarios are virtually equal in size at about 410ha in size and the smaller area about 90ha in size.

It has been assumed that the area, whichever is chosen for acquisition as a conservation reserve, will be given the very highest of management priority, and that every effort will be made to ensure their long-term viability. Thus, fencing, careful fire management, etc., are taken as being essential.

There are many items associated with the establishment of a high priority conservation reserve in the metropolitan area. Capital costs include establishment of an on-site management presence with associated accommodation facilities, a vehicle, VHF radio (for safety and fire fighting communications), etc. These items are inevitably a major part of the establishment cost.

The items listed in Table 1 are those with the greatest cost, and some other items which need to be specifically addressed, e.g. vermin control. Although minor, these have been included because they will be required in the assessment.

TABLE 1

COMPARISON OF CAPITAL COSTS

Item	*Scenario 1 Whole Lexia System*	*Scenario 2 All EPP Wetlands*	*Scenario 3 Ellenbrook EPP Wetlands*	*Scenario 4 Assemblage I1-L1*
Land acquisition	$5,000,000	$3,900,000	$3,900,000	$900,000
Ranger's house	$120,000	$120,000	$120,000	$120,000
Power, drainage, sewerage	No cost	No cost	$8,000	$8,000
Access road	No cost	No cost	$3,000	$3,000
Vehicle	$28,000	$28,000	$28,000	$28,000
Fire-fighting unit	$12,000	$12,000	$12,000	$12,000
Winch and vehicle accessories	$2,000	$2,000	$2,000	$2,000
VHF radio	$1,000	$1,000	$1,000	$1,000
Tractor and accessories	$30,000	$30,000	$30,000	$30,000
Chainsaw, brush cutter, power tools, etc.	$3,000	$3,000	$3,000	$3,000
Miscellaneous	$10,000	$10,000	$30,000	$30,000
Upgrade and repair existing firebreaks	$12,000	$7,000	$7,000	Not applicable
Construction of new firebreaks	$18,000	$17,000	$17,000	$10,000
Fencing to required standard	$119,000	$100,000	$100,000	$40,000
Vermin control	$100	$80	$80	$50
TOTAL COST	$5,355,100	$4,230,080	$4,261,080	$1,187,050

Note: Scenarios 1 and 2 not viable without cooperation of adjacent landowners.

6.2 ASSUMPTIONS

Several assumptions have been made in preparing these estimates. These are set out below.

Land Acquisition

A land value of $10,000/ha has been assumed based on locally available land valuations. As all the land involved in any of the Scenarios is privately owned it would be necessary for Government to purchase it.

Ranger Accommodation

The house under Scenarios 3 and 4 is a prefabricated transportable home with three bedrooms and an office. It has a steel frame construction and is fully insulated. The design is the standard used by the Department of Conservation and Land Management (CALM), although less expensive transportable homes are available. Source of information is CALM. Scenarios 1 and 2 assume that the existing private residence would be acquired. The house and outbuildings have not been valued and a cost equivalent to the establishment of a new facility has been assumed.

Power, Drainage, Sewerage and Access Road

There would be no cost for these items with Scenarios 1 and 2 as an existing house just north of Maralla Road would most likely be incorporated into the reserve. If these had to be constructed from new the costs are approximately as shown. Source of information for the cost estimates is CALM.

Vehicle

The vehicle is a Toyota Land Cruiser with tray top so that a fire-fighting unit can be slipped on and off the tray. This vehicle (6 cylinder) is chosen because of the need to negotiate very soft sand tracks at all times of year, and carrying a fully laden fire-fighting unit on the back. The source of information is CALM.

Fire-fighting Unit

A standard design fire fighting unit, as used by local Bush Fire Brigades, is assumed. The estimate includes the standard 650 litre tank, an 8-10hp pump unit, 50m of hose with a reel, two knapsack sprays and a fire rake-hoe. The costing was provided by the Bush Fire Board of WA.

Winch and Vehicles Accessories

An electric front-mounted winch, extra spare wheel and tools. The costing was provided by CALM.

VHF Radio

Standard two-way VHF radio with CALM frequencies. The costing was provided by CALM.

Tractor and Accessories

This estimate is for a 74hp MF Ursus Tractor with a bucket and rake, tools, etc. Costing was provided by Massey-Ferguson.

Chainsaw, Brush Cutter, Power Tools, Etc.

General operating equipment as required in any reserve management situation. Costs are standard commercial estimates.

Miscellaneous

This includes power supplies, special management equipment, etc. The cost is higher for Scenarios 3 and 4 as there is no existing infrastructure.

Upgrade and Repair Existing Firebreaks

The length of firebreaks has been calculated from Figure 1. Figures are only approximate.

It is assumed that:

- the existing firebreaks will be used wherever possible;
- that the practice of installing two parallel firebreaks about 30-50m apart and then patch burning between them will be the preferred management procedure;
- that a tracked (as opposed to rubber tyred) bulldozer of D8 size will be necessary to handle the very soft, friable sands and the size of trees in the area. It is also assumed that any big trees will be avoided and will not be removed;
- no allowance has been made for the cost of walking and flagging the preferred firebreak alignments before construction commences;
- it has been assumed that the bulldozer operator can undertake clearing of about 1km per day of new ground and 2km per day of existing firebreak;
- the breaks will be one blade width (4m). If wider, the cost would be greater; and
- it has been assumed that all vegetation and debris from the clearing will be windrowed or stacked on-site, and that its removal or burning will be undertaken separately.

The cost of firebreak construction has been taken as the hire rate for a D8 bulldozer plus driver. This is about $1,200/km.

There are about 10km of existing firebreak in Scenario 1, 6km in Scenarios 2 and 3 and none in Scenario 4.

Construction of New Firebreaks

As above. It is estimated there would be about 15km of new firebreak required for Scenario 1, about 14km for Scenarios 2 and 3 and 8km for Scenario 4.

Fencing Materials

The fencing is to keep people and vermin out and would be of a reasonable visual appearance, but not expensive. The following combination of materials and labour is recommended.

- o there would be 1m of standard rabbit-proof fencing dug 0.5m into the ground to prevent foxes, etc., burrowing under it;
- o above ground would be 2m high deer fencing (16 horizontal wires per 2m width and 150mm between verticals). The lower 0.5m of the deer fencing would overlap with the rabbit fencing, as is standard practice;
- o the fence posts would be black star posts (steel) to reduce damage by fire and hence decrease the long-term expense of replacement; and
- o labour cost includes all construction, including burial of the rabbit netting, attachments, etc.

The cost of materials was taken as $5,405/km for wire and $1,622/km for posts, tie-wire, etc. Labour is taken as $2,800/km. Total cost is therefore approximately $9,827/km. Information was supplied by Boral Cyclone Rural Division.

Scenario 1 would require about 12km of fence, Scenarios 2 and 3 about 10km and Scenario 4 about 4km.

Vermin Control

As the area is, at present, relatively undisturbed, it is assumed that rabbits would not be a major problem. Nonetheless, it may be desirable to undertake a rabbit baiting programme. The estimated cost is $7.00 per kilometre including oats, labour and 1080 chemical. The Agriculture Protection Board has provided the cost estimate and would undertake the work.

Similarly, foxes are likely to be scarce in the area because of the lack of water in summer. Assuming a fox control programme is required, the cost would be 50 cents each for 120 gram fresh meat baits laid at 2 per kilometre, plus the cost of labour. The Agriculture Protection Board has provided the cost estimate and would undertake the work.

6.3 RUNNING COST ESTIMATE

It is assumed the ranger would be qualified and appropriately trained, in accordance with the high conservation priority given the area. Thus, if CALM supplied the ranger, that person could be considered a Grade 1 classification with several years of experience and wages would be about $30,000 per annum. On-costs such as training, leave, sick leave, administration and corporate costs would increase this to about $70,000 (based on Commonwealth Department of Finance "Guidelines for Costing of Government Activities" July 1991).

The running costs are assumed to be as follows:

		SCENARIOS 1/2/3 $	SCENARIO 4 $
Ranger's wages	assume	70,000	70,000/yr
Power and other facilities	assume	2,000	2,000/yr
Vehicle fuel and maintenance	assume	15,000	10,000/yr
Tractor fuel and maintenance	assume	8,000	5,000/yr
General expenses	assume	15,000	10,000/yr
APPROXIMATE TOTAL		**110,000**	**$97,000/yr**

6.4 SUMMARY

Most of the items are in common between the different sizes of reserve, and therefore most of the costs are the same. The main differences are the cost of firebreaks and fences, the smaller reserve obviously being the least expensive.

A significant item is the possibility of obtaining the existing house on Maralla Road as a ranger's residence. The house and land would have to be purchased or resumed and a portion of the road closed but this would avoid the cost of construction of a new house. Unlike the Ellenbrook project area wetlands, the land to the north is not owned by the Ellenbrook consortium. This aquisition would be required under Scenarios 1 and 2 and would require the cooperation of the adjacent landowners.

7.0 CONCLUSION

The cost of establishing the conservation area and running it is presented in Table 2 (1992 dollars).

TABLE 2

COST SUMMARY TABLE

	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Establishment Cost (approx.)	5,355,000	4,230,000	4,261,000	1,187,000
Running Cost/Year	110,000	110,000	110,000	97,000
Total Cost for First Year	5,465,000	4,340,000	4,371,000	1,284,000

The preferred scenarios in terms of conservation values are:

Scenario 1 - The Lexia System
Scenario 2 - The EPP Wetlands
Scenario 3 - The Ellenbrook EPP Wetlands only
Scenario 4 - The I1-L1 Assemblage

The preferred options in terms of capital cost are:

Scenario 1 - $5,465,000
Scenario 3 - $4,371,000
Scenario 2 - $4,340,000
Scenario 4 - $1,284,000

As the preferred scenario based on cost is not the same as the preferred scenario based on conservation value it will be necessary for the Government, together with the proponent, to arrive at a satisfactory resolution.

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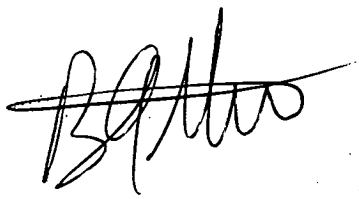
Respectfully submitted
DAMES & MOORE



B.G. Muir
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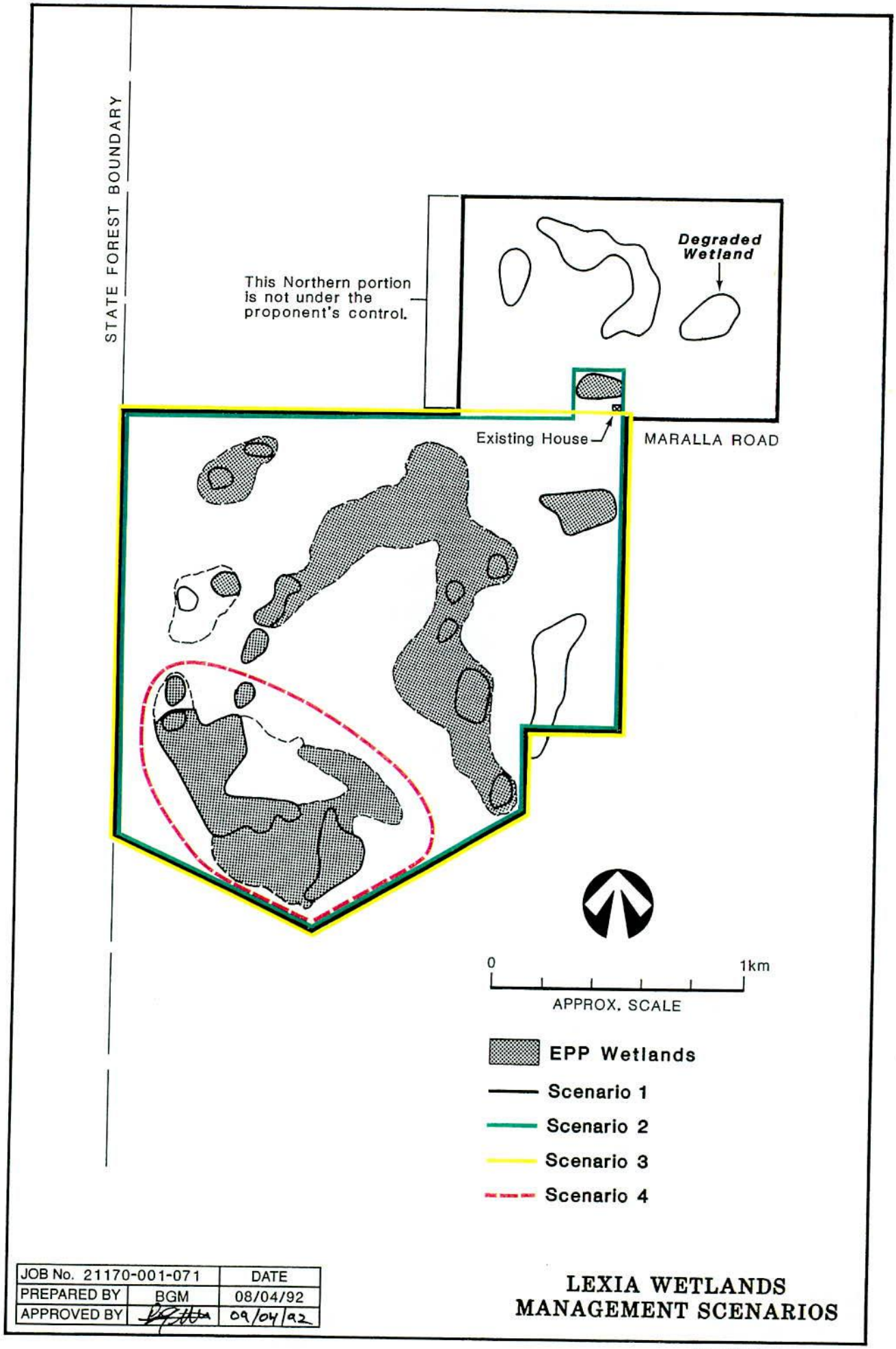
Environmental Services

BGM:sor/21170-001-071/DK:123-3412

Figures



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LEXIA WETLANDS MANAGEMENT SCENARIOS

FIGURE 1
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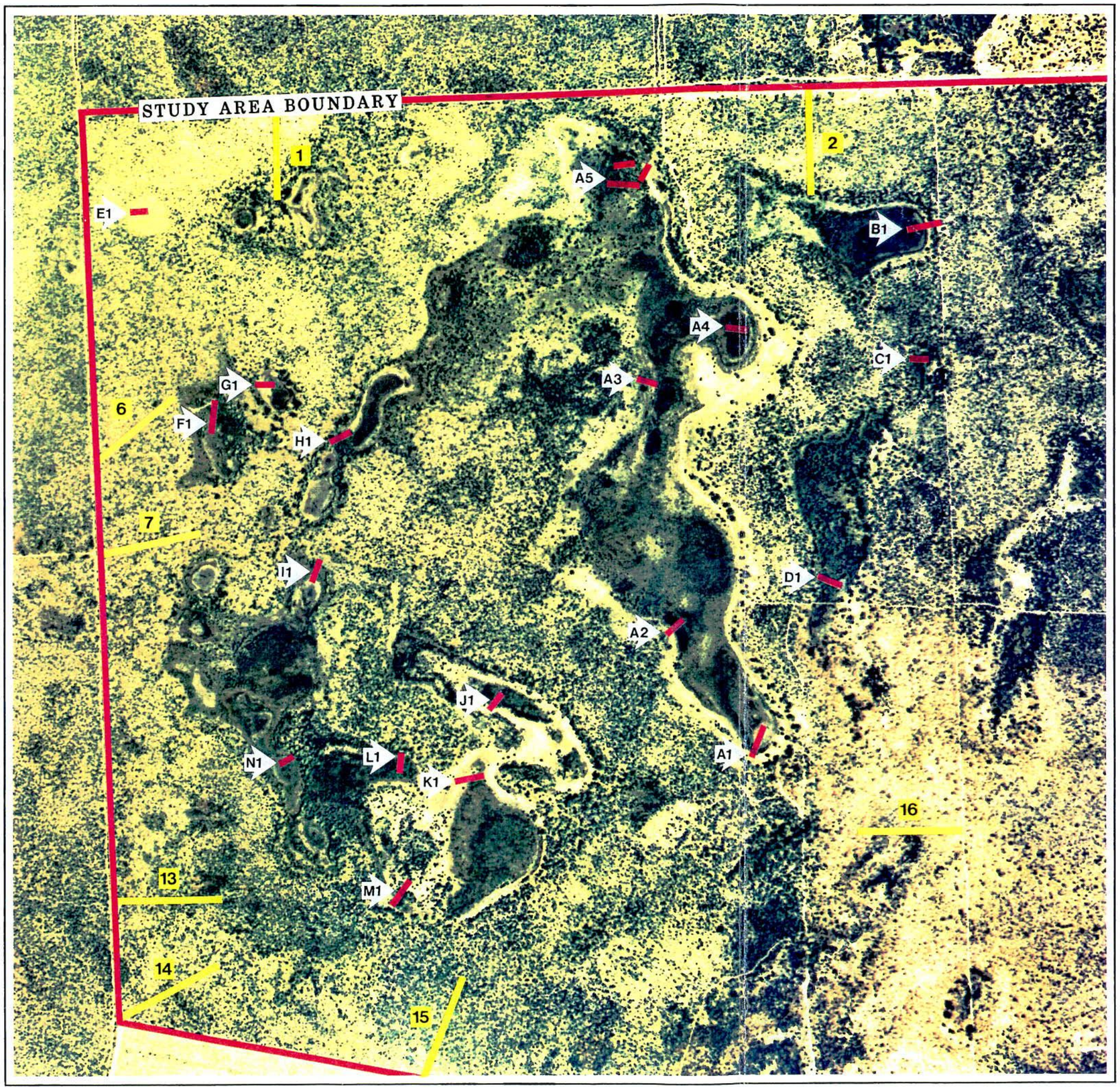

0 100 200 300 400 500m

Woodland Transects

Wetland Transects

TRANSECT LOCATIONS
LEXIA AREA

FIGURE 2
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