A Report on the Flora and Vegetation of the Ningana area and Conservation Issues affecting it

Prepared for Landcorp

by

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CONTENTS

1.0 INTRODUCTION

This report has been prepared to describe the existing flora and vegetation of the Ningana area, it's conservation value and to discuss conservation issues affecting the area.

1.1 Location

The study area (see map one) is approximately 540 hectares in area and is situated on the coast some fourty-nine kilometres north of Fremantle. It is 1.4 km from north to south and 3.8 km from east to west and lies at a moderate angle to the coast. One corner abuts the south-west corner of Yanchep National Park and Neerabup National Park lies some 2.6 km to the south as does the Alkimos area (which has also been surveyed for Landcorp) which is separated from the Ningana area by uncleared land.

1.2 Climate

The Ningana area is only 49 km from Fremantle and a similar distance from Perth and the climate is essentially similar to these locations, particularly Fremantle. That is a Mediteranean climate with a hot dry summer and reliable winter rainfall. However, there is a significant drop in rainfall along the coast north of Fremantle and Perth, which lie between the 30 and 35 inch isohyets on the rainfall map while Ningana lies between the 25 and 30 inch isohyets and recieves approximately 5 inches less rainfall a year (Comm. Bureau Met. 1962). Another feature of the climate of the area is the strong south-westerly sea breezes that blow on many days in summer. These not only make the summer more pleasant but, are important for their ability to cause blowouts of the dunes if the vegetation cover is disturbed.

1.3 Geology

The study area lies on the Swan Coastal Plain and contains two major geological types. These are the Quindalup Dunes (= Safety Bay Sand) and the Spearwood dunes (= Tamala limestone). The former can be divided

into dunes of various ages, often with different topography and the latter into areas with "limestone" at or very close to the surface and areas with deeper sand.

The Quindalup dunes, which abut the coastline in the study area, are composed largely of calcareous sand formed from the remains of calcareous algae, foraminifers and molluscs with some rounded quartz material (Lowry 1974). They have been subdivided into four ages with the oldest referred to as Q1 dunes and the youngest (which are still forming in places) as Q4 dunes, the intermediate age dunes are referred to Q3 and Q2 depending on their age (McArthur and Bartle 1980a, 1980b). The Quindalup Dunes form a narrow to moderately broad but discontinous strip from the Bunbury area to north of Lancelin however, some of the breaks in this strip are quite large. Also, the development along the strip is not uniform, with some areas having only more recent dunes others having older dunes next to the beach and no younger dunes and others having partial or well developed sequences. The Q1 and Q2 dunes tend to be well developed parabolic dunes, the Q3 dunes to be rather irregular (possibly being in places remobilised Q2 dunes with some additional sand material) while the Q4 dunes tend to be a narrow strip of one or two dunes parallel to the coast but also include areas of recent (but small compared to the Q1 and Q2 dunes) parabolic dunes and stabilised blowouts.

Predating the Quindalup dunes are the Spearwood dunes, the other geologic component of the study area. These have been subjected to prolonged weathering, resulting in a profile with siliceous sand at the surface underlain by a cap rock consisting of kankar (sandy accretionary limestone formed in the soil) and indurated and recrystalised eolianite. The cap rock is 1 to 3 m thick and grades down into softer, bedded eolianite. In many areas the siliceous sand has been removed by erosion, resulting in a variety of ecological situations from exposed cap rock to shallow sand over cap rock to deep sand with the latter usually on the east of the exposed cap rock (Lowry 1974). While in situ change within the Spearwood dunes has resulted in the development of a hard cap rock, similar processes have only resulted in weak lithification of some of the older Quindalup dunes (Lowry 1974). (Note: In the rest of this report the cap rock of the Spearwood dunes is referred to as limestone.)

The Quindalup dunes have transgressed over the earlier Spearwood dunes so that generally the surface expression of these is on the inland side of the Quindalup dunes, but they are also often exposed in swales within the older Quindalup dunes (particularly areas of cap rock but also areas of sand) and it is not unsual for Q2 or Q1 age Quindalup Dunes to occur well inland in areas that otherwise have the Spearwood dunes at the surface. In some places the border between the two ages of sand is fairly straight, in others it is quite irregular.

Development of geological types in the study area

The study area has a narrow strip of Q4 dunes at the back of the beach with one large stabilised blowout that is also Q4 in age extending approximately 700 metres ENE inland from the centre of the study area coastline. Behind the strip of Q4 dunes and north of the stabilised blowout there is an area of Q2 dunes and north of this (along the coast) there is an area of Q3 dunes, inland from both there are areas of unit Qp (undulating calcareous sands over limestone) of McArthur and Bartle (1980b). South of the stabilised blowout and extending the same distance inland there are Q2 dunes with areas of Qp in the swales.

Photograph one: View looking south accross the large stabilised Q4 age blowout from the top of a tall dune at its northern edge. In the

foreground there is a variant of vegetation unit Sn (with a large amount of the white shrub, Helichrysum cordatum) and in the background areas of Q2 age Quindalup dunes.

Photograph two: View looking south accross the centre of the study area. In the foreground there is part of a dune of Spearwood sand with Banksia on the slope. There is then an area of the limestone surface of the Spearwood dune system with heath dominated by Allocasuarina humilus (unit Ah), in the small valley beyond this there is Banksia forest on the sand surface of the Spearwood dune system, then a large area of the limestone surface with mixed areas of heath and then Quindalup dunes in the far background.

Inland from this coastal band of Quindalup Dunes there is a large area of the limestone surface of the Spearwood dune system but, with a sand fringe. Elongated Q2 and Q1 dunes overly the limestone surface of the Spearwood dune system in places and adjoining it there are areas of the sand surface of the Spearwood dune system. The limestone areas occur as small to moderate hills with generally shallow siliceous sand (grey at surface, yellow at depth) but with deeper patches on the lower slopes. The coastline currently appears to be prograding (there are very small Q4 dunes forming) however, it appears to have been retreating until fairly

recently. (See Appendix two for the soils and geomorphology map of the study area.)

1.4 Condition of the vegetation

The condition of the vegetation of different parts of the study area differs remarkably because they have been used differently as a result of of their different topography and soil. Thus, the condition of the vegetation varies from very good to completely degraded (where the native flora has been replaced entirely by introduced species). The study area undoubtedly been grazed through and this may have caused some alteration in species density or composition but, in those areas that are in good, very good or very good to excellent condition not to the stage where species composition and abundance are obviously effected

Photograph three: North-west corner of the study area showing the selective clearing of lower areas and retention (in good to very good condition) of areas of Q2 dunes (midground) and Q3 dunes (background).

Spearwood dune system

Some parts of this sytem have had their vegetation cover cleared entirely or almost entirely, these are the siliceous sands on the lower slopes of the limestone areas behind the coastal band of Quindalup dunes. In contrast the areas with limestone at or very close to the surface (and with denser heath vegetation) are largely in very good condition with some

weed invasion and reduction in cover caused by fire and grazing. This includes a large area in the centre of the study area and some smaller outliers of the limestone surface type. The condition of the areas of the sand surface type of the Spearwood dunes varies. Those within the large area of the limestone are in very good to excellent condition but some of the others (particularly next to cleared areas) are in poorer condition.

Quindalup dune system

The area of the Quindalup dune system (including areas of Q2, Q3, Q4 dunes and Qp - the latter in swales) along the coastline of the study area is in good to very good condition although it has probably suffered some reduction in cover due to burning and grazing and has some weed invasion. In contrast to this the areas of Qp just behind the coastal band of dunes in the north western corner of the study area has been cleared and some areas of Qp in the eastern section of the study area have also been cleared or very badly degraded. The Q2 dunes (and a small area of Q1) in the eastern section are quite degraded, or even cleared on their lower slopes, although some of the crests are in good condition (where there are very steep slopes these can be in good condition also). It should be noted that the vegetation of the Q1, Q2 and Q3 dunes is naturally low and open and has a "grassy" or weedy appearance due to the abundance of the grass-like lily Lomandra maritima. This grassy appearance is often leads to the vegetation being considered more weed invaded and degraded than it in fact is (it is a rather unusal vegetation type for the south-west of Western Australia).

2.0 METHODS AND LIMITATIONS

This survey was designed to give sufficient detail to enable the conservation value of the Ningana area for flora and vegetation to be determined without being exhaustive in the collection of flora or the description and mapping of the vegetation. The level of survey is detailed enough to do this and to provide information to enable the vegetation to be taken into account in development plans.

2.1 Methods and limitations of the flora survey

The survey was carried out in late spring and early summer and would be somewhat biased towards species that flower at this time. Such a bias would be minimal for perennials as they are still evident when not flowering but, geophytes (annually renewed plants, from an underground storage organ such as a bulb or rhizome) and annuals that were not flowering (or even dead) would be easier to miss. Collections were made of plant specimens at the sites recorded for the description of the vegetation types and on foot and vehicle traverses of the study area. Common species well known to the authors were recorded but not collected. Specimens were identified using Marchant et al (1987) and comparison to previously identified specimens at the W.A. Herbarium.

Given the size of the study area, the vegetation types found in it and the number of species recorded, it is likely that more than 90% of the plant species with perennial above ground parts and 80% of the geophyte and annual flora have been recorded. To record the other species more intensive searching would be required with field trips in winter and early spring to locate annual and geophyte species.

Exotic (i.e. introduced or weed) species were not exhaustively surveyed but were recorded when appropriate to note the condition of the vegetation. The collection of lower or non-flowering native flora (fungii, lichens, liverworts and mosses) was beyond the scope of this survey.

2.2 Methods and limitations of the vegetation survey

The vegetation survey was based on the description of the vegetation found at representative sites. These were selected using aerial photographs and field examination of the vegetation. The vegetation has

been mapped in complexes whose distribution coincides with the distribution of the soil/geomorphic units found in the study area. Not all the variants of the vegetation have been described, but sufficient have been to enable evaluation of the vegetation.

3.0 FLORA SURVEY

3.1 Flora Recorded

One native non-flowering plant (the Zamia Palm, Macrozamia reidlei) and 183 flowering plants were recorded in the Ningana study area (see Appendix 1). Thirty six of the flowering plant species were introduced species.

Of the 154 native species 33 were monocotyledons from 12 plant families and 121 were dicotyledons from 38 families. The families of monocotyledons with the most species were Cyperaceae (8 species), Poaceae (11), Haemodoraceae (5) and Anthericaceae (6). The most abundant dicotyledons families were Epacridaceae (7), Proteaceae (17), Asteraceae (13), Myrtaceae (8), Papilionaceae (13) and Mimosaceae (7).

More species (187) were recorded at the nearby Alkimos area, probably because of the larger area of that location and the fact that it has larger areas of Banksia woodland, the most species rich of the vegetation types present in either study area.

3.2 Biogeographical relationships of the flora recorded

The family makeup of the native flora recorded from Ningana is relatively typical of the flora of the south-west of Western Australia and is comparable with that of two previous studies (Trudgen 1984, 1988) of coastal and near coastal areas on the Swan Coastal Plain. In all three surveys the Poaceae and Asteraceae are somewhat higher in numbers than would be expected when compared with the flora of the south west as a whole. This is probably because of the sandy soils of the area, particularly the presence of calcareous sands as well as siliceous sands. Annual species of Poaceae and Asteraceae (and Apiaceae) are commonly found in the open sandy patches found in the vegetation of coastal areas and are probably slightly under represented in the list for the survey area as it was carried out late in the flowering season. The number of Mimosaceae is lower than would be expected and this is also a result of the sandy soils of the study area. The absence or poor representation on the list for Ningana of several families (Orchidaceae, Droseraceae and Juncaginaceae) which were better represented in the previous studies

and whose species are mostly geophytes or annuals is almost certainly a result of the timing of the survey.

When the list of species recorded for the Mandurah survey area (Trudgen 1988) is compared to the list of species recorded from Ningana and the nearby Alkimos area it is obvious that while the makeup of the flora at the family level is relatively constant there is a very significant change at the species level. Not including twenty-nine species from the Mandurah list confined to wetlands (as there are no wetlands in the Ningana area or the nearby Alkimos area), 136 species were recorded at Mandurah but not at Ningana or Alkimos, 133 species were recorded at both Mandurah and Ningana and/or Alkimos and 66 species were recorded at Ningana and/or Alkimos but not at Mandurah. While some of this difference can be attributed to variation in the habitat types present in the Mandurah and Ningana areas, it is largely due to a gradual change in the flora up the coast that correlates with the gradual change in climate, particularly the decrease in rainfall. It is very likely that a similar change in flora occurs from the Ningana area north to Lancelin, although the soil systems are still similar to those at Ningana and Mandurah.

Two well known species whose distributions reflect this trend are Eucalyptus todtiana (Pricklybark) which does not grow south of Jandakot and Agonis flexuosa (Peppermint), a characteristic species of coastal areas throughout much of the south-west, which does not grow north of Bold Park (Kieghery et al. in press). Other less well known species whose distributions are similarly affected are Calothamnus sanguineus which does not occur south of Perth on the coastal plain although it does occur further south in inland areas, Calytrix angulata which does not occur further south than Jandakot, Hakea costata which does not occur south of Burns Beach and Persoonia comata which does not grow south of the Yanchep area.

3.3 Introduced flora

Poaceae, Asteraceae and Papilionaceae were the families with the most exotic species present in the study area, some members of these families were very common. Other families represented included

Caryophyllaceae, Brassicaceae and Gentianaceae. Many species were widespread in the study area but except for those abundant in cleared areas tended to have low population levels although *Romulea rosea had moderately high population levels in places.

The parts of the study area that have been cleared have had their native flora replaced entirely (or almost entirely) by exotic species while the bushland areas mostly do not have bad weed infestations. *Briza maxima, *Briza minor, *Petrohagia velutina, *Crassula glomerata, *Dischisma arenarium, *Romulea rosea, *Hypochaeris glabra and *Ursinia anthemoides, were established in relatively undisturbed areas. In more disturbed bushland *Avena fatua, *Erharta calycina, *E. longiflora and *Carpobrotus edulis were well established and/or increasing in abundance. Some species were only found in pasture areas while other such as *Bromus diandrus were very common in pasture areas (as were many other exotics) but were also found sporadically in bushland.

Two new records of introduced flora (weeds!) were made during the survey *Cucurbita pepo a prostrate creeper is a new record for the state and *Lepidium bonariense an erect annual is a new record for the Perth Metropolitan region.

3.4 Species of particular interest

No gazzetted rare flora species were recorded for the study area however, several other species of interest were recorded and are discussed below.

Conostylis pauciflora ssp. euryhipis (Haemodoraceae)

A locally common but restricted taxa confined to the consolidated dunes within ten km of the coast between Cervantes and Yanchep. In the study area being found at sites 4,5,7, and 8. Appears to be restricted to the Quindalup dunes.

Petrophile affinity serruriae (Proteaceae)

Further work on this taxon (a pink variant found on the coastal plain from Perth to Geraldton) will probably result in its recognition as a separate species allied to Petrophile serruriae which is a widespread

variable taxa found from Geraldton to Albany (Marchant et al. 1987). Observed near sites 11 and 19.

Tetragonia tetragoniodes (Aizoaceae)
A poorly collected species in the Perth Region (Wanneroo) and elsewhere although apparently widespread occurring from Albany to Shark Bay and at Mt Magnet (Marchant et al). This species was observed once on the dunes above Pipindinny Swamp.

Alyogyne huegelii ? var. glabrescens (Malvaceae)
Alyogyne huegelii is a widespread variable species with several varieties. The variety occurring in the study area appears to be var. glabrescens and is a new record for the Perth Region. Only one specimen of this variety is presently held at the W.A. Herbarium (more may be among Alyogyne material currently on loan). Unlike other varietys of Alyogyne huegelii, which have lilac flowers, this variant has a cream corolla covered with rusty hairs and a purple throat. It was found in a dense (probably colonial) stand at site 17 (which had been disturbed), another stand of this taxon was found alongside Pipindinny Swamp just outside the study area.

Trymalium albicans (Rhamnaceae)
This species was considered extinct (Conservation and Land Management Priority 4 species in the Metropolitan Region) but recent work on the genus (Keighery, 1989) found that Trymalium ledifolium as previously recognised at the W.A. Herbarium contained two distinct species, the near coastal T. albicans and inland T. ledifolium. This species was found at sites 6,9,13 and 14. It is not rare or restricted.

Stylidium sp. ("maritima") (Stylidiaceae)
This species is related to Stylidium affine but occurs in near coastal locations on calcareous soils and limestone on the coastal plain from Yanchep to Yalgorup. Although it can be common in small areas, populations are not common and much of its habitat between Yanchep and Yalgorup has been cleared or degraded and it should be considered uncommon. In the survey area it was found at sites 5 and 6.

15

Leptorhynchos scabrus (Asteraceae)

This is a poorly collected species both in the Perth Region (where it has been recorded from Mandurah) and elsewhere although, it is fairly widespread extending from Jurien Bay to Bremer Bay. This may be because it is superficially similar to the more widespread and common species Podotheca chrysantha or it may indeed be an uncommon species. In the study area it was locally common in the area of site 13.

4.0 VEGETATION

The vegetation of the study area is varied, reflecting the substantial variation in soil, topography and distance from the sea that occurs in the study area. It is very strongly controlled by the substrate (soil) that it occurs on and is described below in 'complexes' consisting of several vegetation types that occur on a particular geomorphological type.

The geomorphic types present in the study area are the strand, Q4, Q3, Q2 and Q1 age dunes of the Quindalup dune system and associated swales (which are largely cleared) mapped as Qp and Qs by McArthur and Bartle (1980a) and the limestone and sand surface types of the Spearwood dune system. Some of the areas mapped as Qp and Qs by McArthur and Bartle have siliceous soils and more detailed soils mapping would probably refer them to the Spearwood dune system rather than the Quindalup dune system. (See appendix two for the relevant part of McArthur and Bartle's map.)

Vegetation of the strand

The strand (or area of the beach above the tidal zone) has only simple vegetation of colonizing species, where the beach is narrow this is often pushed up onto the base of the first stabilised dune. Where it is well developed the vegetation can include a low foredune (beachridge) that is reasonably well stabilised, with denser cover of Spinifex species. On stable or prograding beaches these can become larger and completely stabilised over a period of time. In exceptional case such as at Port Kennedy (south of Rockingham) series of such dunes can be developed, one behind the other.

ShSl Spinifex hirsutus, S. longifolius, *Agropyron racemosum Hummock grassland

This unit is part of a complex of variation containing the two Spinifex species that occurs on sandy beaches along much of the coast of south-western Western Australia. It is often extremely poor floristically, as at the site recorded. Variants include stands with mostly Spinifex longifolius rather than S. hirsutus and the presence of small amounts of Olearia axillaris and/or Tetragonia decumbens. The unit is very narrow at Ningara as it appears that at least until recently the beach was eroding

(it probably fluctuates but the general impression from the vegetation is of regression) and occurs at the base of the first stabilised dune. This is typical on beaches undergoing regression, where beaches are prograding this unit usually occurs on a very low (< 1m) dune separated from the first stabilised dune by a small swale. It is usually dominated by Spinifex hirsutus or Spinifex longifolius or a mixture of the two. However, at Ningana *Agropyron racemosum (sea wheat) has become naturalised (unfortunately after deliberate introduction for stabilisation purposes) and is replacing the native species. Other plants present were Olearia axillaris (5-10%) and small amounts of Tetragonia and Acanthocarpos.

Site 3. Cream coloured to very pale grey sand. Poor to good condition (poor where the sea wheat is present). Except for sea wheat (which was introduced for use in stabilisation but which now appears to be out-competing the native species and becoming a pest) there were few weeds except *Trachyandra (low to moderate invasion) and *Pelargonium capitatum (low invasion).

Vegetation of the Q4 age Quindalup dunes parallel to the beach

The dunes treated under this category are parallel to the beach and have Scaevola crassifolia as a major component of their vegetation and have soil that is distinctly a very pale grey rather than cream coloured, indicating that they are not very young (or that the soil is reworked from older dunes, as seems likely in this case).

ScOa Scaevola crassifolia, Olearia axillaris Open to closed heath

This unit is common along sandy shores on the coast of south-west Western Australia where it is often the first unit behind the stabilising grasses on the strand. It is very variable with dominance varying from place to place between the Scaevola and the Olearia. At Ningana the Scaevola (40-110 cm) is the more abundant with cover of 65-75% while the Olearia (0.5-1.5 m, 10-30%) is more variable in cover. Other species prominent in this unit were Lepidosperma gladiatum, Hardenbergia comptoniana, Helichrysum cordatum and Acanthocarpos preissii. Spyridium globulosum was present in patches.

Photograph four: Stand of unit ScOA on seaward face of Q4 age dune. Note the small area of unit ShSl (hummock grassland dominatd by Spinifex species) visible at the base of the dune.

Site 2. Slope between Q2 dunes and beach, calcareous cream coloured to very pale grey sand. Condition: good to very good, weed invasion low with some Trachyandra and small annuals (Crassula and annual grasses). Where the strip of Q4 dunes is narrower than at site 2 the vegetation developed grades to the vegetation of the Q2 dunes.

Vegetation of the stabilised Q4 age blowout

The vegetation of the stabilised blowout seems to be more similar to vegetation on dunes classified as Q3 in the area south of Mandurah (see Trudgen 1988), especially in the presence of Scaevola nitida as one of the dominants. This probably indicates that while the disturbance of the dunes is referable to the same time inteval as the development of the Q4 dunes the soil involved is largely reworked older soils and this latter factor is controlling the vegetation, which is more developed than typical Q4 in species composition. Some of the crests have vegetation more typical of Q2 dunes and these are probably areas that were little disturbed by the blowout.

Sn Scaevola nitida Low closed heath to closed heath

This unit occurs on swales and adjoining dune slopes in the stabilised blowout area, but not on crests. The Scaevola nitida has high cover

(80%) and varies from 0.5 - 2 m tall, with most plants from 1-1.5 m tall. Beneath the Scaevola there is an open (30-60 cm, 20-25%) layer of Acanthocarpos preissii while the creeper Hardenbergia comptonia (5%) scrambles through the Scaevola itself. The only other species present at the site recorded with more than 1% cover was Helichrysum cordatum (5%). However, other stands with Olearia axillaris to 10-15% cover or Helichrysum to 25% cover were also observed.

Photograph five: Stand of unit Sn in a swale and on slopes of dunes in stabilised Q4 blowout area. Note the area of Q2 aghe Quindalup dunes iin the backgound with their typicla low, grassy looking, vegetation (unit Lm).

Scaevola nitida is a close relative of Scaevola crassifolia which typically occurs in Q4 dunes (usually in fact on first one or two stabilised dunes) with occassional plants in disturbed areas further from the coast while Scaevola nitida typically occurs further from the coast. The stands of Scaevola nitida in the Niagara study area are the largest known to the author north of Bunbury. They occur in a reticulate fashion between the dune crests and grade (from the type described above) into much more open stands with an understorey of Acacia truncata and other stands which are similar to the vegetation of Q2 dune, with some Scaevola nitida and Acacia truncata and may be less disturbed (by the erosion that caused the blowout) than the swales.

Site 4. South west facing slope, extending into swale. Pale grey calcareous sand. Condition very good. Very few weeds at the site recorded however, in the bottom of some other swales Bromus is well established and there is some Sonchus.

AAMP Acacia truncata, Acrotriche cordata, Melaleuca acerosa, Pimelea ferruginea Low Open Shrubland to Low Shrubland.

This unit occurs on a tall dune in the stabilised Q4 age blowout but, probably is an area of Q2 age that has had minimal (or escaped) disturbance. It represents one point in a complex of variation on the crests ansd upper slopes in which the species (particularly the shrub species) have very variable cover. The total cover of shrubs can vary from about 15% to 30% but, Acacia rostellifera (which usually occurs on lower slopes) is not an important component.

Photograph six: Stand of unit AAMP on the upper slopes and crest of a tall dune. The dark green shrubs are Acacia truncata and Acrotriche cordata, the shrub with the fading flowers is Pimelea ferruginea.

At the site recorded Acacia truncata (40-55 cm) and Acrotriche cordata (30-45 cm) both varied from 5-10%, the Pimelea ferruginea (15-40 cm) from 1-15% while the Melaleuca acerosa (20-25 cm, 5%) was more evenly distributed. Other shrub species present included Scaevola nitida (30-60 cm, 1-3%), Oxylobium reticulatum (20 cm, 2%) Helichrysum cordatum

(40-60 cm, 1-5%), Lysinema ciliatum (30 cm, patches to 3-4%), Trymalium albicans (15-20 cm, < 1%), Hemiandra pungens (20 cm, 2-4%), Santalum acuminatum (30-70 cm, < 1%), Acacia rostellifera (15-25 cm, < 1%) and Acacia cochlearis (40-50 cm, 1% with patches to 15%). Beneath the open shrub layer there was a herb/sedge layer of the liliaceous herb Lomandra maritima (20-30 cm, 25-45%) with smaller amounts of Anigosanthos manglesii (<1%) and Loxocarya flexuosa (5-15 cm, 5%). The creeper Hardenbergia comptoniana (1%) scrambles through the unit.

Site 6. Near crest of tall dune on south west facing slope. Grey calcareous sand. Very good condition with few weeds.

ApHp Acanthocarpos preissii, Hemiandra pungens Low Open Heath
This unit was recorded near the back of the large Q4 age blowout on the the leeward slope of an area of sand that had been mobilised. It is a very variable unit, having patches of Acacia truncata (0.6-1.4 m, 1-15%), Acacia cochlearis (1-1.4 m, < 1-10%), Acacia saligna (1.5-3.5 m, < 5%) and small dense stands of Acacia rostellifera scattered through it. The Acanthocarpus (30-70 cm, 30-60%) is usually more abundant than the Hemiandra (0.4-1.2 m, 10-40%), other shrubs present included Olearia axillaris (1-1.3 m, < 5%) and small amounts of Rhagodia baccata and Eremophila glabra. Other species present included Conostylis candicans (2%), the grasses Poa porphyroclados (2%) and Stipa flavescens (1-2%) and the creeper Hardenbergia comptoniana (< 5%).

The presence of occassional plants of Spinifex longifolius and Scaevola crassifolia, species that usually occur on the beach or the first or second stabilised dunes, indicates that the slope the site was recorded on has not been stabilised very long. At the bottom of the slope there was a strip with Lepidosperma gladiatum abundant.

Site 10. Steep slope north east facing slope at rear of a stabilised blowout. Pale grey calcareous sand. Good to very good condition, but some weeds.

Vegetation of the Q3, Q2 and Q1 age Quindalup dunes
The vegetation on these dunes is often misinterpreted as being highly disturbed because of its low stature and the grassy look given to it by the

liliaceous herb Lomandra maritima. In the study area they have undoubtedly been affected by fire and grazing which have probably reduced the vegetation cover on them. Their overall condition seems to be quite good, being comparable to that of areas of similar vegetation and history of use south of Mandurah (especially taking into account the lower rainfall in the study area) although the swales have often been cleared.

Lm Lomandra maritima herbland

This unit is dominated by the grass like liliaceous plant Lomandra maritima. The only other abundant species were Melaleuca acerosa (10-20 cm 15-20%), Hardenbergia comptoniana (10-20 cm, 5%) and Phyllanthus calycinus (10-20 cm, < 5%). Other species present in this unit included Acanthocarpos preissii (10-20 cm, 1-2%) and (all less than 20 cm tall and less than 1% cover Pimelea ferrugina, Gompholobium tomentosum, Hemiandra pungens Loxocarya flexuosa, Conostylis candicans, Eremophila glabra, Carpobrotus sp. and Acacia cochlearis.

In some places very close to the beach Anigosanthos manglesii (the state floral emblem, the "kangaroo paw") was observed in this unit. Its usual habitat is in Banksia woodland and it is unusual for it to be so close to the beach.

Site 1. West facing slope in somewhat irregular area of Q2 dunes. Very close to beach. Grey calcareous sand. Condition: good, some four-wheel drive tracks in places and weed invasion low to moderate with small annual grasses, *Pelargonium capitatum and Romulea rosea present.

Ma Melaleuca acerosa Low Open Shrubland to Low Open Heath

This is a very low and open unit with 10-20% Melaleuca acerosa (20-50 cm) at the site recorded (although it does get to 50% in some places) with small amounts of a number of other shrub species over a mixed herb/sedge layer. Other shrub species present included Acacia cochlearis (30-50 cm, patches to 5%), Acacia lasiocalyx (10-30 cm, 2-3%) and Phyllanthus calycinus (35 cm, < 1%). The herb/ sedge layer has Lomandra maritima (20-40 cm, < 10%), Conostylis candicans (10-25 cm, < 10%), Loxocarya flexuosa (5-15 cm, 20%), Schoenus subfalcatus (3-4%) and

small amounts of Stipa flavescens, Dianella revoluta and Lepidosperma tenue. Scattered through the unit are small patches of Acacia lasiocalyx with cover 40-60%.

Photograph seven: Stand of unit Ma on the crest of a Q2 age dune in the eastern part of the study area. The Melaleuca has pale yellow heads of flowers.

Site 13. Crest of a Q2 age Quindalup dune in the eastern part of the study area. Pale grey fine calcareous sand with very friable "limestone" outcropping in places. Condition good on the crest but slopes (especially lower slopes) often badly degraded. Weed invasion low on crest (some Avena, a lot of Romulea) but lower slopes have very badly weed infestations.

TAOM Trymalium albicans, Acacia lasiocarpa, Oxylobium reticulatum, Melaleuca acerosa Low Open Heath

This unit has a mixed low shrub layer of Trymalium albicans (40-50 cm, 5-10%), Acacia lasiocarpa (30-65 cm, 10-15%), Melaleuca acerosa (30-60 cm, 10-15%) and Oxylobium reticulatum (20-30 cm, 10-15%) with smaller amounts of Leucopogon parviflorus (40-70 cm, 3-4%), Pimelea ferruginea (35-50 cm, 1-2%), Phyllanthus calycinus (60 cm, 2-3%) and Hemiandra pungens (30-60 cm, 1%). Beneath the shrub layer there was a mixed herb/sedge layer of Lomandra maritima (25-50 cm, 10-25%), Loxocarya

flexuosa (10-15 cm, 5-10%), Lepidosperma tenue (1%), Conostylis candicans (< 1%), Poa porphyroclados (30 cm, 1-3%), Stipa flavescens (< 1%), and Schoenus sub-barbata (3%).

Photograph eight: Stand of unit TAOM on a steep south east facing slope. Note the mixture of different shrub species.

Site 14. Very steep south east facing slope of a Q2 age dune. Pale grey calcareous sand. Good to very good condition but, has moderate to high invasion of *Romulea rosea.

ArMa Acacia rostellifera, Melaleuca acerosa Low Open Heath

This unit (which is quite variable) is common on the slopes of Q2 dunes both in the study area and south of Mandurah. Under and between the shrubs of Acacia rostellifera (30-50 cm, 15-30%) and Melaleuca acerosa (25-40 cm, 35-40%). There is a layer of the liliaceous herb Lomandra maritima (20-35 cm, 50%). With smaller amounts of Loxocarya flexuosa (15 cm, 5-10%). There were then a variety of species (some of which have very patchy distribution over small areas) these included Pimelea ferruginea (30-45 cm, 1-10% patchy), Hemiandra pungens (30-50 cm, 1-5% patchy), Gompholobium tomentosum (20-35 cm, 3%), Poa porphyroclados (25 cm, 2%) and Stylidium sp. ("maritima").

Site 5. South west facing slope, grey calcareous sand. Good to very good condition with low weed invasion by Romulea rosea and small annual Poaceae.

Ar1 Acacia rostellifera Closed Scrub

This unit occurs in swales between taller dunes changing abruptly into Acacia rostellifera closed heath at the edge of the swale. At the site recorded the Acacia rostellifera (2-3 m, 85%) is moderately tall and dense with the only other shrub in the overstorey being small amounts of Spyridium globulosum (1-2.8 m, 5%). Beneath the Acacia there is a very open understorey of Melaleuca acerosa (1-1.3 m, 5%) and Acanthocarpos preissii (0.5-1 m, < 5%). The creepers Clematis microphylla (3 m, 1-15%) and Hardenbergia comptoniana (2 m, > 10%) climb through the upper shrub layer. The unit is fairly species poor, other species present included Conostylis pauciflora, Rhagodia baccata, Parietaria debilis and a Stipa.

Site 7. Swale in area of tall irregular dunes. Grey calcareous sand with 5 cm litter layer. Very good condition.

Ar2 Acacia rostellifera Closed Heath

This unit occurs on dune slopes adjacent to the Acacia rostellifera closed scrub. The transition is abrupt not gradual, presumably reflecting a rapid change in the soil conditions from the slope top the swale (possibly water availablity but, also possibly more silica in the soil of the swale). The Acacia is less than 2m tall, but still >70% cover and the understorey is quite dense with 40-60% of Melaleuca acerosa as well as Lomandra maritima (this unit was not recorded in detail).

Site 7a. Very good condition.

Photograph nine: Stands of units Ar2 (foreground on slope) and Ar1 (in swale) with open variant of Ar2 on the slope in the background.

Vegetation of the Spearwood dune system, limestone surface type

The transition from limestone surface to sand surface is not abrupt with some areas having a thin surface layer of sand over limestone. These often occur as 'fans' or 'skirts' of sand at the edges of some of the limestone areas or on low points in them and often have Xanthorrhoea shrublands on them. For convenience, the dividing line is taken where the vegetation changes from heaths or shrublands to low woodland or forest of Banksia. This gives a more signifiicant division in the vegetation than from one shrubland to another or heath.

Three large shrub species (Hakea trifurcata, Dryandra sessilis and Calothamnus quadrifidus) are dominant over much of the limestone areas, usually forming stands where one has clear dominance (often with minor amounts of the others). They do also form mixed stands, the latter often having some Allocasuarina humilus present. Other species that are dominant in vegetation on the limestone areas at Ningana are Xanthorrhoea preissii, Acacia pulchella and Scaevola nitida.

Ht Hakea trifurcata Open to Closed Heath

At the site recorded the Hakea trifurcata was moderately dense (1.3-1.5 m, 65-75%) but within the stand varied to very dense (90%). The other large shrub species present were Dryandra sessilis (1.4-1.6 m, 5%) and Calothamnus quadrifidus (1-1.4 m, 3-4%). Lower shrub species present included Jacksonia stricta (1-1.1 m, 15%), Hibbertia hypericoides (1 m, 5-10%), Oxylobium reticulatum (5-10%), Melaleuca acerosa (10-15%) and Acacia pulchella (1-2%). There was then an open herb/sedge layer with

Lomandra maritima (5%), Loxocarya flexuosa (5-10%) and a small amount of Poa porphyroclados.

This unit occurs in a mosaic with stands dominated by Dryandra sessilis (intermediate stands do occur). Some stands have small amounts of smoke bush (Conospermum triplinervium), indicating the sand layer (over the limestone) is deeper.

Site 11. West facing slope, some exposed limestone. Grey siliceous sand. Good to very good condition, few weeds.

Ds Dryandra sessilis Closed Heath

This unit is usually clearly dominated by Dryandra sessilis but, often has significant amounts of other large shrub species. At the site recorded the Dryandra sessilis was moderately dense (1-1.5 m, 70-80%) and Calothamnus quadrifidus (0.7 - 1 m, 10-30%) also had significant cover in the upper shrub layer. Other species in the upper shrub layer were Hakea trifurcata (1.5 m, < 1%) and Hakea costata (1-1.2 m, < 1%). The lower shrub layer was also quite dense, species present included Melaleuca acerosa (0.5-0.7 m, 5-10%), Hibbertia hypericoide (0.7-1 m, 60-70%), Calothamnus sanguineus (0.5-0.7 m, 2%) and Acacia pulchella (0.7-1 m, 2%). The herb/sedge layer was quite open with only Loxocarya flexuosa (10-25 cm, 10-20%) having significant cover.

The unit is quite variable with Grevillea thelemanniana, Hakea prostrata, Jacksonia stricta and Phyllanthus calycinus being moderately abundant in patches.

Site 12. West facing slope with grey siliceous sand (yellow at depth) and exposed limestone nearby. Good to very good condition.

Xp Xanthorrhoea preissii shrubland.

This unit was observed on low lying areas of siliceous sand (sometimes very close to dunes of calcareous sand or extending onto their lower slopes) and on the lower slopes of limestone outcrops. At the site recorded the upper storey was open with Xanthorrhoea preissii (1-2 m, 15-25%) with some patches of Acacia saligna. Below this there was a very

open, mixed lower shrub layer. The most abundant species being Melaleuca acerosa (40-70 cm, 2-4%), Calothamnus quadrifidus (60 cm, 1-3% patchy) and Oxylobium reticulatum (40 cm, < 1%). The herb/sedge layer was denser with Lomandra maritima (20-40 cm, 40%), Loxocarya flexuosa (10-15 cm, 10-25%), Stipa (<1%) and Poa (<1%).

Upslope to the west this stand grades into a Q2 dune vegetation type. Downslope it also has Hakea prostrata present in the upper layer.

Site 8. Good condition, but with a lot of Romulea rosea and some Bromus and Melilotus. The invasion of weeds may possibly be beginning to effect the composition of the native annual flora present by competing for nutrients and water.

Cq Calothamnus quadrifidus Open heath to closed heath

This unit is dominated by Calothamnus quadrifidus (1-1.6 m, 50-70+%). The other species present in the upper shrub layer were Dryandra sessilis (1.5-3 m, < 5%), Xanthorrhoea preissii (1-3.5 m, 1-2%), and Hakea trifurcata (1.4-2 m, 1-2%). The lower shrub layer was variable in cover, reflecting the variation in the upper shrub layer, the more abundant species were Hibbertia hypericoides (60-90 cm, 10-50%), Jacksonia stricta (20-50 cm, < 5-10%), Bossiaea eriocarpa (40-60 cm, < 5%) and Dryandra nivea (10-20 cm, < 5% patchy). The herb/sedge layer had only moderate cover with Loxocarya flexuosa (10-15 cm, 10-15%), Lepidosperma angustatum (40-60 m, 10%), and Mesomelaena stygia (50 cm, < 5%) the most abundant species.

Site 16. South facing rise, pale grey siliceous sand, dull yellow at depth, limestone outcropping. Good to very good condition with low weed infestation (some *Avena, *Romulea, *Gladiolus).

SnAt Scaevola nitida, Acacia truncata Open to Closed Heath

The upper shrub layer of this unit consisted mostly of Scaevola nitida (1.3-1.7 m, 30-60%) and Acacia truncata (1-1.7 m, 10-35%). The other shrubs present (mostly lower) were Trymalium albicans (0.8-1.2 m, 5-10%), Olearia axillaris (1-1.5 m < 1%), Templetonia retusa (1.2 m, < 1%) and Melaleuca acerosa (30-60 cm, + 5%). Hakea lissocarpha occured in

open patches with more limestone exposed. The creepers Clematis microphylla (< 1%) and Hardenbergia comptoniana (1-2%) were also present.

Site 9. South facing slope of a limestone ridge. Dark grey siliceous sand with limestone outcropping. Good to very good condition, very few weeds.

Ah Allocasuarina humilus Low open heath

This unit occurs where the layer of sand over the limestone is somewhat deeper than the areas where Dryandra, Hakea and Calothamnus are dominant. There were scattered Banksia attenuata, presumably where the sand is deeper.

The Allocasuarina humilus (0.5-1.2(2) m, 40-50%) is fairly dense and appears to have individuals scattered through it that are older than the others and that presumably survived the last fire. The other tall shrubs in the stand were Xanthorrhoea preissii (1-2.5 m, 5-10%), Acacia pulchella (1.3 m, < 1%), Dryandra sessilis (1-1.8 m, < 1%) and Calothamnus quadrifidus (1 m, 1-2%). Other (smaller) shrubs present were Hibbertia hypericoides (50-70 cm, 40%), Calothamnus sanguineus (40-60 cm, < 5%), Melaleuca acerosa (40-80 cm, < 5%) and Dryandra nivea (10-15 cm, 1-2%). The only sedge present in any quantity was Mesomelaena stygia (40-50 cm, 25%).

Photograph ten: Stand of unit Ah with Banksia attenuata low woodland downslope in the background. Note the dense cover of the Allocasuarina.

Site 19. North east facing slope. Grey siliceous sand, pale yellow at depth. Excellent condition with very few weeds (*Gladiolus, *Hypochaeris).

Vegetation of the Spearwood dune system, sand surface type

As noted above the dividing line between the sand and limestone surfaces of the Spearwood dune system has been taken as the division between heaths or shrublands and woodlands or forests. Most of the woodlands or forests in the Ningana area are dominated by Banksia attenuata and Banksia mensiesii but there are areas dominated by Tuart (Eucalyptus gomphocephala) and a small area of low closed forest dominted by Acacia rostellifera.

Eg Eucalyptus gomphocephala (Tuart) Open Woodland to Woodland

The stand of this unit partly in the study area occurred in a swale with Spearwood sand surrounded by low to moderately tall Quindalup dunes and extended from the swale onto the lower slopes of the dunes.

Photograph eleven: Stand of unit Eg, note the Q2 age Quindalup dune in the background with its low vegetation.

The Tuart was quite tall (10-18 m) but patchy in cover (5-20%). Beneath it there was an open layer of Banksia attenuata (1.3-4(6) m, < 5% to 15% in some patches). The upper shrub layer was also very variable, with patches of Acacia saligna (2-2.5(6) m, 1-20%) and Xanthorrhoea preissii (1.4-3(4+) m, 5-40% in patches) with smaller amounts of Jacksonia furcellata (2-4 m, 1-2%), Dryandra sessilis (2.4 m, < 1%) and Olearia axillaris (1.4-2.4 m, < 1%). The species in the very open lower shrub layer were Phyllanthus calycinus (0.5-1.1 m, 5-10%), Macrozamia reidlei (60 cm, < 1%), Melaleuca acerosa (0.7-1.2 m, < 1%) and small patches of Allocasuarina humilus and Hakea trifurcata. The herb/sedge layer varied, with Lomandra maritima having 5% cover in the bottom of the swale (siliceous sand) and 20% cover on the lower dune slopes (calcareous sand). Other species in the herb/sedge layer were Loxocarya flexuosa (10-25 cm, 20-35%), Conostylis candicans (1-2%), and Carpobrotus virescens (< 1%).

Site 15. Swale. Medium to coarse dull yellow siliceous sand (Spearwood dune sand) in the swale itself and pale grey calcareous sand (Quindalup dune sand) on the lower dune slopes. Condition good to very good with moderate weed infestation (*Avena, *Bromus, *Dischisma).

BaBm Banksia attenuata, Banksia menziesii Low Woodland

This unit is dominated by a mixture of the two Banksia's with Banksia attenuata (2-8 m, 10-15%) somewhat more abundant than Banksia menziesii (2-8 m, 10%). The shrub layer was dominated by Allocasuarina humilus (1-1.5 m, 50%) with other abundant species being Hibbertia hypericoides (30-75 cm, 10-15%), Xanthorrhoea preissii (1-2.5 m, 1-2%), and Hakea russifolia (1-2m, 1-2%). The sedge/herb layer was fairly

open with only two species prominent, Mesomelaena styga (20-50 cm, 5-10(15)%) and Loxocarya flexuosa (20 cm, 5-10%).

Site 18. Subsidiary crest on dune and slopes of dune. Pale yellow siliceous sand, yellow at depth. Condition excellent, with small amounts of very few weeds (*Ursinia, *Hypochaeris, *Romulea and *Gladiolus).

Ar3 Acacia rostellifera low closed forest

One stand of this unit occurs on the north boundary of the study area. It has a dense, tall stand of Acacia rostellifera (4-5 m, 95%) with a small admixture of Banksia attenuata (4-5 m, 2%) and some Hardenbergia comptoniana climbing through it. The understorey is extremely open, with seven perennial species all with less than one percent cover.

Site 20. Very gentle slope (into a stand of Tuart). Pale grey siliceous sand with a thin humus layer, yellow at depth. Very good to excellent condition, some grazing of the understorey.

5.0 CONSERVATION VALUE OF THE NINGANA AREA

5.1 Introduction

The Ningana area undoubtedly has conservation value for flora and vegetation types. The extent of this value is a function of many variables that need to be taken into account when assessing the conservation value of an area for flora and vegetation. These variables are discussed below and then applied to the Ningana area in sections 5.2 and 5.3.

1) the vegetation types and species of flora found there, obviously an area has conservation value for those species or vegetation types that are found within it.

2) how extensive the vegetation type is or how large the population sizes of a species of flora are (both in the area and elsewhere), vegetation types which exist nowhere else or rare flora will be considered to have higher conservation value than vegetation that is extensive or species that are very common over large areas. However it should be noted that this is a human value system that is being applied and that even populations of very common species or stands of common vegetation types still have intrinsic value.

3) their distribution, different vegetation types and individual flora species occur in different ways, for example as single blocks, as part of a recurring pattern or related to a specialised ecological situation such as the strand or wetlands.

4) where in the distribution of the vegetation type or the species the stand or population occurs. It is generally considered important to conserve a vegetation type or species over its range so that a representative sample of the variation is conserved and consequently stands or populations at the ends of the range of a vegetation type or flora species are considered to have higher conservation value.

5) how previous development has effected the extent of a vegetation type or how population sizes of flora species have been reduced by clearing and other development.

6) how well reserved the vegetation types or flora species are in secure conservation reserves. While the conservation value of a particular stand or population is from one point of view an intrinsic value, the percieved need to conserve a particular stand or population (i.e. part of the common useage of the term "conservation value") will vary depending on how well represented the vegetation type or species is in secure conservation reserves.

The factors listed above relate to the value of an area for the conservation of vegetation types or flora species for their continued existence rather than for use by man. An area of land can also have value through the conservation of the vegetation and flora on it from an anthropocentric point of view. For example areas of land with native vegetation in an urban setting offer opportunities for education, enjoyment (bushwalking, observing native flora) and research that would not be possible on areas at a long distance from centres of population because of the distances involved in travel. Kings Park is an excellent example of such a reserve where there is widespread community acceptance that such values exceed the value of the land for development. Another anthropocentric viewpoint is an economic one where conservation value can be understood to exist because of a potential to find value in the flora of an area for economic purposes such as a source of wildflower species for cultivation for export, or as a source of drugs or alternative crops. Such value is extremely difficult to quantify because it is extremely difficult (if not impossible) to forsee the circumstances that will apply in the future to make a particular plant valuable.

Although this section is largely concerned with the conservation value for the protection of flora and vegetation brief comment will be made on the conservation value of the study area from other points of view (see subsections 5.4 & 5.5).

5.2 Conservation value for flora

The Ninŋgana area has particular value for the conservation of the populations of those species known from it that, although not gazetted as rare flora, are either not common or not widespread. These are

Conostylis pauciflora subspecies euryhipis, Stylidium sp. ("maritima"), Leptorhynchos scabrus, Alyogyne huegelii ? var glabrescens and Tetragonia tetragonioides (see section 3.2 for more details on individual species). It also has significant value for the conservation of the species that is at or near the end of its range in the study area this is Stylidium sp. ("maritima").

It also has value for the conservation of the species that do not fall into any of the above categories. Although on an individual basis the value for these species may be smaller than that for the less common species or those at the ends of their range it can still individually be significant and is collectively probably as significant, or more so, than the total value for the special case species (if common species are not adequately protected they will also become rare). For example the Ningana study area has significant value for the conservation of species such as Lomandra maritima and Pimelea ferruginea which are almost entirely restricted to the Quindalup dune system which is not adequately reserved in the metropolitan region (see section 5.3 and section 6).

5.3 Conservation value for vegetation

The Ningana area does not have any vegetation types that are restricted to it however, it contains vegetation types that are restricted to coastal and near coastal areas. These are the vegetation types of the Quindalup dune system and the near coastal variants of the vegetation of the Spearwood dune system. These vegetation types are not adequately reserved.

5.3.1 Conservation value for vegetation of the Quindalup dunes

The vegetation of the Quindalup dune system is moderately well conserved at the extremes of its distribution in Yalgorup National Park (south of Mandurah) and in Nambung National Park and the adjoining Wanagaran Nature Reserve (both north of Lancelin). However, it is not conserved in the middle of its distribution. As a consequence the Ningana area (as well as the nearby Alkimos area and uncleared areas between them and to the north of Ningana) have very significant conservation value for the vegetation of the Quindalup dunes. The degree of this significance is increased by the following points:

1. There are changes in the vegetation of the Quindalup dunes from north to south caused by the gradient of climatic change from north to south over the distribution of the dune systems.

2. Due to the discontinuous distribution of the Quindalup dunes and disturbance by urban development and agriculture there is no significant opportunity to reserve this vegetation complex between the Ningana/Alkimos area and Mandurah.

3. The Quindalup dune system is not represented in Neerabup National Park and there are only a few hectares of the system in Yanchep National Park.

5.3.2 Conservation value for vegetation of the Spearwood dune system

The Spearwood dune system has a similar pattern of distribution to that of the Quindalup dune system, except that it is more continuous and broader. It is generally not well represented in conservation reserves with moderate representation in Yalgorup National Park (south of Mandurah) and poor representation in Nambung National Park and the adjoining Wanagaran Nature Reserve (both north of Lancelin). However, unlike the Quindalup dune system, the Spearwood dune system has significant representation in conservation reserves in the metropolitan area (in Neerabup and Yanchep National Parks and some other smaller conservation reserves). Notwithstanding this latter point, the areas of the Spearwood dunes in the Ningana area (and those in the adjoining uncleared areas and Alkimos area) have significant conservation value. The degree of this significance is increased by the following points:

1. There are changes in the vegetation on this dune system (both the sand and limestone surface types) from north to south and from east to west (Trudgen, 1988, 1987) and the areas of the system in the Ningana area represent the westernmost portion of the system, which is poorly represented in the metropolitan reserves.

2. Even though this system is better represented in reserves in the metropolitan area than the Quindalup system, it is still not well represented and there are very few oppportunities to redress this. (This is also the case to the south of Perth where most of the system has been cleared or very badly degraded.)

3. The vegetation of the Spearwood dunes is more diverse than that of the Quindalup dunes and this means that to adequately conserve this variation larger areas are required.

5.4 Conservation value for protection of landforms

The Ningana area (and adjoining areas) also has value for the conservation of landforms. It includes a relatively undisturbed beach, several ages of Quindalup dunes and areas of the limestone and sand surfaces (including several of the units of McArthur and Bartle 1980) of the Spearwood dune system in a relatively small area. In a similar fashion to the vegetation and flora of the Quindalup dunes these features are in conservation reserves towards the limits of their distribution but are not adequately reserved in the centre of their range.

5.5 Value for education and research

The study area has considerable potential value for educational use, for example:

- the study of the succession of the plants from the shore through the heaths of the Quindalup dunes to the woodlands and forests of the Spearwood dunes.
- the relationship of the different vegetation types developed to the soils that they grow on.
- the geomorphological processes that led to the formation of the dune systems.

These could be studied at various levels of understanding from primary school throught to university study.

Similarly the area has potential for research into a variety of aspects of its botany and geomorphology, for example:

- the role of different factors such as fire and soil nutrients in the development of the different vegetation types found in the study area.

- the taxonomy of the less well known species found in the area.

- the ecological adaptation of the dune species to their environment and the dynamics of their populations.

- the development of the Quindalup dunes and the climatic conditions (much more arid than today) that prevailed when the older ones developed.

6.0 REGIONAL CONSERVATION ISSUES AFFECTING THE CONSERVATION VALUE OF THE NINGANA AREA

The regional conservation issues affecting the Ningana area are:

1) the very extensive clearing of the native vegetation of the Swan Coastal Plain on which the Ningana area occurs.

Beard and Sprenger (1984) gives figures for alienation (which they equate with clearing, although there are remnants in private ownership) of the Plain as 78% overall, with south of Perth virtually 100%. This means that many species of plants found on the Plain have had their populations and ranges decimated and many vegetation types have been lost or reduced to fragentary remains, particularly south of Perth. It also means that the areas of vegetation remaining have greatly increased significance for conservation because of the reduced opportunities for conservation. It should be noted that Beard and Sprenger's figures are now six years old and that some of the data (particularly aerial photography) they were based on could be older than that.

2) the low reservation in the metropolitan area of areas of native vegetation.

Significant areas have been recommended for reservation as reserves and regional parks in the areas surrounding Perth through the "System Six" process (EPA 1983). However, many of these have not been implemented, including a significant number of proposed reserves that have unfortunately been cleared or degraded. The result is that there are relatively few secure conservation areas within the urbanised zone. Ningana is currently at the fringe of the urbanised zone and is likely to be within it within the reasonably near future. It does have the advantage of being close to both Neerabup and Yanchep National Parks but, as noted above, has complimentary conservation values.

3) the desirability of connecting Yanchep National Park to the coast.

There is no significant reservation (for conservation) of the Quindalup dune system in the metropolitan region and in fact no significant reservation of a coastal area. Connecting Yanchep to the coast is one of the few options for remedying this and would have the advantage of conserving a continuous sequence of the Quindalup and Spearwood

dune systems, through adding areas of the Quindalup dunes and more westerly variants of the Spearwood dunes to the areas of Spearwood dunes already in Yanchep.

4) the desirability of improving the boundary to area ratio of Neerabup National Park and providing a corridor of native vegetation linking it to Yanchep National Park.

Neerabup National Park has an attenuated shape that is undesirable because it potentially reduces the effectiveness of the reserve for the protection of the vegetation types and flora species found in it, complicating and making management more exspensive. Consequently it is desirable to improve the boundary to area ratio of the park by making additions to it. It is also desirable to provide protection for the corridor of vegetation that exists between Yanchep and Neerabup National Parks so that the animal populations found in them do not become isolated from each other.

7.0 INTEGRATING MAINTENANCE OF CONSERVATION VALUE WITH DEVELOPMENT

Introduction

There are practical limits to the successful integration of development and conservation as development brings with it not only the removal of the vegetation of the areas actually developed but, also disturbance to adjoining areas (both during and after the actual development) this includes:

- physical disturbance by vehicles, including earthworking vehicles as well as cars and trucks

- the introduction of weeds, resulting in displacement of native species and changes to vegetation structure (and often increased flamability).

- changes to fire regimes (usually in Western Australia this means increased frequency of fire to protect valuable property such as buildings but arson can also be a problem) which results in changes to species composition and in time degradation of the vegetation

- changes to other environmental parameters caused by activities associated with the development can also affect the vegetation and flora. For example: increases in nutrient levels through the use of fertilisers in areas with very nutrient deficient soils such as the Quindalup dune system could result in significant changes in species composition and could very significantly increase the degree of weed invasion; drawdown of water tables can lead to the death of some species, as can increases in water tables caused by clearing of vegetation.

Integration of maintenance of conservation values with a development

The most obvious step in integrating development with the maintence of the conservation values found in the Ningana study area would be to confine as much as possible of the development to those areas that are currently either cleared or badly disturbed. Complimentary to this would be a management plan designed to maintain the condition of the areas of native vegetation. The management plan would:

- designate areas to remain free of development (protected zones).

- designate areas where further development would be allowed and the scale and type of further developments allowed.

- contain prescriptions for routine management procedures such as fire regimes, wildfire fighting procedures, weed control, access control, allowable uses and rehabilitation procedures to be used for areas within protected zones that have been disturbed.

The management plan would have to have some form of security to ensure its effectiveness, otherwise a situation would develop where the plan would exist but a lack of committment to it would lead to the gradual deterioration of the environmental quality it would seek to protect. A form of regular monitoring of adherence to the management plan would be ideal with assistance from an appropriate government department such as the department of Conservation and Land Management to provide biological expertise.

Such a degree of integration of development with the protection of the environment would make a significant contribution to the conservation of flora species and vegetation types. It would also mean that the development (say medium density housing) would be within areas of relatively undisturbed native vegetation of sufficient size and diversity to provide significant recreational opportunities and a positive impact on lifestyle.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

- the Ningna area and adjoining uncleared areas have considerable conservation value for flora, vegetation and geomorphological types (it is beyond the scope of this report to comment on any value for fauna).

- this value has not previously been recognised because of inadequate knowledge of the flora and vegetation of the Swan Coastal Plain, although in a general sense it has been well known (to biologists) that the coastal zone flora and vegetation is inadequately represented in conservation reserves.

- the protection, or realisation, of these values has not occurred because of inadequate weighting for biological conservation in the planning of the development of the Perth metropolitan area and the inadequacy of the "System Six" report (EPA 1980) as a basis for biological conservation in the metropolitan area.

8.2 Recommendations

- Landcorp should accept that there are unresolved regional conservation issues affecting the Ningana area and adjoining areas.

- before proceeding with development at Ningana, Landcorp should encourage the resolution of these issues through initiating discussions with appropriate Government Departments including the Department of Planning and Urban Development and the Department of Conservation and Land Management.

- if the conservation problems identified in this report (including the protection of the less common species, particularly Stylidium sp. "maritima") can not be adequately adequately resolved through reservation outside the Ningana area, then adequate reservation for the protection of flora and vegetation should be made within the Ningana area. Given the scale of the problems this would require a substantial portion of the area, which should include the population of ghe Stylidium and representative areas of the Quindalup and Spearwood dune systems.

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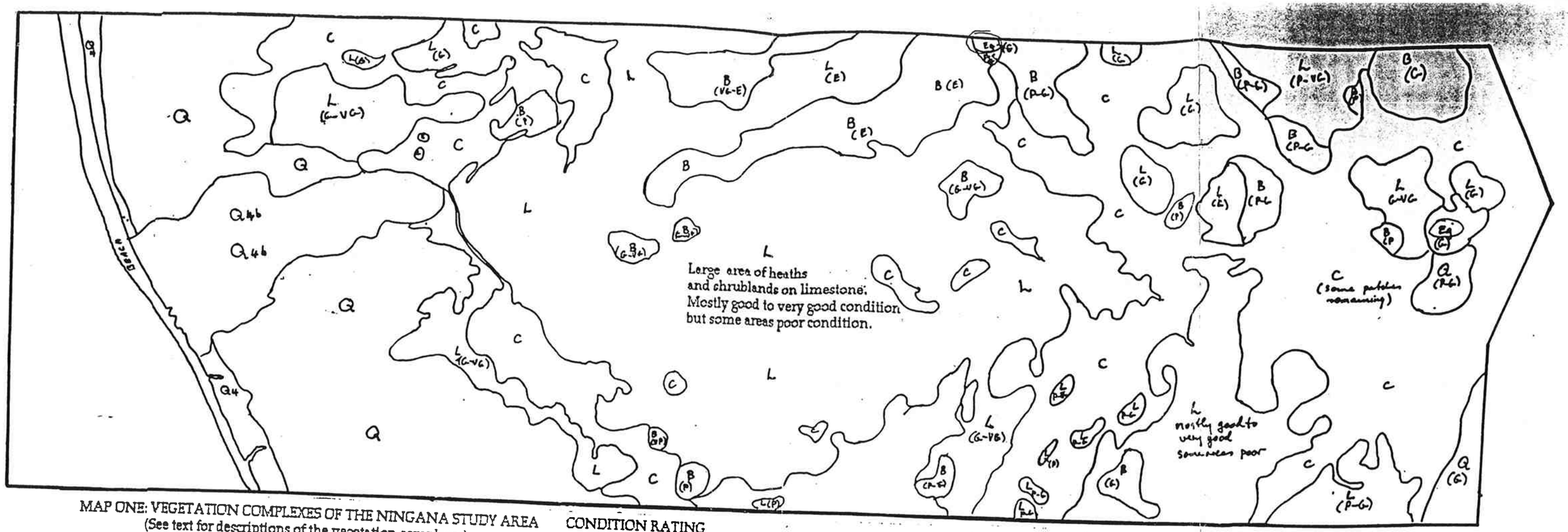

MAP ONE: VEGETATION COMPLEXES OF THE NINGANA STUDY AREA
(See text for descriptions of the vegetation complexes)

Scale: 1:10,000

Quindalup dunes

- Q4 = Vegetation of the Q4 age Quindalup dunes
- Q4b = Vegetation of the Q4 age stabilised blowout
- Q = Vegetation of the Q1, Q2, Q3 age Quindalup dunes

Sand surface of the Spearwood dunes

- B = Banksia low woodlands
- Eg = Tuart (Eucalyptus gomphocephala) open woodland
- Ar = Acacia rostellifera low closed woodland

Limestone surface of the Spearwood dunes

- L = heaths and shrublands found on the limestone

CONDITION RATING

- E = Excellent
- VG = Very good
- G = Good
- P = Poor
- VP = Very poor
- C = totally cleared or with scattered shrubs remaining

Appendix 1 (Modified)

FLORA LIST COASTAL AREAS IN FROM BRETON BAY TO BUNBURY

This list includes comparitvie information from a series of reports, the first two were included in the original report but also included is the flora information from a subsequent report: A report on the flora and vegetation of areas at Wilbinga and Breton Bay proposed as alternatives for a future industrial site Trudgen, Griffin and Keighery 1990.

Species recorded from the

- Leschenault Peninsula (Trudgen 1984), indicated by the letters LP
- the coast of the Shire of Mandurah (Trudgen 1991), indicated by the letter MC
- Alkimos and Ningana (Trudgen, 1990), indicated by the letters A and N respectively.
- Wilbingia, core and buffer areas are indicated by the letters, Wc and Wb
- Breton Bay, core and buffer areas are indicated by the letters Bb and Bc

PTERIDOPHYTA (ferns)

DENNSTAEDTIACEAE

Pteridium aquilinum	LP			

GYMNOPHYTA

ZAMIACEAE

Macrozamia reidlei		MC	A/N	Wb,Wc/Bb, Bc

ANGIOSPERMAE (flowering plants)

MONOCOTYLEDONS

RUPPIACEAE

Ruppia megacarpa	LP			

JUNCAGINACEAE

Triglochin calcitrapa	LP			Wb /Bb
Triglochin centrocarpa		MC		
Triglochin mucronata	LP	MC		
Triglochin striata	LP			
Triglochin trichophora	LP			Bb,Bc

POACEAE

*Agropyron racemosum			A/N	- -
*Aira caryophyllea	LP			
*Aira cupaniana			A/N	
*Ammophila arenaria	LP	MC		
Amphipogon turbinatus			A/N	Wb,Wc
Arundo donax	LP			
*Avena fatua	LP	MC	A/N	
*Briza maxima	LP		A/N	Wb,Wc
*Briza minor	LP		A/N	
*Bromus madritensis		MC		
*Bromus diandrus			A/N	Wc
*Catapodium ridgidum			A/N	
*Cynodon dactlyon	LP			
Danthonia acerosa			A/N	
Danthonia caespitosa			A/N	
Danthonia setacea		MC		

Danthonia occidentalis.			A/N	
*Ehrharta calycina			A/N	
*Ehrharta longiflora	LP	MC	A/N	
*Lolium multiflora		MC		
Microlaena stipoides			N	
Neurachne alopecuroidea				Wb
*Poa annua	LP			
Poa drummondiana	LP	MC	A/N	
Poa porphyrocladus			A/N	Bc
Poa poiformis		MC		
Poa sp				Bc
Spinifex hirsutus	LP	MC	A/N	Wb,Wc
Spinifex longifolius	LP	MC	A/N	Wb,Wc/Bb,Bc
Sporobolus virginicus		MC		Bc
Stipa campylachne		MC		
Stipa compressa		MC	A/N	
Stipa flavescens		MC	A/N	Wb,Wc
Stipa ? variabilis	LP	MC		
*Vulpia membranacea		MC		Wb,Wc
*Vulpia myuros	LP			
CYPERACEAE				
Baumea juncea	LP	MC	N	Wb
Bulboschoenus caldwelli	LP	MC		
Caustis dioica				Wb
Carex preissii	LP	MC	N	
*Cyperus laevigatus		MC		
Cyperus tenellus	LP			
Cyperus tenuiflorus	LP			
Gahnia trifida	LP	MC		
Isolepis cernua			A/N	Wb,Wc/Bb,Bc
Isolepis marginata		MC		
Isolepis nodosa	LP	MC	A/N	Wb,Wc/Bb,Bc
Isolepis sp.	LP			
Lepidosperma angustatum	LP	MC		Wb,Wc/Bb,Bc
Lepidosperma costale			A	
Lepidosperma ? costale		MC		
Lepisosperma gladiatum	LP	MC	A/N	Wb,Wc/Bb,Bc
Lepidosperma ? gracile		MC		
Lepidosperma longitudinale	LP			
Lepidosperma squamatum			A	
Lepidosperma scabrum			A	Wb
Lepidosperma sp. (B)		MC		
Schoenus clandestinius			A	?Wc
Mesomelaena stygia			A/N	Wb,Wc/Bb,Bc
Schoenus curviflorus		MC.	A	Wb,Wc
Schoenus grandiflorus		MC	A/N	Wb,Wc/Bb,Bc
Schoenus lanatus		MC		
Schoenus latitans				Wb
Schoenus nanus		MC		
Scoenus pedicellatus				Wb
Schoenus subbartus			A/N	
Schoenus sp.		MC		
Schoenus sp.		MC		

?Tetraria octandra				Wc
ARACEAE				
*Zantedeschia aethiopica	LP			
RESTIONACEAE				
Alexgeorgia nitens			A	Wb
Hypolaena exsulca			A	?Wb
Lepidobolus chaetocephalus				Wb,Wc/Bb
Loxocarya cinerea		MC		
Loxocarya flexuosa		MC	A/N	Wb,Wc/Bb,Bc
Loxocarya pubescens	LP			
Loxocarya sp. (B)		MC		
Loxocarya sp.				Wb
Lyginia barbarta		MC	A	Wb
Restio scariosus		MC	(male & female)	
Restio sp				Wb
CENTROLEPIDACEAE				
Centrolepis drummondii	LP	MC	N	
JUNCACEAE				
*Juncus bufonius	LP			
Juncus kraussii ssp. australis	LP	MC		
Luzula meridionalis		MC		
DASYPOGONACEAE				
Acanthocarpus preissi	LP	MC	A/N	Wb,Wc/Bb,Bc
Calectasia cyanea		MC		
Lomandra caespitosa			A	Wb
Lomandra hermaphrodita				Wb
Lomandra maritima		MC	A/N	Wb,Wc/Bb,Bc
Lomandra micrantha		MC		
Lomandra purpurea		MC		
Lomandra ?sericea				Wb
Lomandra suaveolens		MC	A	?W
Lomandra sp.	LP			
XANTHORRHOEACEAE				
Xanthorrhoea brunonis ssp. semibarbata		MC		
Xanthorrhoea preissii		MC	A/N	Wb,Wc/Bb,Bc
PHORMIACEAE				
Dianella divaricata		MC	A/N	Wb,Wc/Bb,Bc
ANTHERICAEAE				
Arthropodium capillipes		MC		
Caesia parviflora		MC		
Chamaescilla corymbosa		MC		
Corynotheca micrantha		MC	A/N	Wb,Wc/Bb,Bc
Laxmania sessiliflora ssp australis			A	
Sowerbaea laxiflora		MC	A/N	Wb,Wc/Bb,Bc
Thysanotus arenarius	LP	MC	A/N	Wb,Wc/Bb,Bc

Thysanotus patersonii	LP	MC	A/N	Wb,Wc/Bb,Bc
Thysanotus sparteus		MC		
Thysanotus triandrus			A/N	
Tricoryne elatior	LP	MC	A/N	Wc /Bb,Bc

ASPHODELACEAE

*Asphodelus fistulosus	LP (probably a mis-identification of Trachyandra divaricata)			
Bulbine semibarbarta	LP			
*Trachyandra divaricata		MC	A/N	Wb,Wc/Bb,Bc

COLCHICACEAE

Burchardia umbellata		MC	A/N	Wb
Wurmbea monantha	LP	MC		
Wurmbea pygmaea		MC		

HAEMODORACEAE

Anigozanthos humilis		MC	A	Wb,Wc/Bb,Bc
Anigozanthos manglesii		MC	A/N	Wb,Wc/Bb,Bc
Conostylis aculeata ssp. aculeata	LP	MC	A/N	
Conostylis bracteata				Wb
Conostylis candicans ssp. calcicola		MC	A/N	
Conostylis pauciflora ssp euryhipis		MC	A/N	Wc/Bb,Bc
Conostylis teretifolia ssp planescens		A	Wb,Wc/Bb,Bc	
Conostylis pauciflora X candicans		MC		
Conostylis bracteata X candicans		Wb,Wc		
Haemodorum laxum			A	Wb
Haemodorum spicatum			A	
Haemodorum paniculatum			A/N	

IRIDACEAE

*Gladiolus cayophyllaceus		MC	A/N	Bb,Bc
Orthrosanthos laxus		MC	A	Bb
Patersonia occidentalis		MC		Wb,Wc
*Romulea rosea			A/N	

ORCHIDACEAE

Acianthus reniformis var. huegelii	MC			
Caladenia exilis (MS name of S. Hopper)		MC		
Caladenia flava		MC		Bb,Bc
Caladenia latifolia	LP	MC		Wc/Bb,Bc
Caladenia longicauda		MC		Wb,Wc
Caladenia menziesii	LP	MC		
Caladenia pectinata		MC		
Diuris longifolia				Wb,Wc
Elythranthera brunonis		MC		
Eriochilus dilatatus	LP	MC		
Lypreanthus nigicans				Wb
Microtis unifolia			A/N	
Microtis sp. (material inadequate)		MC		
Prasophyllum elatum		MC		
Prasophyllum giganteum		MC		
Prasophyllum hians		MC		
Prasophyllum macrostachyum ssp. nov.		MC		

Pterostylis vittata		MC		Bc

DICOTYLEDONS

URTICACEAE				
Parietaria debilis	LP	MC	A/N	
CASUARINACEAE				
Allocasuarina fraseriana		MC	A/N	Wb
Allocasuarina humilis		MC	A/N	Wb,Wc/Bb,Bc
Allocasuarina lehmanniana				Wb
Casuarina obesa		MC		
PROTEACEAE				
Adenanthos cygnorum			N	(only one plant seen)
Banksia attenuata		MC	A/N	Wb,Wc/Bb,Bc
Banksia grandis		MC	A/N	Wb
Banksia ilicifolia				Wb
Banksia leptophylla				Bb
Banksia littoralis		MC		
Banksia menziesii			A/N	Wb,Wc/Bb,Bc
Banksia prionotes				Wb, /Bb,Bc
Conospermum incurvum				Wb
Conespermum stoechadis				Wb,Wc/Bb,Bc
Conospermum triplinervium		MC	A/N	Wb,Wc
Dryandra nivea		MC	A/N	Wb,Wc/Bb,Bc
Dryandra sessilis	LP	MC	A/N	Wb,Wc/Bb,Bc
Grevillea crithmifolia		MC		Wb,Wc
Grevillea thelemanniana		MC	A/N	Wb,Wc/Bb,Bc
Grevillea vestita		MC	A/N	? Wc/Bb,Bc
Hakea costata			A/N	Wb,Wc/Bb,Bc
Hakea lissocarpha		MC	A/N	Wb,Wc/Bb,Bc
Hakea prostrata	LP	MC	A/N	Wb,Wc/Bb,Bc
Hakea ruscifolia		MC	A/N	Wb,Wc/Bb,Bc
Hakea trifurcata		MC	A/N	Wb,Wc/Bb,Bc
Hakes undulata				Bb
Hakea varia		MC		
Persoonia comata			A/N	Wb,Wc
Persoonia saccata		MC		
Petrophile brevifolia			A	Wb,Wc/Bb,Bc
Petrophile linearis		MC	A	Wb,Wc
Petrophile macrostachya			A/N	Wb,Wc/Bb,Bc
Petrophile serruriae		MC	A/N	Wb,Wc/Bb,Bc
Stirlingia latifolia		MC	A	Wb,Wc
Synaphea spinulosa		MC		Wb,Wc/Bb,Bc
SANTALACEAE				
Exocarpos sparteus	LP	MC	A/N	Wb,Wc/Bb,Bc
Leptomeria empetriformis		MC		Wb,Wc/Bb
Leptomeria lehmanii		MC		
Leptomeria preissiana			N	
Leptomeria spinosa			N	
Santalum acuminatum	LP	MC		Wb,Wc/Bb,Bc

OLACACEAE				
Olax benthamiana				Wc
LORANTHACEAE				
Amyema miquelii		MC		
Nuytsuia floribunda		MC	A/N	Wb,Wc/Bb,Bc
POLYGONACEAE				
*Emex australia	LP	MC		
CHENOPODIACEAE				
Atriplex cinerea		MC		
Atriplex hypoleuca	LP	MC		
Enchylaena tomentosa				Wb,Wc/ Bc
Halosarcia indica ssp. bidens	LP	MC		
Halosarcia halocnemoides ssp halocnemoides	LP	MC		
Halosarcia syncarpa		MC		
Rhagodia baccata	LP	MC	A/N	Wb,Wc/Bb,Bc
Salsola kali		MC		
Sarcocornia blackiana		MC		
Sarcocornia quinqueflora	LP	MC		
Sarcocornia ?quinqueflora				Bc
Suaeda australis	LP	MC		
Threlkedia diffusa	LP	MC		?W
AMARANTHACEAE				
Ptilotus drummondii		MC		
Ptilotus polystachyus			A	Bb
Ptilotus manglesii				Wb
Ptilotus stirlingii			A/N	
GYROSTEMONACEAE				
Tersonia cyathifolia		MC		Wb,Wc/Bb,Bc
AIZOACEAE				
*Carpobrotus edulis			A/N	Wb,Wc/Bb,Bc
Carpobrotus virescens	LP	MC	A/N	
*Tetragonia decumbens	LP	MC	A/N	Wb,Wc/Bb,Bc
Tetragonia implexicoma		MC		
Tetragonia tetrgoniodes			N	
Threkeldia diffusa			A	
MOLLUGINACEAE				
Macarthuria australis				Wb,Wc
PORTULACACEAE				
Calandrinia brevipedata	LP			Wb,Wc/ Bc
Calandrinia calyptrata	LP	MC		
Calandrinia corrigiogloides		MC		Wb,Wc/Bb,Bc
Calandrinia granulifera				Wb,Wc
Calandrinia liniflora		MC ?	A/N	Bc

CARYOPHYLLACEAE					
*Cerastium ? diffusum		LP			? Wc
*Cerastium glomeratum					Bb,Bc
*Petrohagia velutina		LP		A/N	
*Polycarpon tetraphyllum		LP			
*Silene nocturna			MC		
RANUNCULACEAE					
Clematis microphylla		LP	MC	A/N	Wc
Clematis pubescens			MC		
Ranunculus colonorum		LP	MC		
*Ranunculus muricatus		LP	MC		
LAURACEAE					
Cassytha flava				A/N	
Cassytha glabella			MC	N	Wc/Bb
Cassytha pomiformis				N	
Cassytha racemosa		LP	MC	A/N	Wb,Wc/Bb,Bc
FUMARIACEAE					
*Fumaria capreolata		LP			
BRASSICACEAE					
*Brassica tournefortii	LP	MC			
*Cakile maritima	LP	MC	A/N	Wb,Wc	
*Heliophila pusilla		MC	A/N	Wb	/Bb,bc
*Lepidium bonariense			N		
Stenopetalum lineare	LP (probably misidentificaion of S. robustum)				
Stenopetalum gracilis (previously S. robustum)	MC				
DROSERACEAE					
Drosera erythorrhiza		MC		Wb,Wc/Bb,Bc	
Drosera glandulifera		MC		Wb	
Drosera macrantha		MC		Wb,Wc/Bb,Bc	
Drosera pallida		MC	A		
Drosera stolonifera		MC			
CRASSULACEAE					
Crassula colorata	LP	MC	A/N	Wb,Wc/Bb,Bc	
*Crassula decumbems		MC			
Crassula exserta			A/N		
*Crassula glomerata		MC	A/N	Wb	/Bb,Bc
Crassula natans	LP			Wc	
Crassula pedicellosa	LP			Wb	
PITTOSPORACEAE					
Billardiera variifolia		MC			
Pittosporum phylliraeoides var. phylliraeoides	LP	MC			
?Pronaya fraseri			N	Wc	
MIMOSACEAE					
Acacia alata				Wc	

Acacia cochlearis	LP	MC	A/N	Wb /Bb,Bc
Acacia cyclops	LP	MC	A/N	Wb,Wc/Bb,Bc
Acacia huegelii			A	
Acacia idiomorpha				Bc
Acacia lasiocarpa var. lasiocarpa	LP	MC	A/N	Wb,Wc/Bb,Bc
Acacia pulchella var. glaberrima		MC	A/N	Wb,Wc
Acacia pulchella var. pulchella		MC		Bc
Acacia rostellifera	LP	MC	A/N	Wb,Wc/Bb,Bc
Acacia saligna	LP	MC	A/N	
Acacia sessilis				Wb /Bb
Acacia spathulifolia				Bb
Acacia truncata		MC	A/N	Wb,Wc/Bb,Bc
Acacia wildenowiana		MC		
Acacia xanthina				Bb,Bc
Acacia rostellifera x saligna			A	

PAPILIONACEAE

Bossiaea eriocarpa		MC	A/N	Wb,Wc/Bb,Bc
Burtonia conferta		MC		
Chorizema varium				Bb
Daviesia divaricata		MC	N	Wb,Wc/Bb,Bc
Daviesia decurrens		MC		Wb,Wc/Bb,Bc
Daviesia nudiflora				Wb
Daviesia physodes		MC		
(D. pectinata = D. decurrens)				
Gompholobium tomentosum		MC	A/N	Wb,Wc/Bb,Bc
Hardenbergia comptoniana	LP	MC	A/N	Wb,Wc/Bb,Bc
Hovea pungens		MC		Wb,Wc/Bb,Bc
Hovea trisperma		MC	A/N	Wb,Wc
Isotropis cuneifolia		MC	A	Wb,Wc
Jacksonia furcellata	LP	MC	A/N	Wb
Jacksonia sternbergiana		MC	A/N	WB,Wc
Jacksonia stricta			A/N	Wb,Wc/Bb,Bc
Kennedia coccinea	LP	MC		
Kennedia prostrata		MC	A/N	Wb,Wc/Bb,Bc
*Medicago ? lupulina	LP			
*Medicago polymorpha			A/N	
*Meliotis indica			A/N	
Merbelia spinosa				Bb,Bc
Nemcia reticulatum		MC	A/N	Wb,Wc/Bb,Bc
(Oxylobium reticulatum = Nemcia reticulatum)				
Sphaerolobium medium				Wb,Wc/Bb,Bc
Sphaerolobium ?medium			A/N	
Sphaerolobium aff. macranthum		MC		
Templetonia retusa	LP	MC	A/N	Wb,Wc/Bb,Bc
*Trifolium campestre			A/N	

GERANIACEAE

*Erodium cicutarium	LP	MC		Wb,Wc/Bb,Bc
*Geranium molle	LP (poss. misid. G. solanderi)N			
Geranium solanderi		MC	A/N	
*Pelargonium capitatum	LP	MC	A/N	
Pelargonium littorale		MC	A	

OXALIDACEAE				
*Oxalis corniculata	LP			
*Oxalis pes-caprae	LP			
ZYGOPHYLLACEAE				
Zygophyllum fruticulosum	LP	MC		Bc
Zygophyllum simile		MC		
RUTACEAE				
Boronia alata		MC		
Boronia crenulata		MC		
Boronia ramosa				
Diplolaena dampieri	LP	MC		
Dipolaena microcephala (? relationship to var. drummondii)				
Dilolaena micrcephala var microcephala				Wc/Bb,Bc
Eriostemon spicatus		MC		Wb,Wc/Bb,Bc
POLYGALACEAE				
Comesperma calymega			A	
Comesperma confertum		MC		
Comesperma integerrimum			A/N	Wc
Comesperma virgatum		MC		Wc/Bb,Bc
Comesperma volubile		MC	A	
EUPHORBIACEAE				
Adriana quadripartita	LP	MC	A/N	Bb,Bc
*Euphorbia peplus	LP	MC		Bb,Bc
*Euphorbia terracina			N	
Phyllanthus calycinus	LP	MC	A/N	Wb,Wc/Bb,Bc
Poranthera microphylla	LP	MC		Wc/Bb
Ricinocarpos glaucus		MC	A	Bb,Bc
STACKHOUSIACEAE				
(Stackhousia huegelii = Stackhousia monogyna				
Stackhousia monogyna			A/N	Wb,Wc/Bb
Triterococcus brunonis				Wb,Wc
SAPINDACEAE				
Dodonaea aptera			A	Wb,Wc/Bb,Bc
Dodonaea ?		MC		
Diplopeltis huegelii		MC	N	Wb /Bb,Bc
MALVACEAE				
Alyogyne huegelii		MC		
? var.glabresens			N	Wb,Wc/Bb,Bc
RHAMNACEAE				
Cryptandra arbutiflora		MC		
Cryptandra mutila		MC	N	Wb,Wc/Bb,Bc
Cryptandra pungens			A	Wc/Bb
Spyridium globulosum	LP	MC	A/N	Wb,Wc/Bb,Bc
Spyridium tridentatum			A/N	Bb,Bc
Trymalium albicans		MC	A/N	Wb,Wc/Bb,Bc

STERCULIACEAE					
Guichenotia ledifolia	LP	MC			
Thomasia cognata	LP	MC	A/N		
Thomasia triphylla		MC	A	Wb,Wc/Bb,Bc	
Lasiopetalum membranaceum		MC			
DILLENIACEAE					
Hibbertia acerosa		MC		Wc	
Hibbertia cuneiformis	LP	MC			
Hibbertia huegelii				Wb	
Hibbertia hypericoides		MC	A/N	Wb,Wc/Bb,Bc	
Hibbertia racemosa		MC	A/N	Wb,Wc/Bb,Bc	
Hibbertia spicata ssp leptotheca			A	Wb,Wc/Bb	
FRANKENIACEAE					
Frankenia pauciflora		MC			Bc
VIOLACEAE					
Hybanthus calycinus		MC	A	Wb,Wc/Bb,Bc	
THYMELAEACEAE					
Pimelea argentea		MC		Wb	
Pimelea calcicola		MC	A	Wb,Wc/Bb,Bc	
Pimelea ferruginea		MC	A/N	Wb,Wc/Bb,Bc	
Pimelea gilgiana				Wb,Wc/Bb,Bc	
Pimelea rosea		MC			
Pimelea sulphurea				Wb	
MYRTACEAE.					
Agonis flexuosa	LP	MC			
Baeckea robusta				Wb	
Calothamnus quadrifidus			A/N		
Calothamnus sanguinieus					
Calytrix angulata			A	Wb	
Calytrix sp					Bb
Chamelaucium uncinatum				Wb,Wc/Bb,Bc	
Eremaea pauciflora			A	Wb	
Ereama sp				Wb,Wc	
Eucalyptus calophylla		MC			
Eucalyptus decipiens		MC	A	Wb,Wc/Bb,Bc	
Eucalyptus foecunda		MC		Wb /?B	
Eucalyptus gomphocephala	LP	MC	A/N	Wb,Wc/Bb,Bc	
Eucalyptus marginata		MC	A/N	Wb	
Eucalyptus rudis		MC			
Eucalyptus todtiana			A	Wb,Wc/Bb,Bc	
Eucalyptus sp,(Yanchep) M.I.H. Brooker		8608			Bb
Eucalyptus "petrensis"				Bb	
Hypocalymma robustum		MC			
Kunzea ericifolia				Wb	
Leptospermum spinescens			A/N	Wb,Wc/Bb,Bc	
Leptospermum oligandrum				Wb	
Melaleuca acerosa		MC	A/N	Wb,Wc/Bb,Bc	
Melaleuca cardiophylla			A/N	Wb,Wc/Bb,Bc	

Melaleuca cuticularis	LP	MC		
Melaleuca aff. hamulosa	LP			
Melaleuca huegelii		MC	A/N	Wb,Wc/Bb,Bc
Melaleuca scabra				Wb
Melaleuca rhaphiophylla	LP	MC		
Melaleuca trichophylla			A	
Melaleuca thymoides		MC		
Melaleuca uncinata		MC		
Melaleuca viminea		MC		
Scholtzia laxiflora				Wb,Wc
Verticordia ?penigera				Bb

ONAGRACEAE

Epilobium billardierianum		MC		
*Oenothera drummondii		MC		

HALORAGACEAE

Haloragis sp				Wc

APIACEAE

Apium annuum	LP			
Apium prostratum ssp. prostratum var. prostratum			MC	
Centella asiatica	LP	MC		
Daucus glochidiatus	LP	MC	A/N	Wb,Wc/Bb,Bc
Eringium pinnatifidum		MC	N	
Homalosciadum homalocarpum		MC	A/N	
Hydrocotyle blepharocarpa		MC		Bb,Bc
Hydrocotyle diantha	LP			Wc
Hydrocotyle ? hispidula	LP			
Hydrocoyyle pilifera				Bb
Hydrocotyle tetragonocarpa	LP	MC		Wc
Platysace sp.		MC		
Trachymene caerulea	LP	MC		Wb
Trachymene pilosa	LP	MC	A/N	Wb,Wc/Bb,Bc
Trachymene sp				Bb,Bc
Xanthosia huegelii			A	
Xanthosia pusilla		MC		

EPACRIDACEAE

Acrotriche cordata		MC	A/N	Wb,Wc
Astroloma ciliatum		MC		Wc
Astroloma microcalyx		MC		Wb,Wc
Astroloma pallidum		MC	A/N	Wb,Wc/Bb
Astroloma sp.		MC		Wb,Wc
Conostephium pendulum			A	Wb
Conostephium preissii		MC		
Leucopogon insularis			A	
Leucopogon parviflorus	LP	MC	A/N	Wb,Wc/Bb,Bc
Leucopogon polymorphus		MC	A/N	Wb,Wc/Bb,Bc
Leucopogpn aff.polymorphus			A/N	
Leucopogon propinquus		MC	A/N	Wb,Wc/Bb,Bc
Leucopogon racemulosus		MC		
Leucopogon sp				Wc

Lysinema ciliatum		MC	N	Wb,Wc/Bb,Bc
PRIMULACEAE				
*Anagallis arvensis	LP	MC	A/N	Wb,Wc/Bb,Bc
Samolus junceus		MC		
Samolus repens	LP	MC		
GENTIANACEAE				
*Centaurium erythraea			A/N	
LOGANIACEAE				
Logania vaginalis	LP	MC		
Mitrasacme paradoxa		MC		Bb,Bc
APOCYNACEAE				
Alyxia buxifolia	LP	MC		
CONVOLVULACEAE				
*Convolvulus arvensis	LP			
*Cuscuta epithymum		MC		
Dichondra repens	LP	MC		
Wilsonia backhousei		MC		
Wilsonia humilus		MC		
AVICENNIACEAE				
Avicennia marina	LP			
LAMIACEAE				
Hemiandra pungens	LP	MC	A/N	Wb,Wc/Bb,Bc
Westringia dampieri				Wc
SOLANACEAE				
Anthocercis ilicifolia ssp. ilicifolia		MC		Wb,Wc/Bb,Bc
Anthocercis littorea	LP	MC	A/N	Wb,Wc
*Solanum nigrum	LP	MC	A/N	Wb,Wc
Solanum simile	LP			
*Solanum sodomaeum		MC	A/N	Wb,Wc
Solanum symonii		MC		
SCROPHULARIACEAE				
*Bellardia trixago	LP	MC		
*Dischisma arenarium	LP	MC	A/N	Wb,Wc/Bb,Bc
*Parentucellia latifolia		MC		Bb
Veronica aff.calycina		MC	A	
OROBANCHACEAE				
Orobanche australiana	LP (Probably mis-identification of O. minor)			
*Orobanche minor		MC	N	
MYOPORACEAE				
Eremophila glabra	LP	MC	N	Wb,Wc/Bb,Bc
Myoporum caprarioides		MC		
Myoporum insulare	LP	MC	A/N	Wb,Wc/Bb,Bc

Myoporum tetrandrum	LP (Probably mis-identification of E. caprarioides)				
PLANTAGINACEAE					
Plantago exilis		MC			
* Plantago lanceolata	LP				
Plantago sp					Bb,Bc
RUBIACEAE					
* Galium murale	LP				Bb
Galium sp.	LP				
Opercularia hispidula		MC			
Opercularia vaginata	L	MC	A/N	Wb,Wc/Bb,Bc	
* Sherardia arvensis	LP				
CUCURBITACEAE					
*Cucurbita pepo			N	Wb,Wc	
CAMPANULACEAE					
*Wahlenbergia capensis			A		Bb
Wahlenbergia ? gracilenta		MC			
LOBELIACEAE					
Grammatotheca bergiana	LP				
Lobelia alata	LP	MC			
Lobelia heterophylla			N		
Lobelia ? heterophylla	LP				
Lobelia tenuior		MC	A/N		
Isotoma hypocrateriformis		MC	A/N		Bc
GOODENIACEAE					
Dampiera linearis		MC		Wb,Wc/Bb,Bc	
Lechenaultia linarioides			A/N	Wc	
Scaevola canescens		MC	A/N	Wb,Wc/Bb,Bc	
Scaevola crassifolia	LP	MC	A/N	Wb,Wc/Bb,Bc	
Scaevola globulifera		MC			
Scaevola holosericea		MC	N		
Scaevola paludosa			A	Wb,Wc	
Scaevola phlebopetala					Bb - -
Scaevola nitida		MC	A/N	Wb,Wc	
Scaevola thesioides		MC	A/N		Bb,Bc
Verreauxia reinwardtii			A		
STYLIDIACEAE					
Levenhookia stipitata			A/N		
Stylidium brunonianum			A/N	Wc	
Stylidium calcaratum			A/N		
Stylidium bulbiferum		MC			
Stylidium junceum		MC	A/N		Bc
Stylidium piliferum		MC	A	Wb	
Stylidium schoenoides		MC			
Stylidium repens				Wb,Wc	
Stylidium aff.repens			A		
Stylidium sp. (S. maritima M. S.)		MC	A/N		Bb

ASTERACEAE

Asteridea pulverulenta		MC		
Angianthus tomentosus		MC		
*Arctotheca calendula	LP	MC		Wb,Wc/Bb,Bc
*Arctotheca populifolia	LP	MC		Wb,Wc
Brachycome bellidioides		MC		
Brachycome iberidifolia		MC		Wc/Bb,Bc
Calocephalus brownii	LP	MC		Wb,Wc/Bb,Bc
*Carduus pycnocephalus	LP			
Cotula australis	LP			Bc
Colula cotuloides	LP			
Cotula coronopifolia	LP	MC		
*Dittrichia graveolens	LP			Wb,Wc/Bb,Bc
Gnaphalium sphaericum			A/N	
Helichrysum cordatum	LP	MC	A/N	Wb,Wc/Bb,Bc
Helipterum corymbosum			Wb	/Bb,Bc
Hyalospermum cotula		MC		Bb,Bc
*Hypochaeris glabra			A/N	Wb,Wc/Bb,Bc
Ixiolaena viscosa		MC		
Lagenifera hugelii	LP	MC	A	Wb,Wc/Bb,Bc
Leptorhyncuos scabrus		MC	A/N	
Millotia tenuifolia	L	MC	A/N	Wc,Wb
Olearia axillaris	LP	MC	A/N	Wb,Wc/Bb,Bc
Olearia rudis		MC	A/N	Wb,Wc/Bb,Bc
Pithocarpa pulchella		MC		Bc
Podolepis canescens			A	
Podolepis gracilis		MC	A/N	
Podolepis lessonii		MC		Wb,Wc
Podotheca angustifolia		MC	A/N	
Podotheca chrysantha		MC		
Podotheca gnaphalioides			A/N	Wc
Quinetia urvillei		MC	A/N	Wb,Wc/Bb,Bc
Senecio lautus	LP	MC	A/N	
ssp maritimus				Wb,Wc/Bb,Bc
Senecio ramosissimus		MC		
Siloxerus humifusus			A/N	
*Sonchus oleraceus	LP	MC		Wb,Wc/Bb,Bc
*Urospermum picroides			N	
*Ursinia anthemoides			A/N	Wb,Wc/Bb,Bc
Waitzia citrina	LP			Wb
Waitzia suaevoleons		MC	A/N	

APPENDIX TWO: Map of landforms and soils

The relevant part of the landforms and soils map of the Perth metropolitan north-west corridor and the accompanying legend (see page 57) are reproduced from McArthur and Bartle (1980a).

LEGEND

SPEARWOOD DUNE SYSTEM—Low hilly to undulating terrain with a core of sandy limestone, capped by secondary calcite, overlain by siliceous sand; karst depressions with lakes, swamps, and hydromorphic soils on the floors.

Kls — Bare limestone and shallow brown sandy soils over limestone.

Ky — Karrakatta sand (yellow phase). Grey-brown sandy surface passing into bright yellow sand and often with limestone within two metres.

Kg — Karrakatta sand (grey phase). Grey sandy surface, a very light grey sub-surface, and pale yellow sand within one metre; limestone occurs at depth.

Sp — Spearwood sand. Gently sloping to steep irregular banks of depressions; brown sandy surface over bright yellow-brown sand with limestone often within one metre; much limestone outcrop.

B — Beonaddy sand. Flat topography often surrounding lakes and swamps in floors of depressions; very dark grey sandy surface over very light grey sand, sometimes with brown mottling, with the water table often within one metre.

QUINDALUP DUNE SYSTEM—Parabolic calcareous sand dunes of different ages; minimal soil profile development; undulating landscapes within dunes.

Q1 — The oldest phase. Dunes or remnants with low relief; soils have organic staining to about 30 cm, overlying pale brown sand, and within definite cementation below one metre.

Q2 — The second phase. A complex pattern of dunes with moderate relief; soils have organic staining to about 20 cm, passing into pale brown sand; some cementation below one metre.

Q3 — The third phase. Steep irregular dunes with high relief; soils consist of loose sand with little surface organic staining and incipient cementation at depth.

Q4 — The youngest phase. Steep irregular dunes of loose pale brown sand with no soil profile development.

Qu — Presently unstable sand.

Qp — Undulating landscapes with deep calcareous sands overlying limestone; soils have dark grey-brown sand to about 50 cm and then pale brown sand; remnants of hummocks are often present.

Qs — Undulating landscapes with shallow calcareous sand over limestone and much rock outcrop.