39

Gibson et al 1994

Floristic Groupings

PLOTS

KEMERTON 21a, 21c, 25

Guthrie (North) 4, 5, 21a

Capel (South) 16, 4, 12, 13, 21a, 21b

Plus BJK 21a 1998

Interest Gordia

16, 2, 4, 7, 12, 13,

21a, 21b + 25

B.J. Keighery

02/1998

ENTERED ON GIS

Name: Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area
Date: 28/04/2006
Capture Author: Thomas Leong / Ian Steward

Comments:
Polygon
Created to match documented study area with high level of accuracy

Accuracy Levels:
- High = Document contained visual and or described spatial references easily copied, resulting in little or no polygon boundary errors
- Acceptable = Document contained visual references with complex boundaries, resulting in minor boundary errors
- Low = Document contained little or no visual references, resulting in polygon boundary errors

Attributes
Report Info – Captured without problems
Custodial/Contact – Captured without problems
Content – Captured without problems

FLORA & VEGETATION SECTION

Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area

Background and Information Sources

While Western Extension of the Kemerton Silica Sands Project is currently being assessed this report details values of the entire naturally vegetated area (study area). This was considered necessary in the light of new information and the interpretation of previous information, according to a more detailed knowledge of the vegetation and flora of the Swan Coastal Plain (after Atkins 1997, Gibson *et al* . 1994, DEP 1996 and English and Blyth 1997). These data indicated that there are important flora and vegetation conservation issues that were not addressed in the previous assessment. These issues relate to the identification of threatened ecological communities, possible occurrences of Declared Rare Flora, occurrences of additional Priority Flora and the diversity of major landform units in and adjacent to the Kemerton Silica Sands Project area.

When appropriate the vegetation and flora conservation values are related to the biodiversity criteria developed for the consideration of clearing proposals by the EPA (Safstrom and Craig 1996).

This report considers aspects of the vegetation and flora values of the Kemerton Silica Sands Project as described in flora and vegetation information supplied by Gwalia Consolidated Ltd, information collated by DEP in 1993 and limited field work by DEP staff in 1997 (field visit by Bronwen Keighery and Michelle Mifka, 1.5 days October 1997).

Representation of Vegetation Complexes (after Heddle *et al.* 1980)

Within the Perth Metropolitan Area (PMA) government policy, as detailed in the Urban Bushland Strategy (Government of WA 1995) recognises that at least 10% of each vegetation complex should be protected for conservation of bushland. Outside the PMA there is general recognition through the 'MOU for the protection of remnant vegetation on private land in the agricultural region of WA' (March 1997) that 20% of each local government area should remain as native vegetation. As a consequence, it is generally recognised, that between 10 and 20% of each ecological community should be retained as native vegetation. In addition the biodiversity criteria developed for the consideration of clearing proposals (Safstrom and Craig 1996) consider this 20% representation in a 15kms radius of the area proposed to be cleared.

As vegetation complexes are mapped for the System 6 area these can be used as basis for the determination of percentage of each complex remaining. The entire area of the Kemerton Silica Sands Project (Map 1) is mapped as being on the Bassendean Complex (Central and South), abutting the Serpentine and Guildford Complex to the east and the Karrakatta Complex (Central and South) to the west (Heddle *et al* . 1980 and Mattiske 1993b, Map 1). However some of the plant communities mapped by Mattiske (1993b) are considered to be representative of communities of the eastern side of the Swan Coastal Plain and as such would be more correctly mapped in the Guildford Complex (Map 2 and sections on Floristic Community Types and Flora below). That is the study area contains areas of Bassendean Complex (Central and South, one of the largest remaining areas in the south of the complexes' range), Guildford Complex and the interface between them. As it is generally considered that less than 15% of the former and much less than 10% of the later of the complexes remains uncleared on the Plain (Dixon *et al* 1994, Keighery and Trudgen 1992, Trudgen and Keighery 1995) the entire study area is of regional conservation value.

Summary: The Kemerton Silica Sands Project area is considered to contain areas of Bassendean Complex (Central and South), Guildford Complex and the interface between them and as it is generally considered that less than 15% of the former and much less than 10% of the later of the complexes remains uncleared on the Plain the entire study area is of regional conservation value. In addition the study area provides an opportunity to conserve a transect on the Plain through three major landform units; Spearwood Dunes, Bassendean Complex (Central and South) and Guildford Complex and the interfaces between them.

Table 1: Floristic Community Types identified Gibson *et al.* (1994) and in the System 6 and part 1 Update (DEP 1996).

Key

Column 1: Floristic Community Type Codes

The numbers of the types additional to Gibson *et al.* are italicised if they are subsets of an existing group (in type 19, 20, 23 and 30) and italicised and preceded by an S if they are supplementary groups.

Column 2: General description of Floristic Community Types

Descriptions are based on generalised information from all plots in the group. Structural units are categorised into forest, woodlands, shrublands, sedgelands and herblands after Gibson *et al.* (1994).

Column 3: Average Species Richness per Floristic Community Type

Average species richness per 10X10m plot less those species only occurring in a single plot (singletons). Some community types can have a high proportion of singeletons and these estimates of average species richness are underestimates in some cases.

Supergroup 1 - Foothills/Pinjarra Plain

1b	Southern *E. calophylla* woodlands on heavy soils	65.0
2	Southern wet shrublands	50.3

Supergroup 2 - Seasonal Wetlands

4	*Melaleuca preissiana* damplands	33.2
7	Herb rich saline shrublands in clay pans	44.8
12	*M. teretifolia* and / or *Astartea* aff. *fascicularis* shrublands	27.3
13	Deeper wetlands on heavy soils	16.9

Supergroup 3 - Uplands, centred on Bassendean Dunes

21a	Central *Banksia attenuata* - *E. marginata* woodlands	52.0
21b	Southern *Banksia attenuata* woodlands	57.5

Supergroup 4 - Uplands centred on Spearwood and Quindalup Dunes

Spearwood Dunes		
25	Southern *E. gomphocephala* - *Agonis flexuosa* woodlands	48.1

Table 2: Threatened Ecological Communities on the Swan Coastal Plain (English and Blyth 1997).

KEY

Bold Type	Ecological Communities in the PMA
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
*	Community further defined by DEP 1996, here as identified by Gibson *et al.* 1994

A. Floristic Community Types

Supergroup 1 - Foothills/Pinjarra Plain

1b	Southern *E. calophylla* woodlands on heavy soils	VU

Supergroup 2 - Seasonal Wetlands

7	**Herb rich saline shrublands in clay pans**	**VU**

B: Restricted floristic community type mosaics

Muchea Limestones (Keighery and Keighery 1995)	**CR**

Floristic Community Types and Threatened Ecological Communities

The DEP field inspection in conjunction with Mattiske (1993a & b) was used to infer regional floristic groupings (floristic community types) after Gibson *et al.* (1994) and DEP (1996). All floristic community types considered to be present in the study area (Table 1) were identified in Gibson *et al.* (1994). A total of seven regional floristic groupings are considered to be present in the study area, a relatively diverse assemblage. An additional group is present to the west of the area giving a total of eight groups in the transect across the three major landform units.

Floristic community types 1b, 2 and 7 are principally associated with the eastern side of the Swan Coastal Plain (that is the Pinjarra Plain with which the Guildford Complex is associated). When compared with the plant communities mapped by Mattiske (1993a & b) floristic community type 1b is considered to be associated with units B1 and C3 and floristic community type 7 with D2, F2, F3 and areas of F1 (Map 2). Of particular interest is an area where communities D2, F2 and F3 are mapped (M, Map 2). This area contains a sequence of species considered to be associated with areas of Muchea Limestones (Keighery and Keighery 1995, see Flora below). No area of these communities is known south of Gosnells and the only protected areas are north west of Gingin. Communities 1b, 7 and the Muchea Limestones floristic community type mosaics are classified as threatened ecological communities (English and Blyth 1997).

Species richness in the floristic community types ranges from 16.9 to 65.0 per 100 square metres (Table 1). At least three of the floristic community types (1b, 21a and 21b) would be considered to show high species richness (Safstrom and Craig 1996, Criterion 2.1.3). In addition floristic community types 2 and 7 show high species richness in regard to both perennials and annuals. Communities of heavy soil wetlands, woodlands on the eastern side of the Plain and *Banksia* Woodlands show high species richness.

Summary: The Kemerton Silica Sands Project area is considered to contain a diversity of regional floristic groupings (eight floristic community types). Five of these floristic community types show high species richness. In addition the study area the provides a rare opportunity to conserve a transect of regional floristic groupings on the Plain through three major landform units; Spearwood Dunes, Bassendean Complex (Central and South) and Guildford Complex and the interfaces between them. Three floristic groups are classified as threatened ecological communities.

Plant Communities

Twenty four plant communities have been mapped, representing a diverse assemblage of communities (Mattiske 1993b). This diversity is particularly evident in the variety of wetland communities (Mattiske 1993b). Thirteen of these communities were considered to be of significance by Mattiske (1993b) as they:

- are poorly represented regionally (A2, C2, D1, D3, E3, F1, F2, F3 and H3
- contain populations of particularly significant flora (A3, H1 and H2)
- contain communities with a high diversity of native taxa (A1, A3 , H1 and H2).

Summary: - The study area contains a high degree of diversity of plant communities, thirteen of which have been identified as having significance.

Wetlands

A diverse assemblage of wetland communities were described by Mattiske (1993a and 1993b). The current status of the wetlands (other than those mined) is as described or better than in 1993 having recovered from disturbance caused by grid clearing for exploration. In addition it is considered from the DEP survey and interpretation of the Mattiske (1993b) survey results in light of Semeniuk (1987), Gibson *et al* . (1994) and DEP (1996) that the area also contains a diverse assemblage of wetland types and wetlands floristically typical of the Pinjarra Plain (see Floristic Community Types above).

Summary: The wetlands in the study area are significant as they
- form a diverse assemblage of wetlands types (after Semeniuk 1987)
- are the most southern occurrence of the Jandakot Suite
- form a diverse assemblage of wetland plant communities (Mattiske 1993b)
- represent a floristic sequence of wetlands of the Bassendean Dune System and the Pinjarra Plain and the interface between them
- contain a series of wetlands and their associated uplands.

Flora

Mattiske (1993b) identified 291 native taxa in the study area. The brief DEP October 1997 survey work identified a further 28 native taxa. It would be expected from long term survey of other areas (Ruabon Nature Reserve 390 native taxa (Keighery *et al.* 1996a), Capel Nature Reserve 381 native taxa (Keighery *et al.* 1996b)), in the region that similar levels of survey in the study area would identify a flora of close to 400 native taxa.

Significant Flora

Declared Rare Flora and Priority Taxa

Six priority taxa (Atkins 1997) are recorded for the Reserve (Mattiske 1993b and DEP 1997): *Boronia capitata* subsp. *gracilis* (2, Mattiske 1993b), *Dillwynia dillwynioides* (3), *Anthotium junciforme* (3), *Myriophyllum echinatum* (3), *Acacia semitrullata* (3, Mattiske 1993b)and *A. flagelliformis* (4, Mattiske 1993b). The priority 3 taxon, *Schoenus* sp. Waroona and priority 4 taxon *Drosera occidentalis* subsp. *occidentalis* are also tentatively identified from the study area (material was too immature for definitive identifications). It is also considered, based on the habitats available, that the following Declared Rare Flora (R) and priority taxa may be present in the area: *Hydatella dioica* (R), *Centrolepis caespitosa* (R) and *Schoenus capillifolius* (2). These species are all small annual aquatics that can only be located through detailed survey in late spring.

All priority taxa identified or potentially identified, additional to Mattiske (1993b), are found on the heavy soil wetland communities towards the eastern side of the Plain (Map 2). *Dillwynia dillwynioides* is also found in wetlands to the west and would be expected in plant communities H1, possibly H2, F1 and F2. That is it would be expected to be found in the area of Western Extension.

Other significant taxa/species groups

Boronia juncea subsp. *juncea* (Rutaceae)
Mattiske (1993a and 1993b) located five populations of this taxon in the study area (Map 2). Recent work on a revision of the species has identified the material from the study area (*Boronia juncea* - true type DW 184/EH304) as *Boronia juncea* subsp. *juncea* (Paul Wilson pers. comm.). This is the only known location of *Boronia juncea* subsp. *juncea*. The first collections of this taxon were made by Preiss in the Wellington district in 1839. While this taxon is not currently on CALM's priority list it is recommended that it be listed in 1998 as Priority 1 (Ken Atkins pers. comm.). That is further survey work is considered necessary to determine whether it should be gazetted as Declared Rare Flora. If no further populations are located it would be expected to be recommended for recognition as Declared Rare Flora. Mattiske (1993b) and Johns Consulting Services (1997) considered this the taxon with highest conservation significance in the study area.

Cyathochaeta stipoides (Cyperaceae)
Cyathochaeta stipoides was found in the wetland adjacent to the northern margin of the dredge pond (Site 2, Map 2). This is one of four (possibly five) species of *Cyathochaeta* found on the Swan Coastal Plain. *Cyathochaeta stipoides* ms (K. Wilson pers comm.) is currently known from Bow Bridge to the Scott River Plain and the Capel Nature Reserve (Keighery *et al* . 1996b). The populations in Capel Nature Reserve were previously considered to represent the most northern population and the only record of this species on the Plain (Keighery *et al.* 1996b).

Evandra pauciflora (Cyperaceae)
This sedge grows in damplands on the Plain from Anstey Road Bushland in Forrestdale to the Capel Nature Reserve. This distinctive sedge with its emergent weeping flowering branches is a distinctive feature of the wetlands with mixed shrub heaths.

Species characteristic of Muchea Limestones
An area of *Eucalyptus decipiens* Closed Tree Mallee was identified at Site 12 (Map 2) by DEP. Associated with this community were a series of species considered characteristic of communities associated with Muchea limestones (Keighery and Keighery 1995). These are *Eucalyptus decipiens*, *Pimelea rosea*, *Stipa flavescens*, *Gahnia trifida* and *Logania vaginalis*. A series of uncommon and restricted taxa on the Plain were also found in this community. These are:

- an unusual form of *Melaleuca acerosa* growing to two metres (possibly unnamed species of *Melaleuca* in Mattiske 1993b)
- *Melaleuca brachyphylla* an uncommon species on the Plain (possibly unnamed species of *Melaleuca* in Mattiske 1993b)
- *Hakea trifurcata* small flowered form previously only known from the Peel-Harvey region
- *Hibbertia perfoliata* an uncommon poorly collected species on the Plain.

Mattiske (1993b) listed all of these species but the significance of this community has only recently been delineated (Keighery and Keighery 1995). Gibson *et al* (1994) considered the communities of Muchea Limestones to be extinct.

Species characteristic of the eastern side of the Plain
Approximately forty taxa present in the study area are characteristic of the heavier soils of the eastern side (or southern side of the Plain south of Busselton) of the Swan Coastal Plain.

Species at the limit of their range
At least two taxa, *Verticordia nitens* and *Banksia menziesii*, are at the southern limits and one, *Cyathochaeta stipoides,* at the northern limit of their distribution on the Swan Coastal Plain in the study area. *Verticordia nitens* (Morrison) is a conspicuous summer flowering species which is common to the north of Perth but very uncommon south of Perth. Only two areas with large populations are known to the south of Perth. This record of *Banksia menziesii* is the most southern and is somewhat disjunct from the nearest known population in the Peel area.

Summary: The study area contains a diverse assemblage of flora representative of the two major landforms present in the area. Six priority taxa have been identified in the area. Another three priority taxa and two DRF may occur in the area. A detailed late spring survey would be required to locate these taxa. Over 45 taxa in the area are considered to be of special significance one of which is not currently known from any other area.

General Summary

The principal conservation values of the vegetation and flora in the Kemerton Silica Sands Project Area are:

- all vegetation complexes are inadequately represented according to DEP's Biodiversity criteria (Safstrom and Craig 1996, Map 1)
- the study area contributes to a transect of vegetation complexes (Map 1) and regional floristic communities characteristic of the three major landforms of the Plain (Spearwood Dunes, to west area, Bassendean Dunes and Pinjarra Plain) and the area of Western Extension is central to the transect
- some of the regional floristic groupings/community complexes are 'threatened ecological communities', one vegetation association is not known from any other reserve south of Gingin, and no other area is known south of Perth
- the area contains a high degree of diversity of vegetation associations (Mattiske 1993), wetland types, floristic community types and flora which is probably unique and gives the area a high degree of regional significance at the regional level
- over 45 significant taxa are found in the study area one of which is not currently known from any other area.

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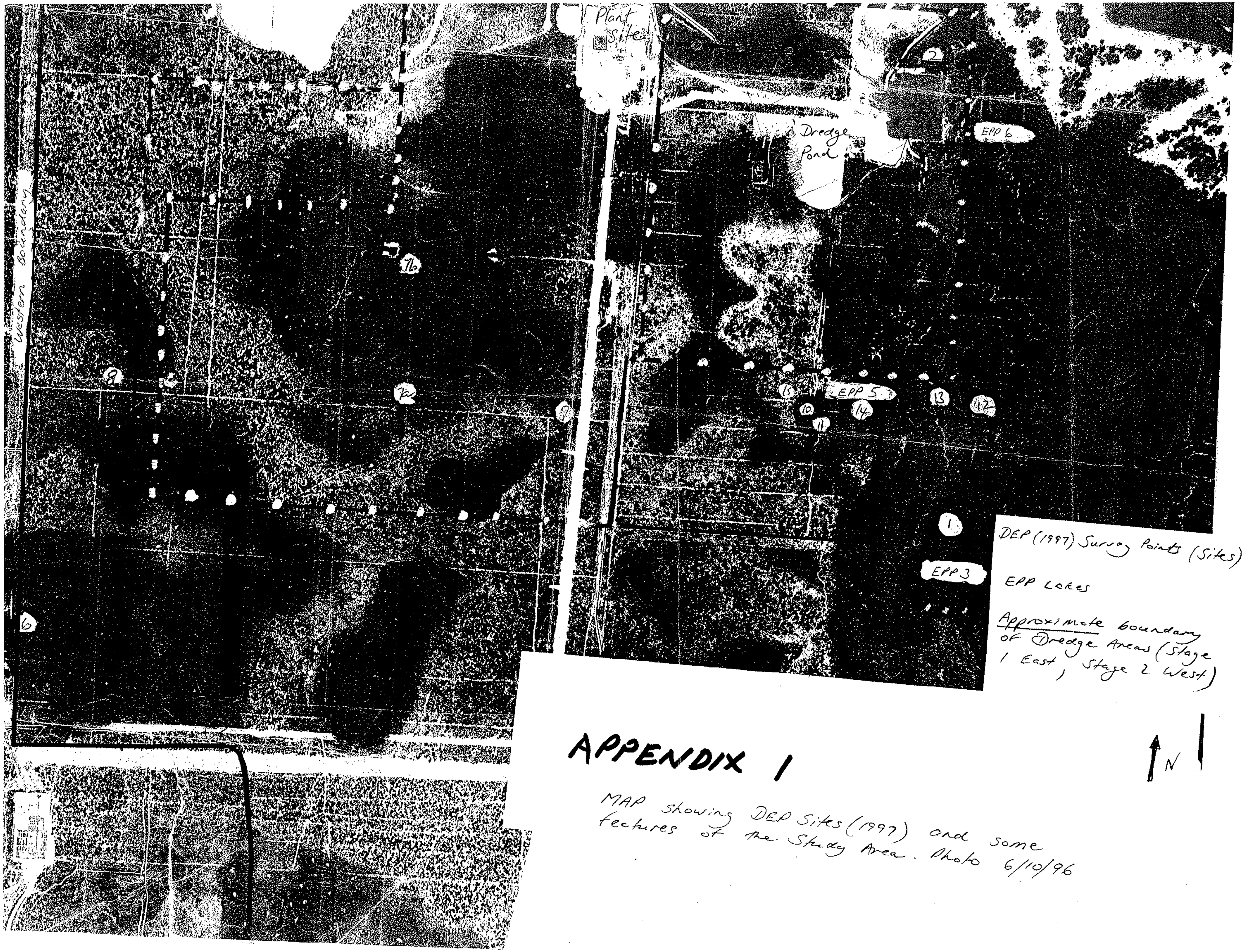
Semeniuk, C.A. (1987) Wetlands of the Darling System - A geomorphic approach to habitat classification. Journal of the Royal Society of Western Australia, 69 : 95-112.

APPENDIX 1

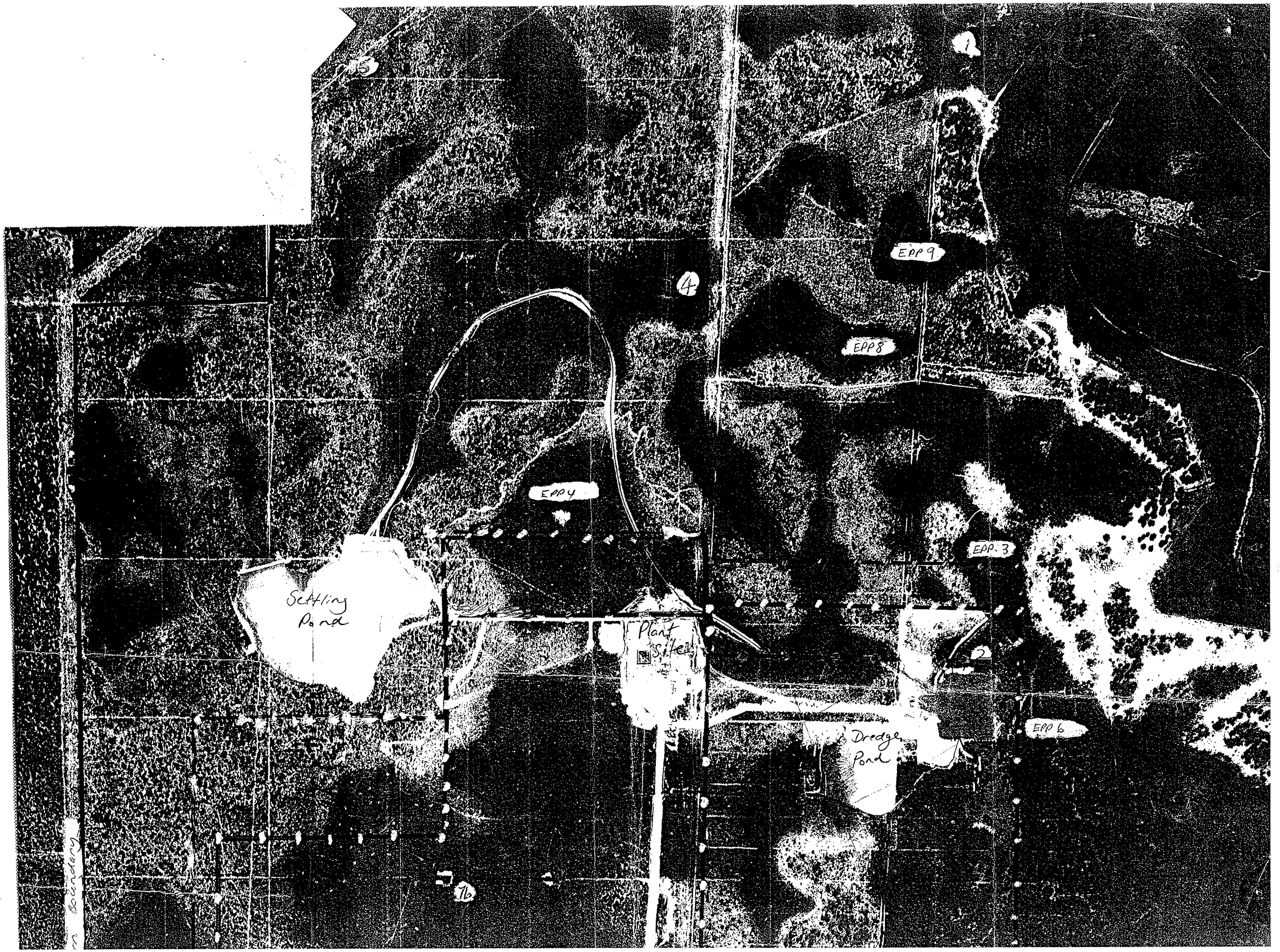


DEP (1997) Survey Points (Sites)

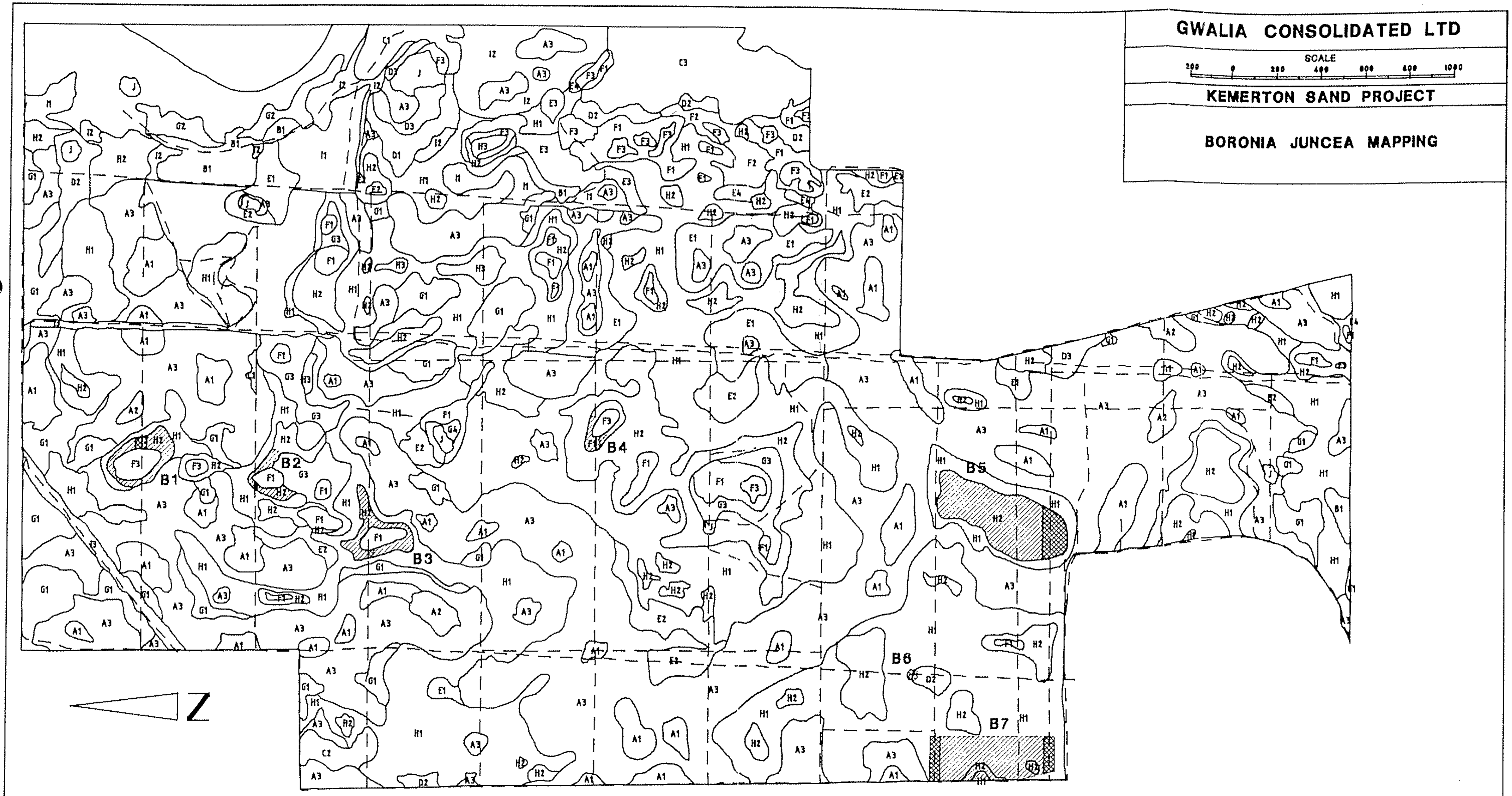
EPP Lakes

Approximate boundary of Dredge Areas (Stage 1 East, Stage 2 West)

MAP showing DEP Sites (1997) and some features of the Study Area. Photo 6/10/96


EPP 9
4
EPP 8
EPP 4
EPP 3
Settling Pond
Plant Site
2
Dredge Pond
EPP 6
16
Boundary

MAP 3



NOTE

FOR DETAILED VEGETATION MAP REFER MAP No. GWA001/026/D1 COMPILED BY E M MATTISKE AND ASSOCIATES, JUNE 1993.

From Mattiske 1993b

LEGEND

TRACKS

VEGETATION COMMUNITY BOUNDARIES

REPORTED BORONIA JUNCEA

LIKELY BORONIA JUNCEA EXTENTS

MAP 2: Location of expected Threatened Communities, cleared areas and areas proposed for clearing

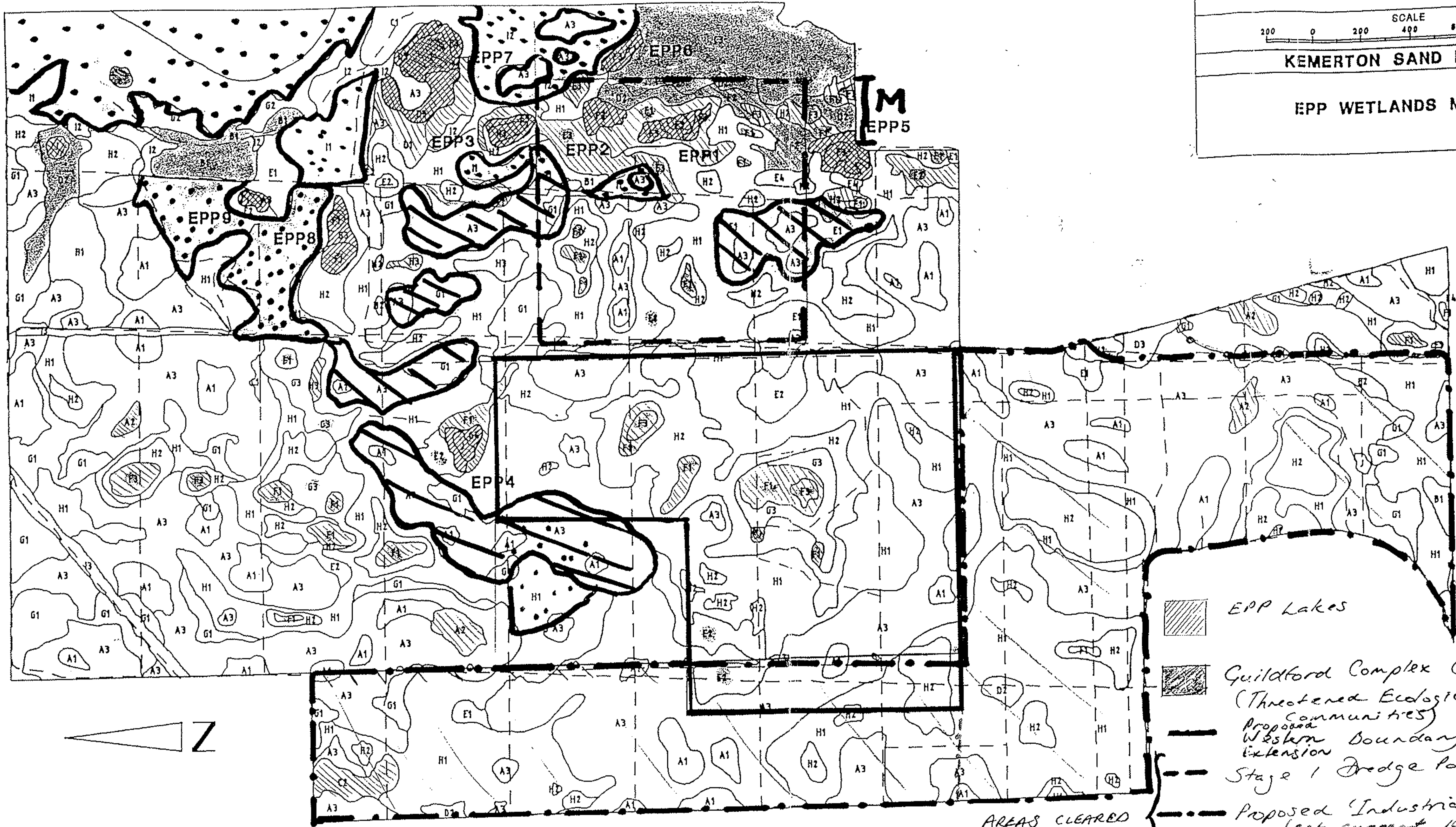
GWALIA CONSOLIDATED LTD

SCALE

200 0 200 400 600 800 1000

KEMERTON SAND PROJECT

EPP WETLANDS MAPPING



NOTE

FOR DETAILED VEGETATION MAP REFER MAP No. GWA001/026/D1 COMPILED BY E M MATTISKE AND ASSOCIATES, JUNE 1993.

LEGEND

EPP WETLANDS

A3 VEGETATION COMMUNITY BOUNDARIES

EPP Lakes

Guildford Complex Communities (Threatened Ecological Communities)

Proposed Western Boundary Extension

Stage 1 Dredge Pond Boundary

Proposed 'Industrial Lands' (not current 14/1/99)

Dry mining

Cleared

Mattiske (1993b) Regionally significant communities

AREAS CLEARED OR PROPOSED FOR CLEARING in proposal pre Bulletin 741 July 1994

PHOTOGRAPHIC STUDY AREA RELATED TO SITES / GENERAL AREA.

Area of Site 1

Photo 1

Site 1

Photo 2

Site 1

Photo 3

Photo 4

Site 14

Photo 5

Photo 6

Site 13

Photo 7

Site 12 to right (E) Site 13 to left (W).

Photo 8

Photo 9

Photo 10

Photo 11

"Typical" landscape of the study area (Stage 2)
very low relief looking E to Plateau

Photo 12

Photo 13

Photo 14

Photo 15

Wetland Site 6

Photo 16

Copy to B. Moore

Department of Environmental Protection Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area

B.J. Keighery February 1998

FULL REPORT

DEPARTMENT OF ENVIRONMENTAL PROTECTION

TO:	-	MICHELLE MIFKA
FROM:	-	BRONWEN KEIGHERY, GARY WHISSON
SUBJECT:	-	FLORA AND VEGETATION OF THE KEMERTON SILICA SANDS PROJECT AREA
DATE:	-	9TH FEBRUARY 1998

Attached is the report on the 'Issues Associated with the Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area' for your use in preparing the Bulletin.

G. Whisson 9/2/98

Issues Associated with the Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area

Part A: Regional Values of the Vegetation and Flora in the Kemerton Silica Sands Project Area

Background and Information Sources

While Stage Two of the Kemerton Silica Sands Project is currently being assessed this report details values of the entire naturally vegetated area (study area). This was considered necessary in the light of new information and the interpretation of previous information, according to a more detailed knowledge of the vegetation and flora of the Swan Coastal Plain (after Atkins 1997, Gibson *et al*. 1994, DEP 1996 and English and Blyth 1997). These data indicated that there are important flora and vegetation conservation issues that were not addressed in the previous assessment. These issues relate to the identification of threatened ecological communities, possible occurrences of Declared Rare Flora, occurrences of additional Priority Flora and the diversity of major landform units in and adjacent to the Kemerton Silica Sands Project area.

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This report considers aspects of the vegetation and flora values of the Kemerton Silica Sands Project as described in flora and vegetation information supplied by Gwalia Consolidated Ltd, information collated by DEP in 1993 and limited field work by DEP staff in 1997 (field visit by Bronwen Keighery and Michelle Mifka, 1.5 days October 1997, see Appendix 1 for area surveyed).

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Within the Perth Metropolitan Area (PMA) government policy, as detailed in the Urban Bushland Strategy (Government of WA 1995) recognises that at least 10% of each vegetation complex should be protected for conservation of bushland. Outside the PMA there is general recognition through the 'MOU for the protection of remnant vegetation on private land in the agricultural region of WA' (March 1997) that 20% of each local government area should remain as native vegetation. As a consequence, it is generally recognised, that between 10 and 20% of each ecological community should be retained as native vegetation. In addition the biodiversity criteria developed for the consideration of clearing proposals (Safstrom and Craig 1996) consider this 20% representation in a 15km radius of the area proposed to be cleared.

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Summary: The Kemerton Silica Sands Project area is considered to contain areas of Bassendean Complex (Central and South, one of the largest remaining areas in the south of the complexes' range), Guildford Complex and the interface between them and as it is generally considered that less than 15% of the former and much less than 10% of the later of the complexes remains uncleared on the Plain the entire study area is of regional conservation value. In addition the study area provides an opportunity to conserve a transect on the Plain through three major landform units; Spearwood Dunes, Bassendean Complex (Central and South) and Guildford Complex and the interfaces between them.

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Summary: The Kemerton Silica Sands Project area is considered to contain a diversity of regional floristic groupings (eight floristic community types). Five of these floristic community types show high species richness. In addition the study area provides a rare opportunity to conserve a transect of regional floristic groupings on the Plain through three major landform units; Spearwood Dunes, Bassendean Complex (Central and South) and Guildford Complex and the interfaces between them. Three floristic groups are classified as threatened ecological communities.

Plant Communities

Twenty four plant communities have been mapped, representing a diverse assemblage of communities (Mattiske 1993b). This diversity is particularly evident in the variety of wetland communities (Mattiske 1993b). Other work by V & C Semeniuk Research Group (1993, Appendix 2) and DEP has recognised similar levels of diversity.

Thirteen of these communities were considered to be of significance by Mattiske (1993b) as they:

- are poorly represented regionally (A2, C2, D1, D3, E3, F1, F2, F3 and H3
- contain populations of particularly significant flora (A3, H1 and H2)
- contain communities with a high diversity of native taxa (A1, A3 , H1 and H2).

Summary: - The study area contains a high degree of diversity of plant communities, thirteen of which have been identified as having significance.

Wetlands

A previous report to the Department (V & C Semeniuk Research Group December 1993, Appendix 2) clearly outlines the wetland values of the study area (note the comment on the cover sheet regarding usage of the document). The current status of the wetlands (other than those mined) is as described or better than in 1993. In addition it is considered from the DEP survey and interpretation of the Mattiske (1993b) survey results in light of Gibson *et al* . 1994 and DEP 1996 that the area also contains wetlands floristically typical of the Pinjarra Plain (see Floristic Community Types above).

Summary: The wetlands in the study area are significant as they

- form a diverse assemblage of wetlands types (after Semeniuk 1987)
- form a diverse assemblage of wetland plant communities (Semeniuk 1993, Mattiske 1993b)
- are the most southern occurrence of the Jandakot Suite
- are 'outstanding as an example of Bassendean Dune wetland geomorphology, soils, vegetation and hydrology' (V & C Semeniuk Research Group December 1993)
- represent a rare remaining example of a floristic sequence of wetlands of the Bassendean Dune System and the Pinjarra Plain and the interface between them
- contain a series of wetlands and their associated uplands.

Flora

Mattiske (1993b) identified 291 native taxa in the study area. The brief DEP October 1997 survey work identified a further 28 native taxa. It would be expected from long term survey of other areas (Ruabon Nature Reserve 390 native taxa (Keighery *et al.* 1996a), Capel Nature Reserve 381 native taxa (Keighery *et al.* 1996b)), in the region that similar levels of survey in the study area would identify a flora of close to 400 native taxa.

Significant Flora

Declared Rare Flora and Priority Taxa

Six priority taxa (Atkins 1997) are recorded for the Reserve (Mattiske 1993b and DEP 1997): *Boronia capitata* subsp. *gracilis* (2, Mattiske 1993b), *Dillwynia dillwynioides* (3), *Anthotium junciforme* (3), *Myriophyllum echinatum* (3), *Acacia semitrullata* (3, Mattiske 1993b)and *A. flagelliformis* (4, Mattiske 1993b). The priority 3 taxon, *Schoenus* sp.

Waroona and priority 4 taxon *Drosera occidentalis* subsp. *occidentalis* are also tentatively identified from the study area (material was too immature for definitive identifications). It is also considered, based on the habitats available, that the following Declared Rare Flora (R) and priority taxa may be present in the area: *Hydatella dioica* (R), *Centrolepis caespitosa* (R) and *Schoenus capillifolius* (2). These species are all small annual aquatics that can only be located through detailed survey in late spring.

All priority taxa identified or potentially identified, additional to Mattiske (1993b), are found on the heavy soil wetland communities towards the eastern side of the area (Map 2). *Dillwynia dillwynioides* is also found in wetlands to the west and would be expected in plant communities H1, possibly H2, F1 and F2. That is it would be expected to be found in the area of Stage Two.

Other significant taxa/species groups

Boronia juncea subsp. *juncea* (Rutaceae)
Mattiske (1993a and 1993b) located five populations of this taxon in the study area (Map 3). Recent work on a revision of the species has identified the material from the study area (*Boronia juncea* - true type DW 184/EH304) as *Boronia juncea* subsp. *juncea* (Paul Wilson pers. comm.). This is the only known location of *Boronia juncea* subsp. *juncea*. The first collections of this taxon were made by Preiss in the Wellington district in 1839. While this taxon is not currently on CALM's priority list it is recommended that it be listed in 1998 as Priority 1 (Ken Atkins pers. comm.). That is further survey work is considered necessary to determine whether it should be gazetted as Declared Rare Flora. If no further populations are located it would be expected to be recommended for recognition as Declared Rare Flora. Mattiske (1993b) and Johns Consulting Services (1997) considered this the taxon with highest conservation significance in the study area.

Cyathochaeta stipoides (Cyperaceae)
Cyathochaeta stipoides was found in the wetland adjacent to the northern margin of the dredge pond (Site 2, Appendix 1). This is one of four (possibly five) species of *Cyathochaeta* found on the Swan Coastal Plain. *Cyathochaeta stipoides* ms (K. Wilson pers comm.) is currently known from Bow Bridge to the Scott River Plain and the Capel Nature Reserve. The populations in Capel Nature Reserve were previously considered to represent the most northern population and the only record of this species on the Plain (Keighery *et al.* 1997.

Evandra pauciflora (Cyperaceae)
This sedge grows in damplands on the Plain from Anstey Road Bushland in Forrestdale to the Capel Nature Reserve. This distinctive sedge with its emergent weeping flowering branches is a distinctive feature of the wetlands with mixed shrub heaths.

Species characteristic of Muchea Limestones
An area of *Eucalyptus decipiens* Closed Tree Mallee was identified at Site 14 (Photo 8, Appendix 1) by DEP. Associated with this community were a series of species considered characteristic of communities associated with Muchea limestones (Keighery and Keighery 1995). These are *Eucalyptus decipiens*, *Pimelea rosea*, *Stipa flavescens*, *Gahnia trifida* and *Logania vaginalis*. A series of uncommon and restricted taxa on the Plain were also found in this community. These are:

- an unusual form of *Melaleuca acerosa* growing to two metres (possibly unnamed species of *Melaleuca* in Mattiske 1993b)
- *Melaleuca brachyphylla* an uncommon species on the Plain (possibly unnamed species of *Melaleuca* in Mattiske 1993b)

- *Hakea trifurcata* small flowered form previously only known from the Peel-Harvey region
- *Hibbertia perfoliata* an uncommon poorly collected species on the Plain.

Mattiske (1993b) listed all of these species but the significance of this community has only recently been delineated (Keighery and Keighery 1995). Gibson *et al* (1994) considered the communities of Muchea Limestones to be extinct.

Species characteristic of the eastern side of the Plain
Approximately forty taxa present in the study area are characteristic of the heavier soils of the eastern side (or southern side of the Plain south of Busselton) of the Swan Coastal Plain.

Species at the limit of their range
At least two taxa, *Verticordia nitens* and *Banksia menziesii*, are at the southern and one, *Cyathochaeta stipoides,* at the northern limit of of their distribution on the Swan Coastal Plain in the study area. *Verticordia nitens* (Morrison) is a conspicuous summer flowering species which is common to the north of Perth but very uncommon south of Perth. Only two areas with large populations are known to the south of Perth. This record of *Banksia menziesii* is the most southern and is somewhat disjunct from the nearest known population in the Peel area.

Summary: The study area contains a diverse assemblage of flora representative of the two major landforms present in the area (Photos 1 - 16). Six priority taxa have been identified in the area. Another three priority taxa and two DRF may occur in the area. A detailed late spring survey would be required to locate these taxa. Over 45 taxa in the area are considered to be of special significance one of which is not currently known from any other area.

General Summary

The principal conservation values of the vegetation and flora in the Kemerton Silica Sands Project Area are:

- all vegetation complexes are inadequately represented according to DEP's Biodiversity criteria (Safstrom and Craig 1996, Map 1)
- the study area contributes to a transect of vegetation complexes (Map 1) and regional floristic communities characteristic of the three major landforms of the Plain (Spearwood Dunes, to west area, Bassendean Dunes and Pinjarra Plain) and the area of Stage Two is central to the transect
- some of the regional floristic groupings/community complexes are 'threatened ecological communities', one vegetation association is not known from any other reserve south of Gingin, and no other area is known south of Perth
- the area contains a high degree of diversity of vegetation associations (Mattiske 1993), wetland types, floristic community types and flora which is probably unique and gives the area a high degree of significance at the regional level
- over 45 significant taxa are found in the study area one of which is not currently known from any other area.

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Part B:
Rehabilitation of Cleared and Mined/Dredged Areas

Both the 1993 and 1997 documents (identical sections on Rehabilitation) have stated that the rehabilitation of the wetland areas would
"..replace, if not enhance, the pre-mining wetland values.."
"..both species diversity and vegetation structure will be accommodated, to re-establish representative flora and fauna habitat values..."
If the complexity of the existing plant communities is considered from a structural and floristic (species diversity) perspective (see previous sections, Mattiske 1993b, V & C Semeniuk Research Group 1993) this is not feasible.

This is well illustrated by average species diversity of the floristic communities considered to occur in the study area. Species richness ranges from 17 to 65 taxa per 100 square metres. At this time there is no rehabilitation that demonstrates success in this type of situation. In fact all recent studies have established that the communities of the Plain are generally floristically and structurally extremely diverse, especially complex wetland systems. Small changes in topography and soil type (varying combinations of clays, sands and peats) can result in very different plant comminutes in close proximity to each other. While the plant community mapping (Mattiske 1993) is detailed at the level of the entire study area its detail is not sufficient rehabilitate at the local scale of each community and the variation in each community. In addition recent studies indicate that there has been a significant underestimate of the diversity of the flora in the study area.

To even attempt to approach the level of rehabilitation indicated for the type of wetlands and uplands in the study area would require the expenditure of many years of research and practice. In addition the proponents have not described the areas to be mined in sufficient detail to be able to demonstrate that they have achieved their stated aims.

A condition of the environmental approvals Stage One was that the cleared areas would be revegetated to a natural self-sustaining system. At this stage rehabilitation work has not even been initiataed and there is no evidence that it is possible. Until this condition can be demonstrated to be met for already cleared areas in Stage One (and it is considered very doubtful that this can be done) no further approvals should be considered.

Summary: A condition of the previous approvals was that the cleared areas would be revegetated. Considering the complex nature of the uplands and wetlands in the study area these would not be possible to be re-established.

Part C:
Other proposals for study area and adjacent lands

The Kemerton Expansion Study Final Structure Plan is currently underway. This identifies a large portion of the study area for industrial zoning (Map 2). Planning for conservation of the lands within this entire area must take into account all of these issues.

Table 1: Floristic Community Types identified Gibson *et al.* (1994)

Key

Column 1: Floristic Community Type Codes

The numbers of the types additional to Gibson *et al.* are italicised if they are subsets of an existing group (in type 19, 20, 23 and 30) and italicised and preceded by an S if they are supplementary groups.

Column 2: General description of Floristic Community Types

Descriptions are based on generalised information from all plots in the group. Structural units are categorised into forest, woodlands, shrublands, sedgelands and herblands after Gibson *et al.* (1994).

Column 3: Average Species Richness per Floristic Community Type

Average species richness per 10X10m plot less those species only recorded in a single plot (singletons). Some community types can have a high proportion of singeletons and these estimates of average species richness are underestimates in some cases.

Supergroup 1 - Foothills/Pinjarra Plain

1b	Southern *E. calophylla* woodlands on heavy soils	65.0
2	Southern wet shrublands	50.3

Supergroup 2 - Seasonal Wetlands

4	*Melaleuca preissiana* damplands	33.2
7	Herb rich saline shrublands in clay pans	44.8
12	*M. teretifolia* and / or *Astartea* aff. *fascicularis* shrublands	27.3
13	Deeper wetlands on heavy soils	16.9

Supergroup 3 - Uplands, centred on Bassendean Dunes

21a	Central *Banksia attenuata - E. marginata* woodlands	52.0
21b	Southern *Banksia attenuata* woodlands	57.5

Supergroup 4 - Uplands centred on Spearwood and Quindalup Dunes

Spearwood Dunes		
25	Southern *E. gomphocephala - Agonis flexuosa* woodlands	48.1

Table 2: Threatened Ecological Communities on the Swan Coastal Plain (English and Blyth 1997).

KEY

Bold Type	Ecological Communities in the PMA
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
*	Community further defined by DEP 1996, here as identified by Gibson *et al.* 1994

A. Floristic Community Types

Supergroup 1 - Foothills/Pinjarra Plain

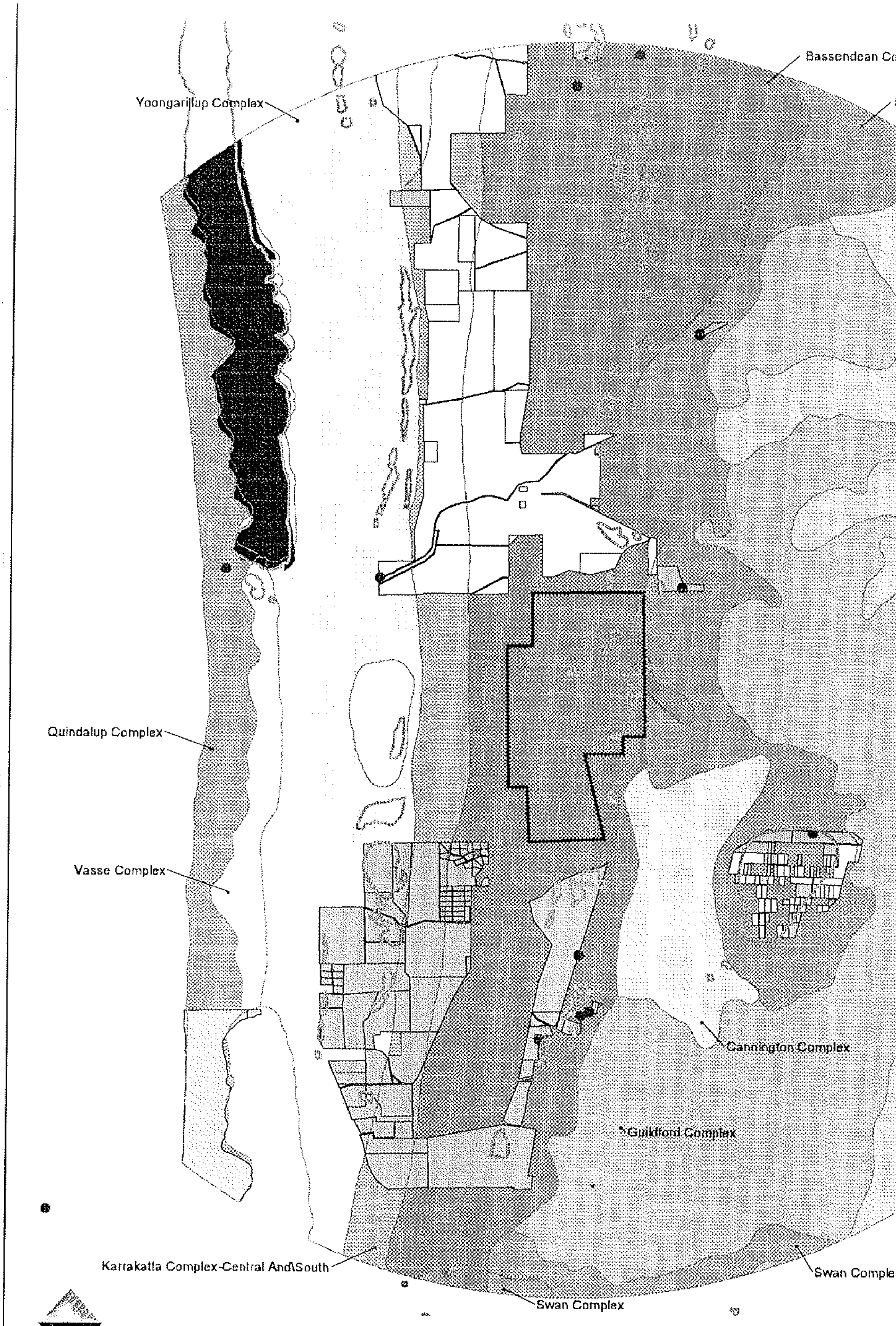
1b	Southern *E. calophylla* woodlands on heavy soils	VU

Supergroup 2 - Seasonal Wetlands

7	**Herb rich saline shrublands in clay pans**	**VU**

B: Restricted floristic community type mosaics

Muchea Limestones (Keighery and Keighery 1995)	**CR**

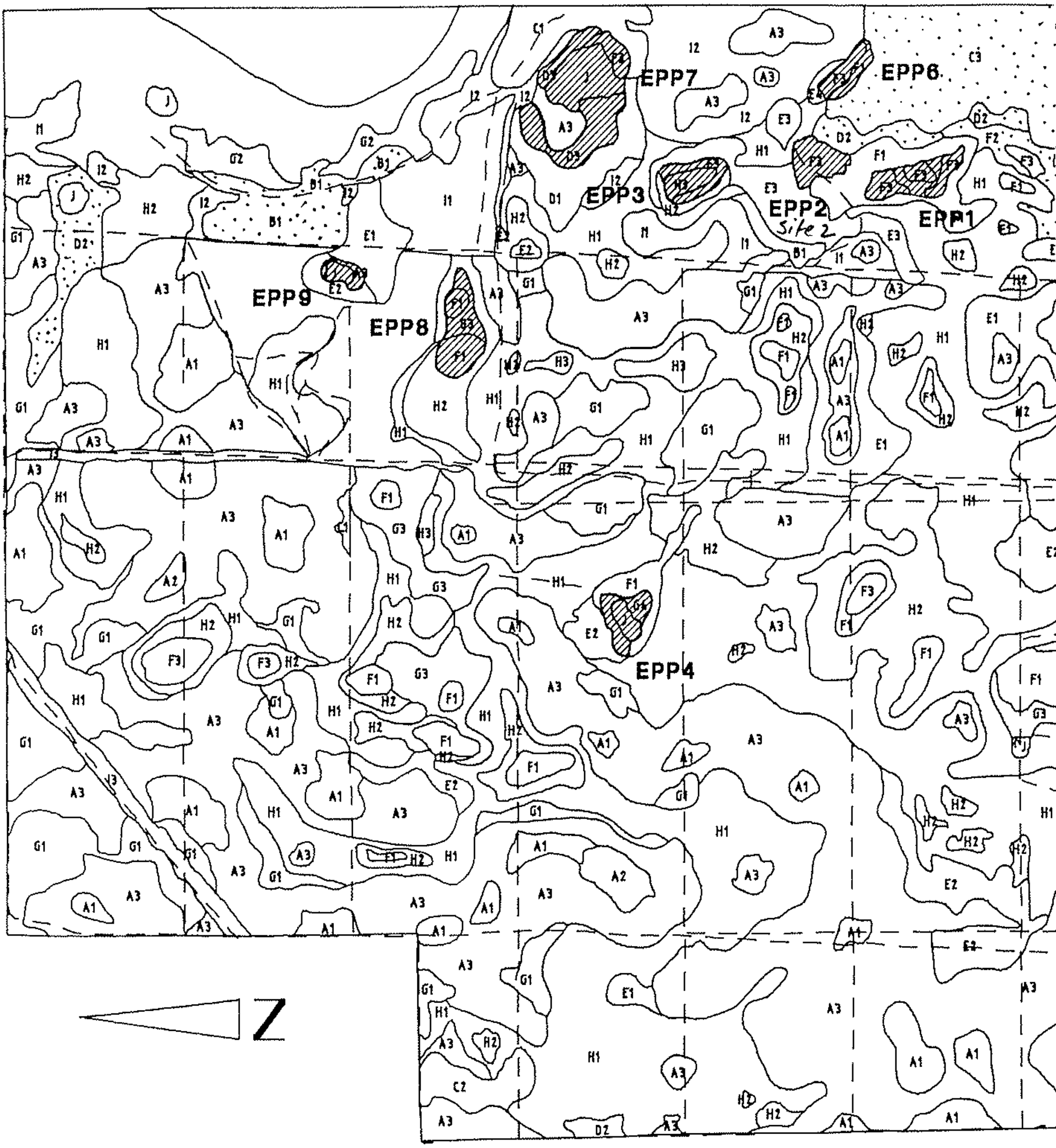


Department of Environmental Protection, Western Australia

15 km RADIUS

Produced by Andrew Moore (DEP-GIS) 08/12/97

MAP 2



NOTE

FOR DETAILED VEGETATION MAP REFER MAP No. GWA001/026/D1 COMPILED BY E M MATTISKE AND ASSOCIATES, JUNE 1993.

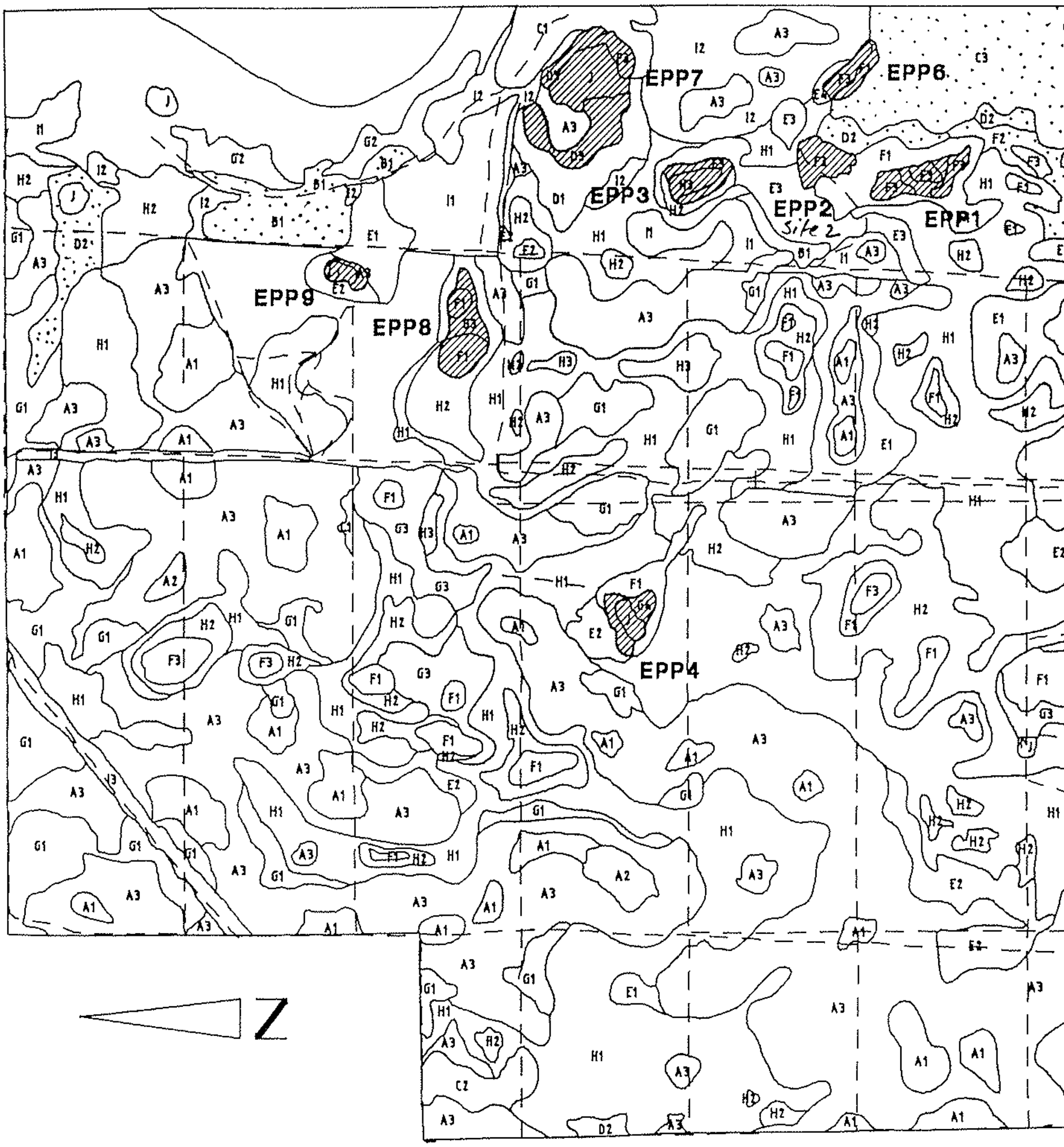
from Mattiske 1993b

LEGEND

EPP WETLANDS

VEGETATION COMMUNITY BOUNDARIES

MAP 2



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LEGEND

EPP WETLANDS

A3 VEGETATION COMMUNITY BOUNDARIES

FULL REPORT — Reference to Semeniuk document not distributed
March 1998

'Stage 2 changed to
'Western Extension'

Issues Associated with the Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area

Part A:
Regional Values of the Vegetation and Flora in the Kemerton Silica Sands Project Area

Background and Information Sources

While Western Extension of the Kemerton Silica Sands Project is currently being assessed this report details values of the entire naturally vegetated area (study area). This was considered necessary in the light of new information and the interpretation of previous information, according to a more detailed knowledge of the vegetation and flora of the Swan Coastal Plain (after Atkins 1997, Gibson *et al*. 1994, DEP 1996 and English and Blyth 1997). These data indicated that there are important flora and vegetation conservation issues that were not addressed in the previous assessment. These issues relate to the identification of threatened ecological communities, possible occurrences of Declared Rare Flora, occurrences of additional Priority Flora and the diversity of major landform units in and adjacent to the Kemerton Silica Sands Project area.

When appropriate the vegetation and flora conservation values are related to the biodiversity criteria developed for the consideration of clearing proposals by the EPA (Safstrom and Craig 1996).

This report considers aspects of the vegetation and flora values of the Kemerton Silica Sands Project as described in flora and vegetation information supplied by Gwalia Consolidated Ltd, information collated by DEP in 1993 and limited field work by DEP staff in 1997 (field visit by Bronwen Keighery and Michelle Mifka, 1.5 days October 1997, see Appendix 1 for area surveyed).

Representation of Vegetation Complexes (after Heddle *et al.* 1980)

Within the Perth Metropolitan Area (PMA) government policy, as detailed in the Urban Bushland Strategy (Government of WA 1995) recognises that at least 10% of each vegetation complex should be protected for conservation of bushland. Outside the PMA there is general recognition through the 'MOU for the protection of remnant vegetation on private land in the agricultural region of WA' (March 1997) that 20% of each local government area should remain as native vegetation. As a consequence, it is generally recognised, that between 10 and 20% of each ecological community should be retained as native vegetation. In addition the biodiversity criteria developed for the consideration of clearing proposals (Safstrom and Craig 1996) consider this 20% representation in a 15km radius of the area proposed to be cleared.

As vegetation complexes are mapped for the System 6 area these can be used as basis for the determination of percentage of each complex remaining. The entire area of the Kemerton Silica Sands Project (Map 1, Photos 1 - 16) is mapped as being on the Bassendean Complex (Central and South, one of the largest remaining areas in the south of the complexes' range), abutting the Serpentine and Guildford Complex to the east and the Karrakatta Complex (Central and South) to the west (Heddle *et al* . 1980 and Mattiske 1993b, Map 1). However some of the plant communities mapped by Mattiske (1993b) are considered to be representative of communities of the eastern side of the Swan Coastal Plain and as such would be more correctly mapped in the Guildford Complex (Map 2 and sections on Floristic Community Types and Flora below). That is the study area contains areas of Bassendean Complex (Central and South), Guildford Complex and the interface between them. As it is generally considered that less than 15% of the former and much less than 10% of the later of the complexes remains uncleared on the Plain (Dixon *et al* 1994, Keighery and Trudgen 1992, Trudgen and Keighery 1995) the entire study area is of regional conservation value.

Summary: The Kemerton Silica Sands Project area is considered to contain areas of Bassendean Complex (Central and South, one of the largest remaining areas in the south of the complexes' range), Guildford Complex and the interface between them and as it is generally considered that less than 15% of the former and much less than 10% of the later of the complexes remains uncleared on the Plain the entire study area is of regional conservation value. In addition the study area provides an opportunity to conserve a transect on the Plain through three major landform units; Spearwood Dunes, Bassendean Complex (Central and South) and Guildford Complex and the interfaces between them.

Floristic Community Types and Threatened Ecological Communities

The DEP field inspection in conjunction with Mattiske (1993a & b) was used to infer regional floristic groupings (floristic community types) after Gibson *et al.* (1994) and DEP (1996). All floristic community types considered to be present in the study area (Table 1) were identified in Gibson *et al.* (1994). A total of seven regional floristic groupings are considered to be present in the study area, a relatively diverse assemblage. An additional group is present to the west of the area giving a total of eight groups in the transect across the three major landform units.

Floristic community types 1b, 2 and 7 are principally associated with the eastern side of the Swan Coastal Plain (that is the Pinjarra Plain with which the Guildford Complex is associated). When compared with the plant communities mapped by Mattiske (1993a & b) floristic community type 1b is considered to be associated with units B1 and C3 and floristic community type 7 with D2, F2, F3 and areas of F1 (Map 2, Photos 1 - 8). Of particular interest is an area where communities D2, F2 and F3 are mapped (M, Map 2, Photos 4 - 8). This area contains a sequence of species considered to be associated with areas of Muchea Limestones (Keighery and Keighery 1995, see Flora below). No area of these communities is known south of Gosnells and the only protected areas are north west of Gingin. Communities 1b, 7 and the Muchea Limestones floristic community type mosaics are classified as threatened ecological communities (English and Blyth 1997).

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- form a diverse assemblage of wetland plant communities (Semeniuk 1993, Mattiske 1993b)
- are the most southern occurrence of the Jandakot Suite
- are 'outstanding as an example of Bassendean Dune wetland geomorphology, soils, vegetation and hydrology' (V & C Semeniuk Research Group December 1993)
- represent a rare remaining example of a floristic sequence of wetlands of the Bassendean Dune System and the Pinjarra Plain and the interface between them
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Other significant taxa/species groups

Boronia juncea subsp. *juncea* (Rutaceae)
Mattiske (1993a and 1993b) located five populations of this taxon in the study area (Map 3). Recent work on a revision of the species has identified the material from the study area (*Boronia juncea* - true type DW 184/EH304) as *Boronia juncea* subsp. *juncea* (Paul Wilson pers. comm.). This is the only known location of *Boronia juncea* subsp. *juncea*. The first collections of this taxon were made by Preiss in the Wellington district in 1839. While this taxon is not currently on CALM's priority list it is recommended that it be listed in 1998 as Priority 1 (Ken Atkins pers. comm.). That is further survey work is considered necessary to determine whether it should be gazetted as Declared Rare Flora. If no further populations are located it would be expected to be recommended for recognition as Declared Rare Flora. Mattiske (1993b) and Johns Consulting Services (1997) considered this the taxon with highest conservation significance in the study area.

Cyathochaeta stipoides (Cyperaceae)
Cyathochaeta stipoides was found in the wetland adjacent to the northern margin of the dredge pond (Site 2, Appendix 1). This is one of four (possibly five) species of *Cyathochaeta* found on the Swan Coastal Plain. *Cyathochaeta stipoides* ms (K. Wilson pers comm.) is currently known from Bow Bridge to the Scott River Plain and the Capel Nature Reserve. The populations in Capel Nature Reserve were previously considered to represent the most northern population and the only record of this species on the Plain (Keighery *et al.* 1997.

Evandra pauciflora (Cyperaceae)
This sedge grows in damplands on the Plain from Anstey Road Bushland in Forrestdale to the Capel Nature Reserve. This distinctive sedge with its emergent weeping flowering branches is a distinctive feature of the wetlands with mixed shrub heaths.

Species characteristic of Muchea Limestones
An area of *Eucalyptus decipiens* Closed Tree Mallee was identified at Site 14 (Photo 8, Appendix 1) by DEP. Associated with this community were a series of species considered characteristic of communities associated with Muchea limestones (Keighery and Keighery 1995). These are *Eucalyptus decipiens*, *Pimelea rosea*, *Stipa flavescens*, *Gahnia trifida* and *Logania vaginalis.* A series of uncommon and restricted taxa on the Plain were also found in this community. These are:

- an unusual form of *Melaleuca acerosa* growing to two metres (possibly unnamed species of *Melaleuca* in Mattiske 1993b)
- *Melaleuca brachyphylla* an uncommon species on the Plain (possibly unnamed species of *Melaleuca* in Mattiske 1993b)

- *Hakea trifurcata* small flowered form previously only known from the Peel-Harvey region
- *Hibbertia perfoliata* an uncommon poorly collected species on the Plain.

Mattiske (1993b) listed all of these species but the significance of this community has only recently been delineated (Keighery and Keighery 1995). Gibson *et al* (1994) considered the communities of Muchea Limestones to be extinct.

Species characteristic of the eastern side of the Plain
Approximately forty taxa present in the study area are characteristic of the heavier soils of the eastern side (or southern side of the Plain south of Busselton) of the Swan Coastal Plain.

Species at the limit of their range
At least two taxa, *Verticordia nitens* and *Banksia menziesii,* are at the southern and one, *Cyathochaeta stipoides,* at the northern limit of of their distribution on the Swan Coastal Plain in the study area. *Verticordia nitens* (Morrison) is a conspicuous summer flowering species which is common to the north of Perth but very uncommon south of Perth. Only two areas with large populations are known to the south of Perth. This record of *Banksia menziesii* is the most southern and is somewhat disjunct from the nearest known population in the Peel area.

Summary: The study area contains a diverse assemblage of flora representative of the two major landforms present in the area (Photos 1 - 16). Six priority taxa have been identified in the area. Another three priority taxa and two DRF may occur in the area. A detailed late spring survey would be required to locate these taxa. Over 45 taxa in the area are considered to be of special significance one of which is not currently known from any other area.

General Summary

The principal conservation values of the vegetation and flora in the Kemerton Silica Sands Project Area are:

- all vegetation complexes are inadequately represented according to DEP's Biodiversity criteria (Safstrom and Craig 1996, Map 1)
- the study area contributes to a transect of vegetation complexes (Map 1) and regional floristic communities characteristic of the three major landforms of the Plain (Spearwood Dunes, to west area, Bassendean Dunes and Pinjarra Plain) and the area of Western Extension is central to the transect
- some of the regional floristic groupings/community complexes are 'threatened ecological communities', one vegetation association is not known from any other reserve south of Gingin, and no other area is known south of Perth
- the area contains a high degree of diversity of vegetation associations (Mattiske 1993), wetland types, floristic community types and flora which is probably unique and gives the area a high degree of significance at the regional level
- over 45 significant taxa are found in the study area one of which is not currently known from any other area.

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Part B:
Rehabilitation of Cleared and Mined/Dredged Areas

Both the 1993 and 1997 documents (identical sections on Rehabilitation) have stated that the rehabilitation of the wetland areas would
"..replace, if not enhance, the pre-mining wetland values.."
"..both species diversity and vegetation structure will be accommodated, to re-establish representative flora and fauna habitat values..."
If the complexity of the existing plant communities is considered from a structural and floristic (species diversity) perspective (see previous sections, Mattiske 1993b, V & C Semeniuk Research Group 1993) this is not feasible.

This is well illustrated by average species diversity of the floristic communities considered to occur in the study area. Species richness ranges from 17 to 65 taxa per 100 square metres. At this there is no rehabilitation that demonstrates even minor success in this type of situation. In fact all recent studies have established that the communities of the Plain are floristically and structurally extremely divers, especially complex wetland systems. Small changes in topography and soil type (varying combinations of clays, sands and peats) can result in very different plant comminutes in close proximity to each other. While the plant community mapping (Mattiske 1993) is detailed at the level of the entire study area its detail is not sufficient rehabilitate at the local scale of each community and the variation in each community. In addition recent studies indicate that there has been a significant underestimate of the diversity of the flora in the study area.

To even attempt to approach the level of rehabilitation indicated for the type of wetlands and uplands in the study area would require the expenditure of many years of research and practice. In addition the proponents have not described the areas to be mined in sufficient detail to be able to demonstrate that they have achieved their stated aims.

A condition of the environmental approvals Stage One was that the cleared areas would be revegetated to a natural self-sustaining system. At this stage there is no evidence that this is possible. Until this condition can be demonstrated to be met for already cleared areas in Stage One (and it is considered very doubtful that this can be done) no further approvals should be considered.

Summary: A condition of the previous approvals was that the cleared areas would be revegetated. Considering the complex nature of the uplands and wetlands in the study area these would not be possible to be re-established.

Part C:
Other proposals for study area and adjacent lands

The Kemerton Expansion Study Final Structure Plan is currently underway. This identifies a large portion of the study area for industrial zoning (Map 2). Planning for conservation of the lands within this entire area must take into account all of these issues.

Table 1: Floristic Community Types identified Gibson *et al.* (1994)

Key

Column 1: Floristic Community Type Codes

The numbers of the types additional to Gibson *et al.* are italicised if they are subsets of an existing group (in type 19, 20, 23 and 30) and italicised and preceded by an S if they are supplementary groups.

Column 2: General description of Floristic Community Types

Descriptions are based on generalised information from all plots in the group. Structural units are categorised into forest, woodlands, shrublands, sedgelands and herblands after Gibson *et al.* (1994).

Column 3: Average Species Richness per Floristic Community Type

Average species richness per 10X10m plot less those species only occurring in a single plot (singletons). Some community types can have a high proportion of singeletons and these estimates of average species richness are underestimates in some cases.

Supergroup 1 - Foothills/Pinjarra Plain

1b	Southern *E. calophylla* woodlands on heavy soils	65.0
2	Southern wet shrublands	50.3

Supergroup 2 - Seasonal Wetlands

4	*Melaleuca preissiana* damplands	33.2
7	Herb rich saline shrublands in clay pans	44.8
12	*M. teretifolia* and / or *Astartea* aff. *fascicularis* shrublands	27.3
13	Deeper wetlands on heavy soils	16.9

Supergroup 3 - Uplands, centred on Bassendean Dunes

21a	Central *Banksia attenuata - E. marginata* woodlands	52.0
21b	Southern *Banksia attenuata* woodlands	57.5

Supergroup 4 - Uplands centred on Spearwood and Quindalup Dunes

Spearwood Dunes		
25	Southern *E. gomphocephala - Agonis flexuosa* woodlands	48.1

Table 2: Threatened Ecological Communities on the Swan Coastal Plain (English and Blyth 1997).

KEY

Bold Type	Ecological Communities in the PMA
CR	Critically Endangered
EN	Endangered
VU	Vulnerable
*	Community further defined by DEP 1996, here as identified by Gibson *et al.* 1994

A. Floristic Community Types

Supergroup 1 - Foothills/Pinjarra Plain

1b	Southern *E. calophylla* woodlands on heavy soils	VU

Supergroup 2 - Seasonal Wetlands

7	**Herb rich saline shrublands in clay pans**	**VU**

B: Restricted floristic community type mosaics

Muchea Limestones (Keighery and Keighery 1995)	**CR**

B. Keighery

Kemerton silica sand mining proposal

Gwalia Consolidated Ltd

Full document
available
on request

Report and recommendations
of the Environmental Protection Authority

Environmental Protection Authority
Perth, Western Australia
Bulletin 741
July 1994

GWALIA CONSOLIDATED LIMITED - KEMERTON SAND PROJECT

UPDATED FLORA AND VEGETATION REPORT

Full document available on request

Prepared by: E M Mattiske and Associates

Prepared for: John Consulting Services

November 1993

GWA003/062/93

GWALIA
QUALITY AUSTRALIAN MINERALS

GWALIA CONSOLIDATED LTD

KEMERTON SILICA SAND PROJECT

PUBLIC ENVIRONMENTAL REVIEW

July 1993

SUBMISSIONS ON THE PROPOSAL

Invitation

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

This Public Environmental Review (PER) has been prepared in accordance with the relevant procedures of the Government of Western Australia. The PER will be open for comment until 20 September 1993.

Comments from Government agencies and the public will assist the EPA to prepare an Assessment Report in which it will make a recommendation to the Government.

Following receipt of comments from Government agencies and the public, the EPA will discuss the comments with the proponent and may ask for further information. The EPA will then prepare the Assessment Report, taking into account issues raised in public submissions.

Why write a submission?

A submission allows you to provide information, express opinions and put forward suggested courses of action, including alternative approaches. It is helpful if you indicate any suggestions you may have to improve the proposal.

All submissions will be acknowledged upon receipt.

Developing a submission

You may agree or disagree with, or comment on, either the general issues addressed in the PER or specific proposals. It helps if you can give reasons for your conclusions, supported by relevant data.

You can make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the PER:
- clearly state your point of view;
- indicate the source of your information or argument; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed.

Attempt to list points so that the issues raised are clear. A summary of your submission is helpful. Refer each point to the appropriate section, chapter or recommendation in the PER. If you discuss different sections of the PER, keep them separate, so that there is no confusion as to which section you are referring to.

Attach any factual information you wish to provide and give details of the source. Make sure your information is correct.

Please indicate whether your submission can be quoted, in full or in part, by the EPA in its Assessment Report.

REMEMBER TO INCLUDE YOUR NAME, ADDRESS AND THE DATE

THE CLOSING DATE FOR SUBMISSIONS IS 20 September 1993.

SUBMISSIONS SHOULD BE ADDRESSED TO:

> The Chairman
> Environmental Protection Authority
> 141 St George's Terrace
> PERTH WA 6000
> Attention: Mr Robert Griffiths

SUMMARY

Gwalia Consolidated Ltd (Gwalia) is examining the feasibility of a silica sand mining and processing operation on private land north of the Kemerton Industrial Area, approximately 12 km south-west of Harvey, WA.

The unique geochemical qualities of the orebody, plus its proximity to the Port of Bunbury, make it unique in the South-East Pacific.

The project would involve both dry mining and dredge mining, on-site washing and screening of ore and campaign trucking of product to the Inner Harbour at the Port of Bunbury for shipment overseas to glass manufacturers. Operations would probably commence at a rate of some 200,000 tonnes p.a., with the feasibility study based on achieving a production rate of 840,000 tonnes p.a. by the year 2001.

This Public Environmental Review (PER) is submitted to the Environmental Protection Authority as part of the process of environmental impact assessment under the terms of the *Environmental Protection Act 1986*.

The major potential environmental impacts are on flora and fauna, wetlands, groundwater and noise from product transport. Specially commissioned studies show that:

- no rare or endangered flora and fauna have been detected on the project area, and rare fauna which, on the basis of existing regional information, might be expected to occur, are either well-represented in other secure habitats in the region or would be relocated (in many cases temporarily) by the project;

- of nine wetlands in the project area covered by the *Environmental Protection (Swan Coastal Plain Lakes) Policy (1992)* (aimed at preventing unauthorised disturbance of lakes/wetlands), two which would be directly affected by the project have moderate conservation values (classified 'Category R' by application of the questionnaire contained in EPA Bulletins 374 and 686, (guides towetland management in and near Perth) – those values are well-represented in the region and can be re-established or even enhanced by post-mining rehabilitation;

- seven other wetlands covered by the *Environmental Protection (Swan Coastal Plain Lakes) Policy (1992)* would not be affected directly by project operations, and can easily be insulated from indirect effects;

- groundwater abstraction for process water supplies and dredge pond operation would have no negative effects on water tables in wetlands not directly affected by project operations, or on the regional ground water resource;

- noise from mining and processing operations would not cause noise at residences in the area at levels exceeding those embodied in noise control regulations that are currently in the final stages of drafting by the EPA; and

- noise from truck transport of product to the Port of Bunbury would not exceed the noise exposure criteria used by the Main Roads Department for management of traffic noise.

To enhance the understanding of biological systems in the project area, investigations carried out in December 1992 and April 1993 are being extended throughout 1993, with intensive flora and fauna studies scheduled for the spring of 1993. These studies are designed to facilitate development of monitoring programmes and subsequent environmental management plans, and to direct the development of appropriate rehabilitation plans and prescriptions.

Gwalia has consulted with a wide range of government instrumentalities and community groups and members since December 1992, and plans to maintain appropriate liaison during development and operation of the project, to practicably manage the impacts of the project.

A number of environmental management commitments have been developed during the preparation of this PER, and are summarised at the end of the document. The commitments will form the basis of the environmental management programme which will progressively be developed to responsibly manage the impacts of the project during its operation and decommissioning.

CONTENTS

1. Introduction

Gwalia Consolidated Ltd (Gwalia) is examining the feasibility of a silica sand mining and processing operation on private land north of the Kemerton Industrial Park, 12 km south-west of Harvey, Western Australia (Figure 1). A feasibility study, addressing engineering, commercial and environmental factors, is expected to be completed in July 1993. Market considerations make desirable a commencement of construction as soon thereafter as is possible, with operations commencing in the second quarter of 1994.

The project would involve both dry and dredge mining, on-site processing (washing and screening) and campaign trucking of product to the Port of Bunbury for export to glass manufacturers in SE Asia and possibly Europe.

The project would involve capital expenditure of approximately $10 million and an annual expenditure on goods and services of some $9 million at full production. An estimated 40 people would be directly employed at full production.

Between December 1992 and June 1993, Gwalia has consulted with a wide range of organisations and parties with an interest in or potentially affected by the project, to determine environmental and other issues requiring evaluation during the feasibility study. These consultations were based on a project model which, as a result of comments and suggestions from those contacted, has progressively been modified to optimise the commercial viability of the project and minimise its impacts.

A Development Proposal describing the proposed project and its perceived impacts was submitted to the EPA in March 1993; that document has also been used to explain the proposal to the various interested and potentially-affected parties.

On 26 March 1993, the EPA advised that a level of assessment of Public Environmental Review (PER) had been set under the terms of the *Environmental Protection Act 1986*. On 7 April 1993, the EPA provided guidelines for the preparation of the PER – the guidelines are included in this document as Appendix A.

This PER identifies the environmental issues involved (wetland conservation, groundwater impacts and transport noise impacts are the major considerations), outlines plans developed to manage these impacts on the basis of studies carried out to date, and describes ongoing studies designed to allow refinement of environmental management programmes. It also contains a summary of commitments by the proponent to environmental management of the project.

2. The Proponent

Gwalia Consolidated Ltd is a Western Australian public company with interests in tantalum, tin, talc, kaolin, graphite and petroleum operations in Australia. The Company specialises in the mining and marketing of strategic and industrial minerals. In WA, it operates the Greenbushes (tantalum, lithium and tin) and Mt Seabrook (Meekatharra – talc) mines. It has an annual revenue of the order of $70 million per annum.

3. Description of the Project

3.1 General

The following project description is based on a development concept of a 10-year mine life. While the silica sand resource already identified by exploration could provide a longer life, the 10-year model allows a realistic financial evaluation – beyond 10 years, market and other commercial considerations are relatively imprecise.

The Kemerton orebody was selected for development after evaluation of silica sand resources throughout the South-East Pacific, including Australia. The particular grade and quality (trace element composition) of this orebody, together with its proximity to the Port of Bunbury, make it unique in both geological and commercial terms.

It is anticipated that initial production would be about 200,000 tonnes p.a. of silica sand. The market-driven project could develop over the subsequent five years to 840,000 tonnes p.a. Initially, operations would involve one shift per day; as throughput increased, a second and then a third shift (24-hour operation) would be added.

3.2 Location and Access

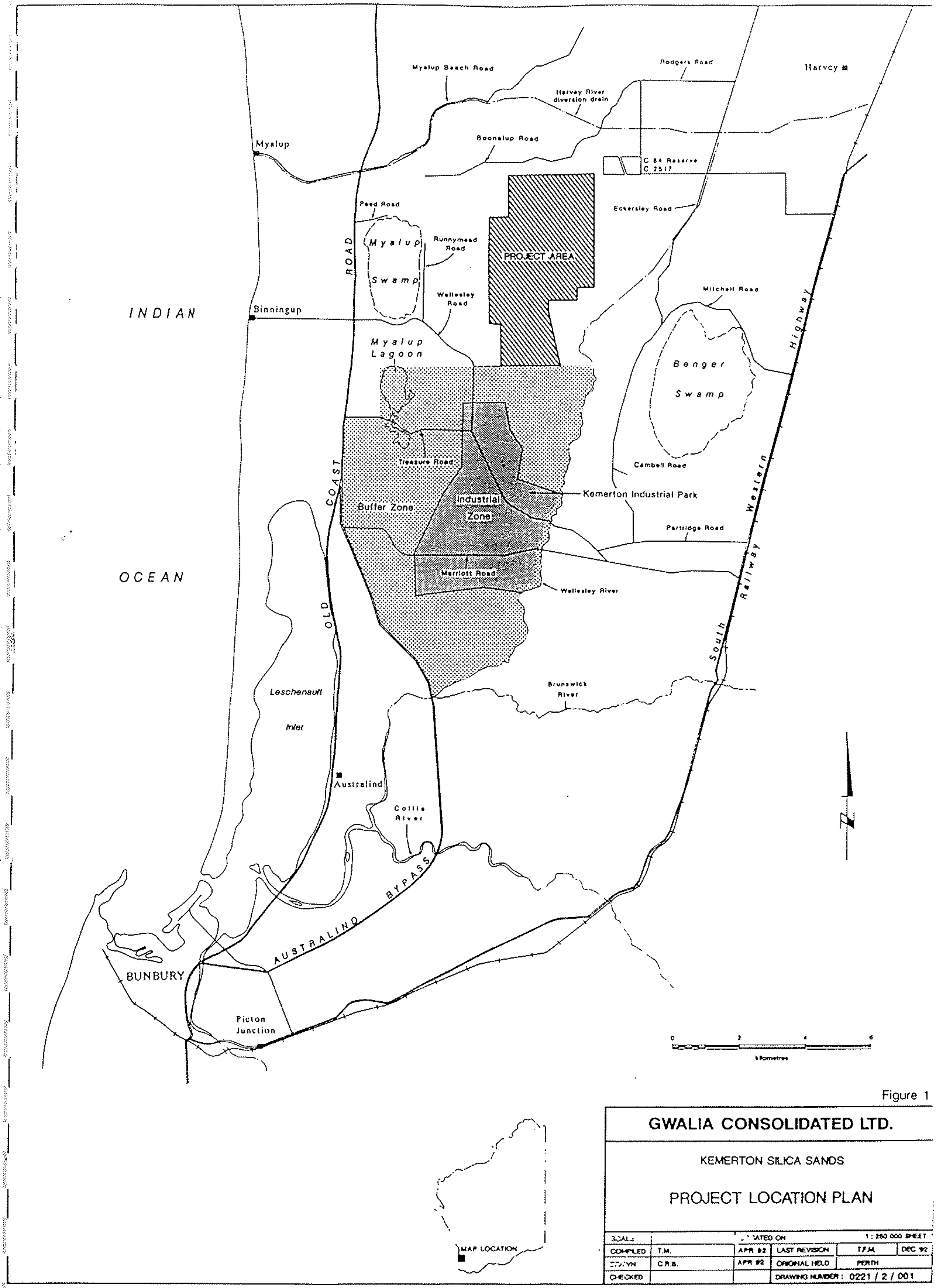
The silica sand deposit is located on a 1,620-hectare freehold property over which Gwalia has an option to purchase – that option would be exercised if the project were implemented. Mineral rights are to the land-owner.

The property lies north of Wellesley Road, approximately 4 km north of the Kemerton Industrial Park and 12 km south-west of Harvey (Figure 1). It is crossed north-south by the SECWA 132 kV Bunbury-Cannington No. 1 and No. 2 electricity transmission lines, the 415 kV Harvey-Kemerton transmission line and the Perth-Bunbury Natural Gas Pipeline (Figure 2).

Access to the southern boundary of the property is via Wellesley and Rhodes Roads, which are controlled by the Shire of Harvey. An unsealed internal access road would be constructed across the southern part of the property and then north to the mine-site along the already-cleared easement of the 132 kV Bunbury-Cannington No. 1 transmission line. Power supply to the project would also be constructed in this corridor.

3.3 Land Use, Vegetation and Geology

The area around the project is currently zoned "rural", although smaller subdivisions exist in the Wellesley Parklands area approximately half a kilometre south of the junction of Rhodes and Wellesley Roads (see Figure 11). Landcorp has advised that, save for one property in Wellesley Parklands (at the junction of Wellesley Road and Ridgeview Road) which is not owned by Landcorp, this subdivision constitutes the north-eastern part of the Kemerton Industrial Area Buffer Zone.



Myalup Beach Road
Rodgers Road
Harvey
Harvey River diversion drain
Boonalup Road
Myalup
C 84 Reserve
C 2517
Peed Road
Eckersley Road
Runnymead Road
Myalup Swamp
ROAD
PROJECT AREA
Mitchell Road
Wellesley Road
INDIAN
Binningup
Myalup Lagoon
Benger Swamp
Highway
Treasure Road
Cambell Road
Kemerton Industrial Park
COAST
Industrial Zone
Buffer Zone
Western
Partridge Road
Railway
OCEAN
Marriott Road
Wellesley River
OLD
South
Brunswick River
Leschenault Inlet
Australind
Collie River
BYPASS
AUSTRALIND
BUNBURY
Picton Junction
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kilometres
MAP LOCATION
GWALIA CONSOLIDATED LTD.
KEMERTON SILICA SANDS
PROJECT LOCATION PLAN
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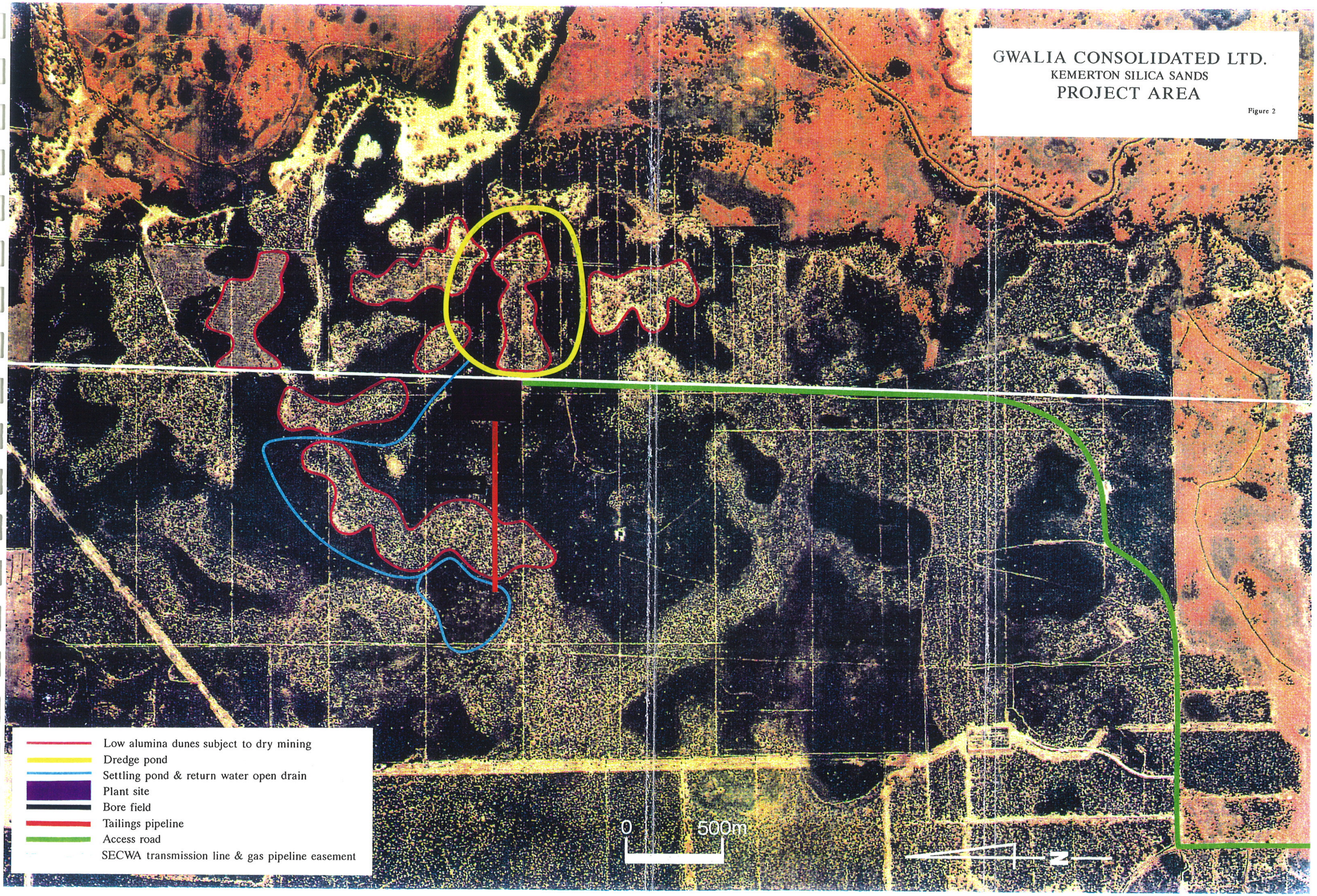
Figure 1


GWALIA CONSOLIDATED LTD.
KEMERTON SILICA SANDS
PROJECT AREA
Figure 2
Low alumina dunes subject to dry mining
Dredge pond
Settling pond & return water open drain
Plant site
Bore field
Tailings pipeline
Access road
SECWA transmission line & gas pipeline easement
0
500m
N

Other residences in the area are at least 1.8 km from the proposed plant-site. In relation to product transport, two residences are located within 100 metres of Wellesley Road between Rhodes Road and the Old Coast Road (see Figure 11), the next nearest residence being approximately 1.3 km from this section of Wellesley Road (see Figure 11).

The property on which the project would be developed has historically been used, with limited success, for grazing. Marketable timber has been removed from almost the whole of the area in past decades, and evidence of extensive brush-cutting exists, particularly in wetland areas. As evidenced by man-made drains, attempts have been made in the past to drain the property to improve agricultural productivity; however, the water table remains generally less than a metre below surface and sometimes above surface in broad depressions in winter.

The existing vegetation has been defined by studies by E M Mattiske & Associates in December 1992 (Mattiske & Associates 1993a) and April 1993 (Mattiske & Associates 1993b). A total of 24 plant communities and 27 vegetation mapping units have been mapped, dominated by the following plant communities:

- Upper slope Open Woodland dominated by *Eucalyptus marginata - Banksia* spp. and *Kunzia ericifolia* over *Stirlingia latifolia* and mixed shrubs over *Dasypogon bromeliifolius*

- Lower slope Open Woodland of *Eucalyptus marginata - Banksia* spp. and *Kunzea ericifolia* over *Melaleuca thymoides, Calytrix fraseri* and mixed shrubs

- Low closed heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* over mixed shrubs and mixed sedges, with occasional emergent trees

- Closed heath of *Astartea fascicularis, Calothamnus lateralis* and *Cassytha racemosa* over mixed sedges

The main vegetation communities are shown in Figure 3, in which a more detailed vegetation analysis carried out by Mattiske & Associates (1993 b) has been simplified to show basic types by amalgamation of similar sub-types.

The north-eastern part of the property in particular contains a number of wetlands/swamps, some of which are bounded by thickets of Paperbark (*Melaleuca spp.*): *M. viminea, M. rhaphiophylla, M. preissiana*. The understorey in these areas consists of various admixtures of *Viminea juncea, Pericalymma ellipticum, Calothamnus lateralis, Baumea articulata, Kunzea recurva, M. lateritia, Hypocalymma angustifolium* and sedges. All of these wetlands have sandy bottoms, with various amounts of accumulated organic matter. Several of the wetlands were gazetted in the *Environmental Protection (Swan Coastal Plain Lakes) Policy* established in December 1992.

The silica sand orebody occurs within the sandy Superficial Formation, which is underlain by a clay/shale unconformity separating the Superficial Formation from the Leederville Formation. Ore occurs over the full depth of the Superficial Formation – 15-20 metres. In some areas, ore exists in dunes elevated 3-5 metres above the generally flat terrain, which drains (sluggishly) to the east to the Wellesley River.

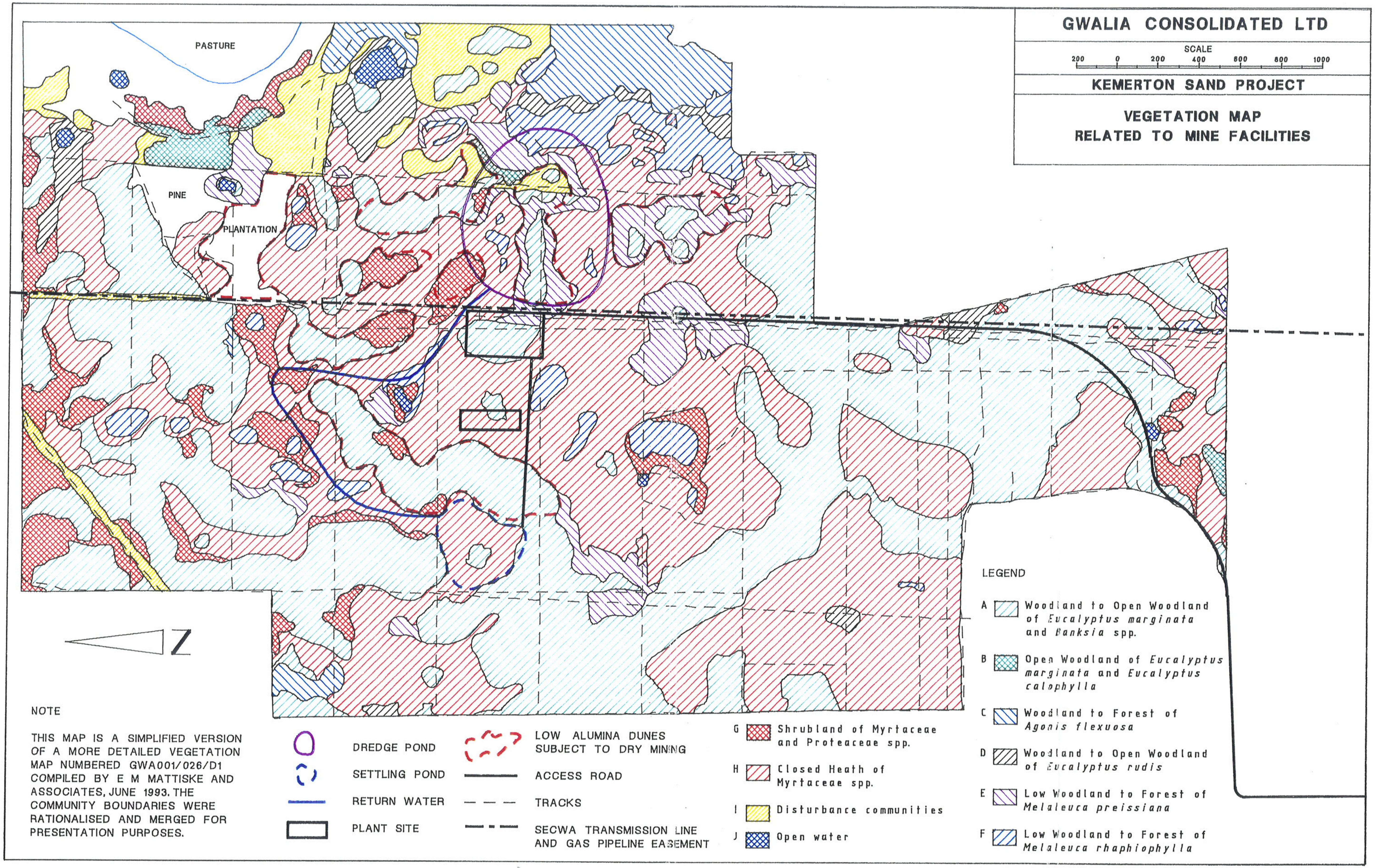

GWALIA CONSOLIDATED LTD
SCALE
200 0 200 400 600 800 1000
KEMERTON SAND PROJECT
VEGETATION MAP
RELATED TO MINE FACILITIES
PASTURE
PINE
PLANTATION
N
NOTE
THIS MAP IS A SIMPLIFIED VERSION OF A MORE DETAILED VEGETATION MAP NUMBERED GWA001/026/D1 COMPILED BY E M MATTISKE AND ASSOCIATES, JUNE 1993. THE COMMUNITY BOUNDARIES WERE RATIONALISED AND MERGED FOR PRESENTATION PURPOSES.
DREDGE POND
SETTLING POND
RETURN WATER
PLANT SITE
LOW ALUMINA DUNES SUBJECT TO DRY MINING
ACCESS ROAD
TRACKS
SECWA TRANSMISSION LINE AND GAS PIPELINE EASEMENT
LEGEND
A Woodland to Open Woodland of Eucalyptus marginata and Banksia spp.
B Open Woodland of Eucalyptus marginata and Eucalyptus calophylla
C Woodland to Forest of Agonis flexuosa
D Woodland to Open Woodland of Eucalyptus rudis
E Low Woodland to Forest of Melaleuca preissiana
F Low Woodland to Forest of Melaleuca rhaphiophylla
G Shrubland of Myrtaceae and Proteaceae spp.
H Closed Heath of Myrtaceae spp.
I Disturbance communities
J Open water

Figure 3

3.4 Mining Operations

3.4.1 Dry Mining

Ore occurring in the slightly-elevated dunes (see Figure 2) would be mined by front-end loader and delivered by pipeline to the processing plant as a slurry. This dry mining would constitute the initial operation of the project, and would continue during the life of the operation, contemporaneously with dredge mining.

Dry mining would simply remove or lower the height of parts of some of the dunes; not all of each dune is ore, so that no entire dune would be mined. Rehabilitation is addressed in Section 3.9 below. Over the ten-year project life, an area of approximately 20 hectares would be dry-mined – a significant proportion of this area would subsequently be subjected to dredge mining.

3.4.2 Dredge Mining

Proceeding at an average rate of 4-5 hectares per year, dredge mining would be commenced during the first year of operation. Thus, after 10 years, a pond of some 40-50 hectares would be established (Figure 2 shows the projected dredge pond area after 10 years of operation).

The dredge would operate over the full face of the orebody without the need to reduce the water table to access ore in the lower parts of the soil profile. The maximum depth of ore extraction would be 15 metres below the water table, as defined by the design of the dredge. Figure 4 shows a typical geological cross-section.

Slurried ore would be delivered by pipeline to the processing plant.

3.5 Ore Processing

Ore, comprising 95-97% silica sand, would be processed on site (Figure 2) using wet-separation washing, milling and screening techniques to produce silica sand product. No chemical treatments are required, other than the possible addition of flocculants to facilitate settling of the clay tailings produced from the ore processing plant (see Section 3.6 below). Figure 5 shows a schematic outline of the process, and Figure 6 shows the detail of facilities in the plant-site area.

Product would be stockpiled in the open on site prior to trucking to the Port of Bunbury for shiploading and export. The freely-draining product is expected to contain 3-5% moisture (by weight) at the point of shiploading – rain water would quickly drain from the product stockpile.

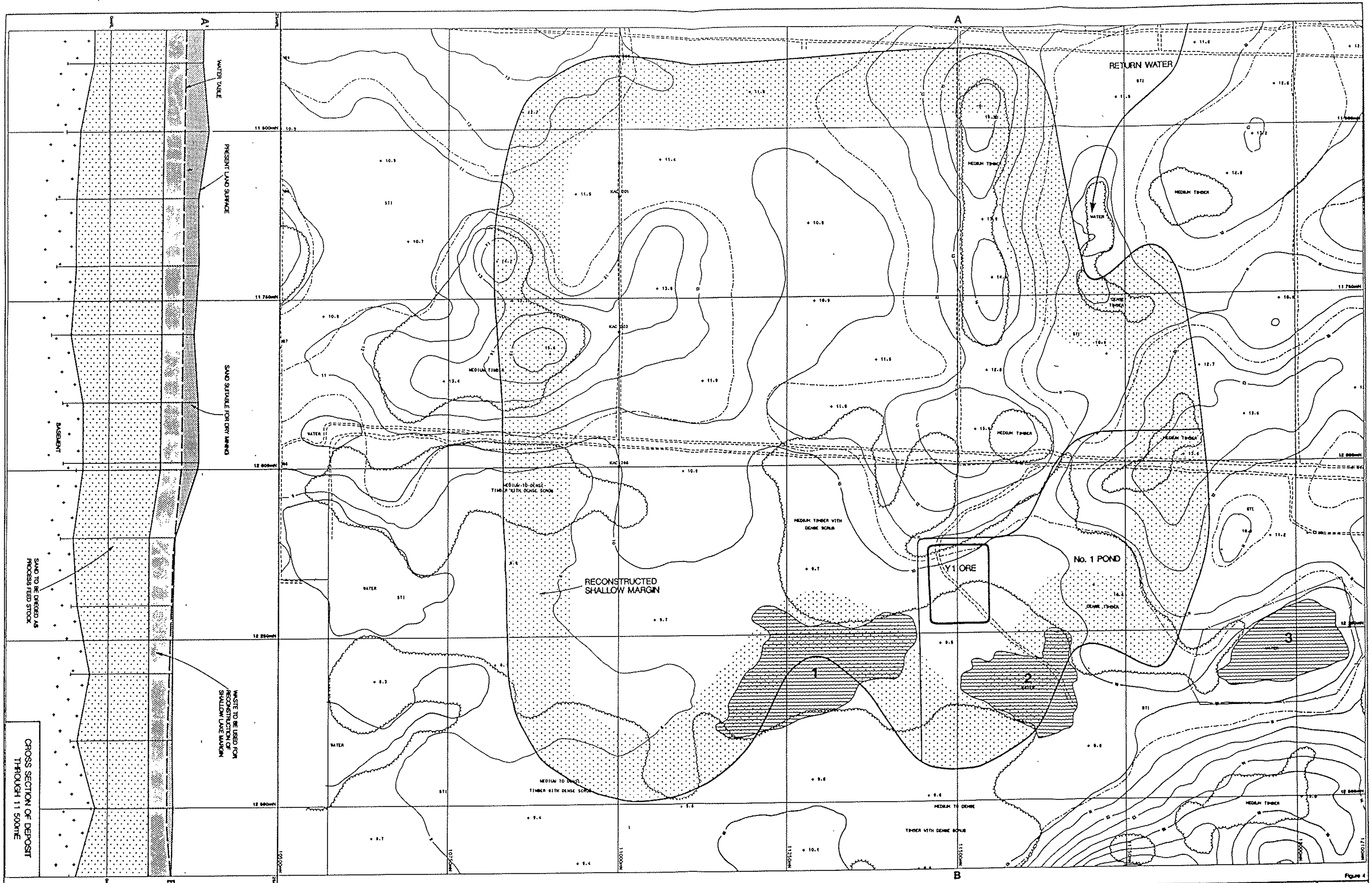


Figure 4

Date	Revision	Chkd	By	Date	Revision	Chkd	By

Orientation

Date of Photography 22 July 1992 Scale 1:10000

GWALIA CONSOLIDATED LTD.
KEMERTON

PROPOSED DREDGE POND
& TYPICAL CROSS SECTION

Surveyd	
Field Bk	
Level Bk	
V.Datum	LOCAL
H.Datum	LOCAL
Check'd	

ASSOCIATED SURVEYS INTERNATIONAL Pty. Ltd.

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Date	23/11/92
Scale	1:2500
Drawn	DIGITAL/CS
Ref. No.	9317/92
Plan No. 9317-11	Rev 0

DRAWING NUMBER : 0221 / 7 / 001

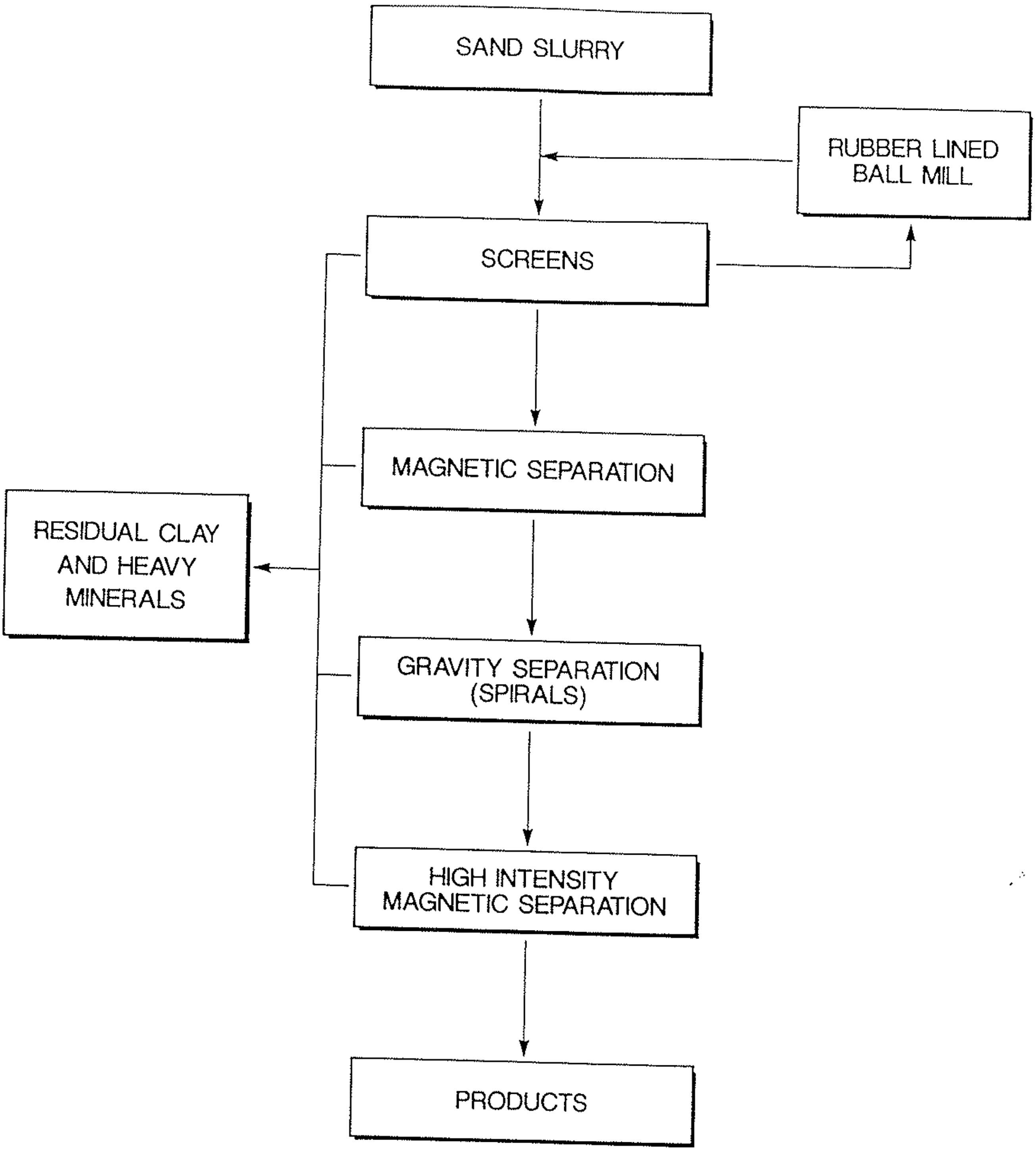


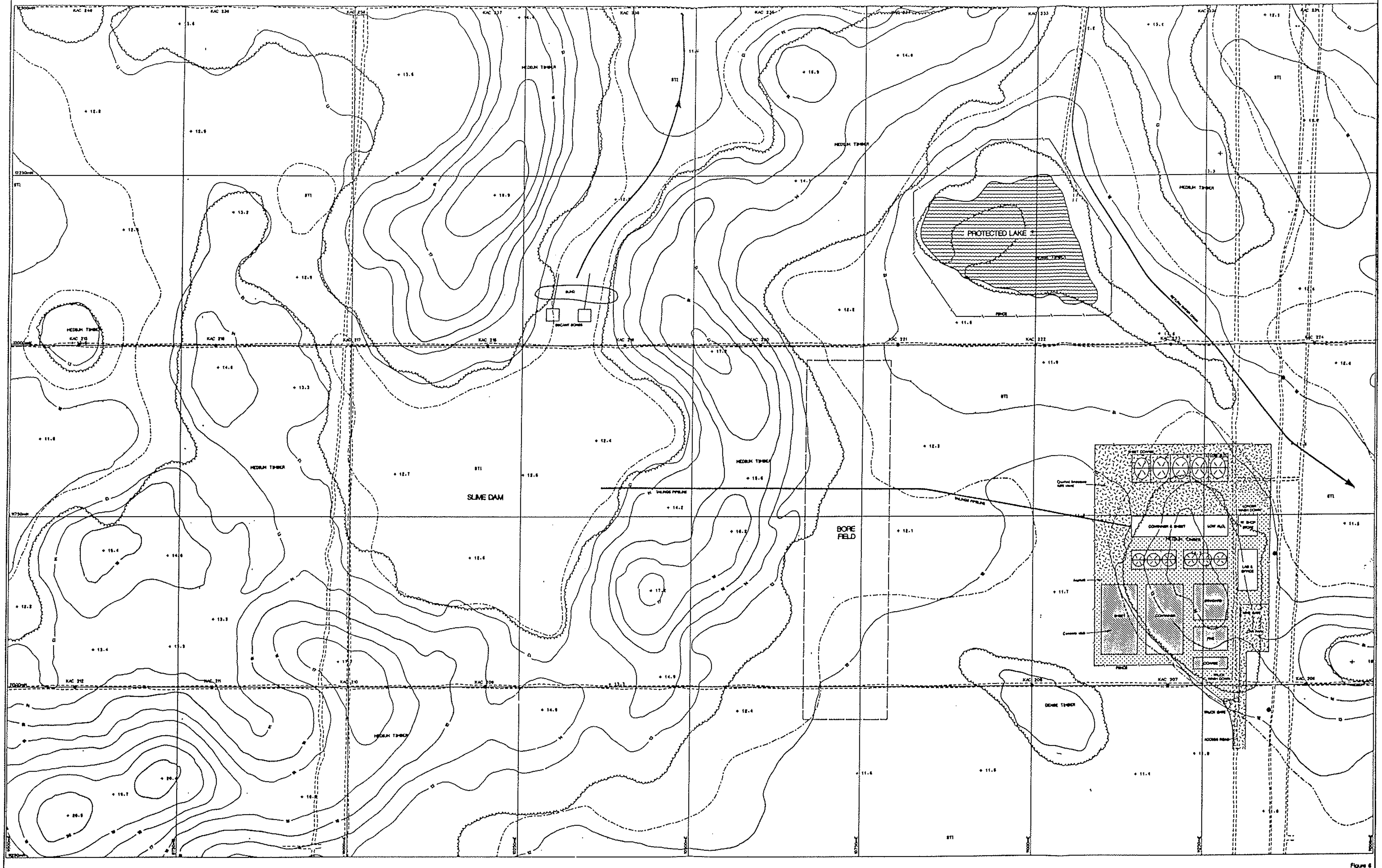
Figure 5

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SANDS

GENERALIZED PROCESS FLOW SHEET

SCALE			LOCATED ON	1 : 250 000 SHEET
COMPILED	M. D. BALE	JUNE'93	LAST REVISION	
DRAWN	C. L. SCAFE	JUNE'93	ORIGINAL HELD	PERTH
CHECKED			DRAWING NUMBER : 0221 / 2 / 019	



Date	Revision	Chkd	By	Date	Revision	Chkd	By

Orientation

NOTE:
THIS MAP WAS PRODUCED FROM 1:10000 AERIAL PHOTOGRAPHY. ACCURACIES OF THE MAP DATA ARE TO NORMAL MAPPING SPECIFICATIONS OF 0.5 METRES HORIZONTALLY AND 0.2 METRES VERTICALLY. CAUTION SHOULD BE TAKEN IF USED FOR ENGINEERING PURPOSES.

Date of Photography 22 JULY 1992 Scale 1:10000

GWALIA CONSOLIDATED
LOCATION MAP
PROPOSED PLANT SITE

Surveyd	
Field Bk	
Level Bk	
V.Datum	LOCAL
H.Datum	LOCAL
Check'd	31/5/93

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Date	28/5/93
Scale	1:2500
Drawn	DIGITAL/CS
Ref. No.	9317/92
Plan No.	9317-12
Rev	0

DRAWING NUMBER: 0221 / 7 / 002

3.6 Tailings Management

Clay material, comprising 3-5% of the ore, would be separated from the ore in the processing plant as a low-density slurry (2-4% solids, by weight). This tailings slurry would be pumped to a Tailings Pond (and drying bed) created from a natural depression on the property, approximately 1 kilometre to the west of the processing plant (Figure 2). A simple, adjustable weir system would be used to recover supernatant water (decant) from the settled solids, and the decant returned to the dredge pond and/or the processing plant via a drain to be constructed along natural contours (Figure 2). As necessary, non-hazardous and degradable flocculants would be added to the tailings slurry at the processing plant to facilitate settling of solids and thus recovery of decant water for the processing and dredge-mining operations.

After cessation of tailings discharge to the Tailings Pond, solar drying would produce material which would be recovered for incorporation into the sandy soils on the property, thereby improving their water- and nutrient-holding properties. This clayey material would be particularly useful in the rehabilitation of dry-mined areas and dredge pond perimeters (see Section 3.9 below).

3.7 Product Transport

Product would be trucked to the Port of Bunbury for export. Because of the current lack of dock-side storage facilities, the high capital cost of establishing new facilities and the additional operating costs that would be involved in double handling through such facilities, trucking campaigns would be used.

Shiploading would take place at the Bunbury Inner Harbour; the Bunbury Outer Harbour would not be used. Initial plans were to use the Outer Harbour, but these were altered in light of potential noise impacts on Bunbury residents, and when re-development plans for the Outer Harbour were brought to Gwalia's attention.

Initially (for the first year or two, depending on project development time-lines), 20,000-tonne shiploads would be used, but the viability of the project depends on the economies of scale that come from ship-loadings of 40,000 tonnes.

Prior to the establishment of an appropriate berth and permanent loading facilities at the Inner Harbour, Gwalia would construct temporary facilities at the existing General Cargo berth at the Inner Harbour, to the east of the woodchip stockpile and loading facility. These temporary loading facilities would be constructed so that other uses of the General Cargo berth were not impeded, and the timing of silica sand loadings would be planned in consultation with the Bunbury Port Authority to manage potentially-conflicting demands on the berth.

Campaign trucking at the initial production rate of 200,000 tonnes p.a., using 20,000 tonne loadings, would involve 10 campaigns a year, each of two days duration. With 40,000 tonne shipments, campaigns would each be of four days duration; at a production rate of 200,000 tonnes p.a., five campaigns a year would be required, increasing to 21 campaigns p.a. at the feasibility study production capacity of 840,000 tonnes p.a. All campaign transport of product would be conducted on a 24-hour basis; regardless of annual production rate, truck separation during campaigns would be some seven minutes in each direction – an estimated 9-10 kilometres.

To minimise potential impacts of truck transport of product, studies have been carried out to ascertain the feasibility of developing storage facilities at Bunbury Port; scenarios of reduced trucking frequencies and restricted trucking times during the day have been examined. Port storage would involve a covered stockpile, together with unloading, reclaim and loading equipment. It has been shown that the additional capital costs of constructing the storage and handling facilities, plus the additional operating costs associated with demurrage and double-handling of product, seriously diminish the financial viability of the project – this reflects the very nature of this low-margin, high-volume project.

The route used for campaign trucking would be via Rhodes and Wellesley Roads to the Old Coast Road, and then via the Australind Bypass, Eelup Rotary and Koombana Drive and Leschenault Drive to the Inner Harbour.

The Main Roads Department (MRD) have advised that concept plans exist for the creation of a dual carriageway on the Old Coast Road between Wellesley Road and the Eelup Rotary. While it is unlikely that the whole section will be upgraded by 1995, some parts will be completed if funds become available. Even at full production, the traffic impacts of campaign trucking are considered by MRD to be manageable with this level of road design, and the project is unlikely to be operating much above the 200,000 tonnes p.a. level prior to 1995.

To facilitate road transport of product, Gwalia plans, in consultation with the Shire of Harvey, to upgrade Wellesley Road between Rhodes Road and the Old Coast Road to a standard commensurate with the vehicles and loads proposed. At the Wellesley/Old Coast Roads junction, it is planned that merging and turning lanes be constructed to MRD requirements.

Within the Bunbury area, campaign trucking is an established operation for mineral sands export to the Outer Harbour. Since this project does not involve use of the Outer Harbour, potential noise nuisance in the Bunbury area would be limited to the extreme eastern part of the East Bunbury residential area near Koombana Drive, between the Eelup Rotary and Leschenault Drive (see Figure 10 insert).

3.8 Water Supply and Management

The dredge operation would be feasible without supplementary water supply to the dredge pond, simply by utilising the existing high water table (generally less than one metre below surface; sometimes at or above surface). Supplementary water for processing would be sourced from the unconfined aquifer of the Superficial Formation, subject to the approval of the Water Authority of WA (see Figure 5 for proposed borefield location). Once reasonably steady-state processing operations were established, decant return from the Tailings Settling Pond would return water to the dredge pond and/or the processing plant, reducing the need for supplementary water.

The question of water supply, water balance and water management has been addressed in a study commissioned by Gwalia in December 1992. That study, carried out by Dames & Moore, was completed in February 1993. The study includes assessment of the likely impacts of project operations on local and regional groundwater, and thus likely impacts on water levels in swamps and wetlands – see Section 4.3.

3.9 Rehabilitation

3.9.1 General

Rehabilitation planning is critically dependent on long-term land use strategies. It would be in the proponent's interest to maintain the commercial value of the property, so that at this stage of project evaluation, the primary aim of rehabilitation is to restore stable, vegetated landforms to prevent erosion and other forms of land degradation. Other, longer-term options include hardwood plantations, agricultural development and conservation, especially of natural and man-made swamps and wetlands.

Topsoil (up to 10 cm) from all areas disturbed for project activities would be salvaged and stockpiled for subsequent use in rehabilitation. In addition to providing a suitable physico-chemical substrate for plant growth, this topsoil would also contain plant propagules and diapausal and aestivating stages of lower animals (especially invertebrates) which would enhance the effectiveness of rehabilitation.

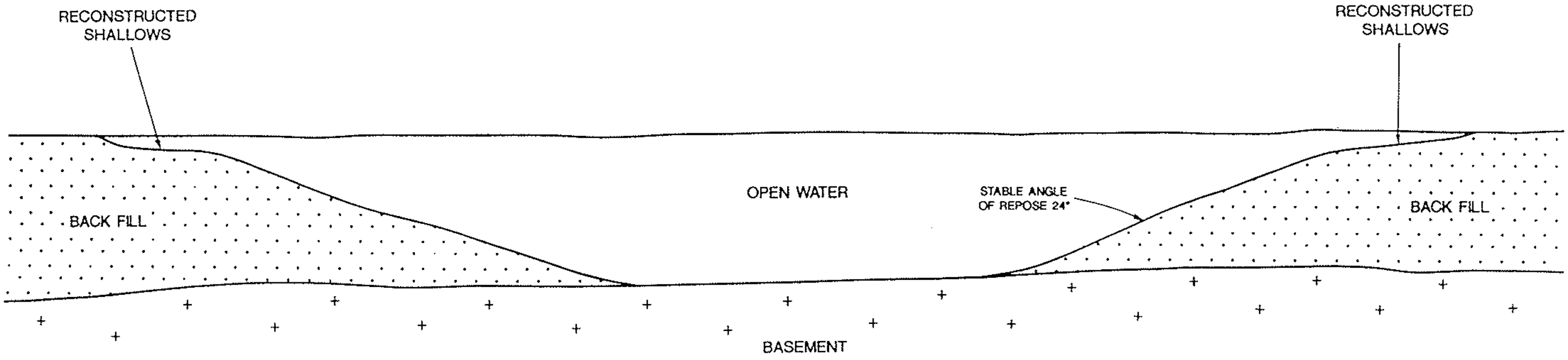
3.9.2 Dry-Mining Areas

Dry mining areas not ultimately subjected to dredge mining would be battered down to stable slopes as advised by the Department of Minerals and Energy and revegetated with appropriate plant species. Improved soil water- and nutrient-holding capacity would be provided by the blending of dried process tailings into the poor-quality sandy soils.

3.9.3 Dredge Pond

The dredge pond, occupying an area of 40-50 hectares after 10 years, has the potential to be developed as an artificial wetland, as at least replacement for the two wetland areas disturbed by mining. It has been determined that the mining plan can include a wetland design, with engineered shallows over a 100-metre wide perimeter around the pond and minimisation of the area of deep water (Figure 7 shows a schematic cross-section after rehabilitation).

Plant species can be established around the pond perimeter to provide ecological values appropriate to the geographical location. There are a number of examples of such man-made wetlands in the South West of WA; for example, RGC's wetland at Capel; Gwalia's ponds at Greenbushes.



SCHEMATIC DIAGRAM ONLY

Figure 7

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SANDS

FINAL LAKE FORM - POST REHABILITATION

SCALE	—		LOCATED ON	1 . 250 000 SHEET
COMPILED	M. D. BALE	JUNE'93	LAST REVISION	
DRAWN	C. L. SCAFE	JUNE'93	ORIGINAL HELD	PERTH
CHECKED			DRAWING NUMBER : 0221 / 2 / 020	

In rehabilitating the dredge pond, Gwalia is committed to attaining a standard acceptable to the State. This standard would be agreed on in consultation with the EPA, the Department of Minerals and Energy and the Department of Conservation and Land Management, whose advice would be sought during development of detailed prescriptions based to a large extent on the results of detailed biological studies to be carried out in the spring of 1993 (see Section 4.2 below).

In relation to the role of invertebrates, which are an important part of the food-chain for waterbirds, discussions with CALM (Mr S Halse, CALM Woodvale) have been held to assess particular rehabilitation needs. CALM have advised that, provided that rehabilitation re-establishes a vegetation structure and function comparable with that existing before disturbance, especially in terms of vegetation strata and capacity to provide organic matter input to shallows through leaf litter, an adequate suite of invertebrate species should recolonise. Even if the rehabilitated wetland is somewhat wetter or drier than the pre-disturbance state, invertebrate populations have sufficient adaptability and resilience to establish a stable and functional component of the total ecosystem.

3.9.4 Tailings Pond

The dried clay from the Tailings Pond would be re-won and used as a soil conditioner, as described above. It could be applied to dry-mined areas, the dredge pond/wetland periphery and other cleared areas. The resultant improvement in water- and nutrient-holding capacities would improve the productivity of the soils, and reduce the potential for eutrophication of water bodies from nutrients originating from fertilisers.

The Tailings Pond area itself, after decommissioning, could be cultivated to blend remnant dried tailings into the underlying sandy soil profile and revegetated. Depending on resultant characteristics of the soil and on the water table, appropriate plant species could be sown or planted – options include trees.

4. Environmental Issues and their Management

4.1 Wetlands

Nine of the wetlands in the project area or in the immediate vicinity are protected under the terms of the *Environmental Protection (Swan Coastal Plain Lakes) Policy* (EPP) established in December 1992 under the provisions of the *Environmental Protection Act 1986* (Figure 8). The EPP has the aim of protecting the environmental values of remaining wetlands and lakes on the Coastal Plain; more than two-thirds of the areas existing at the time of European settlement have been degraded or destroyed. The EPP does, however, provide a mechanism for mining in lakes: specific authorisation under the *Environmental Protection Act 1986* is required, one of the pragmatic considerations being the extent to which post-mining rehabilitation can re-establish pre-mining values.

Only two of these wetlands (Nos 1 and 2 on Figure 8) would be directly impacted by project operations, and the remaining seven can be protected from both direct and indirect impacts.

All nine wetlands have been subjected by flora and fauna consultants to the questionnaire contained in EPA Bulletins 374 and 686 (Environmental Protection Authority 1990, 1993) (see Appendix B). Wetlands 1 and 2 (those to be disturbed) have been classified in 'Category R' (Resource Enhancement). EPA Bulletins 374 and 686 state:

> *"The term 'resource enhancement' has been used to indicate that opportunities may exist for commercial developments to enhance the conservation values of wetlands (ie the wetland resource) ..."*

As part of a biological investigation carried out in December 1992, these and other wetlands were assessed by E M Mattiske & Associates (Mattiske & Associates 1993) and Ninox Wildlife Consulting (Ninox Wildlife Consulting 1993a). Wetland vegetation was classified using the system developed by Semenuik (1987) and management objectives ascribed using categories developed by the Environmental Protection Authority (1990,1993).

As noted in the Ninox study, some of the faunal habitat values of wetlands which would be disturbed by project operations are dwarfed by the habitats provided regionally by Benger Swamp to the south east and Leschenault Inlet to the south west. The total area of the two wetlands which would be disturbed by this project is 4.0 ha (the total area of all EPP-wetlands in the project area is 12.6 ha), compared with an area of Benger Swamp of 1,086 ha – these data are taken from 1:10,000 aerial photographs of the project area and from a 1:25,000 topographic map (South West, Harvey sheet).

The findings of these biological studies, and the impacts of the project on individual wetlands, is summarised below in Table 1; detailed descriptions of individual EPP-wetlands are contained in Appendix B.

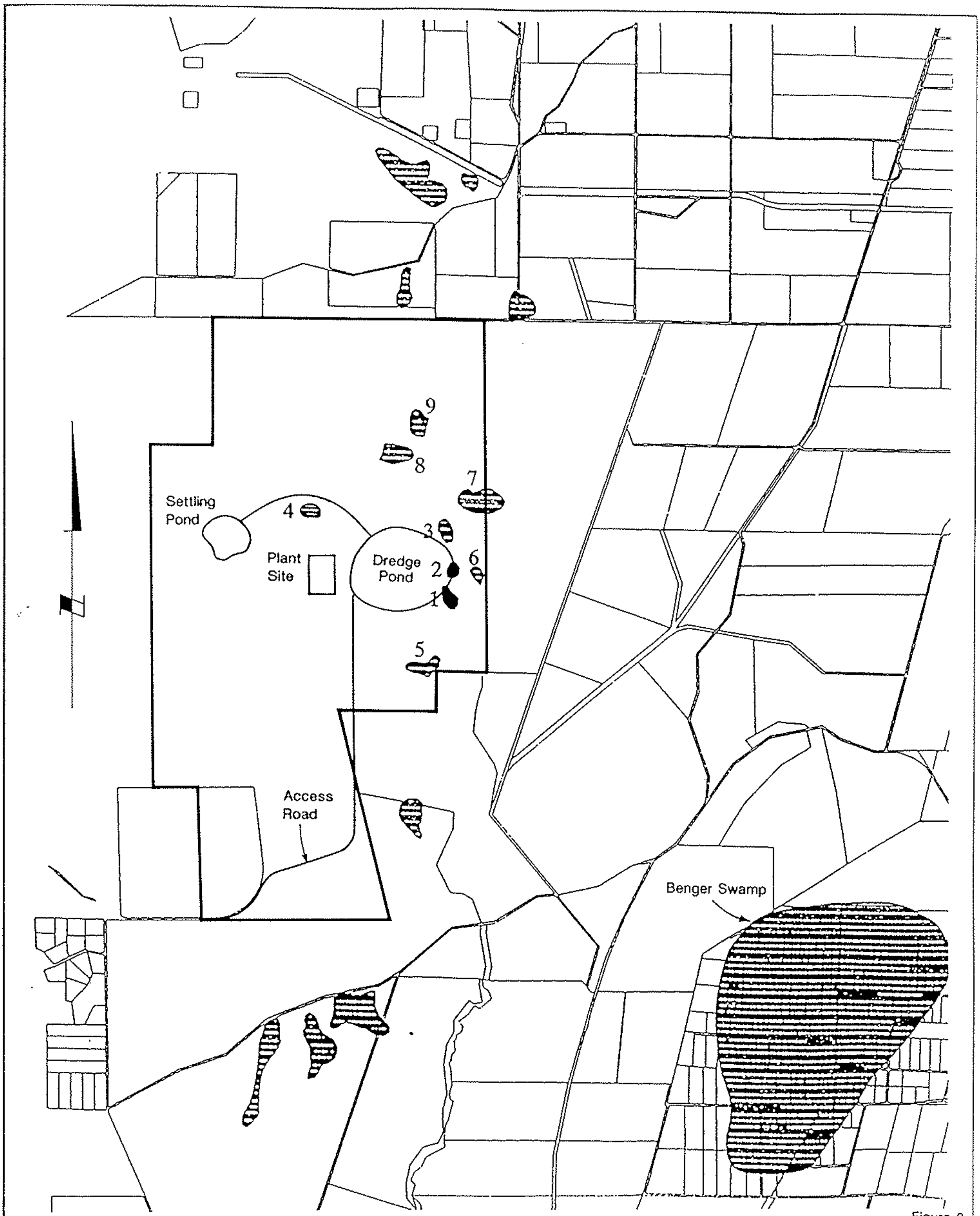


Figure 8

Scale 1 : 50 000

0 1 2

kilometres

Project area

1 & 2 Lakes to be affected by mining

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SAND PROJECT

E.P.A. NOMINATED WETLANDS

SCALE	1 : 50 000	LOCATED ON	COLLIE	1 : 250 000 SHEET
COMPILED	T. F. MONKS	DEC'92	LAST REVISION	FEB 93
DRAWN	C. L. SCAFE	DEC'92	ORIGINAL HELD	PERTH
CHECKED			DRAWING NUMBER :	0221/2/011

Table 1: Summary data for wetlands in the Kemerton Silica Sand project area

	Conservation Significance			
Wetland Code (refer Figure 5)	**Vegetation**	**Fauna Habitat**	**Impact of Project**	**Area** (ha)
1	Moderate	Moderate	Mining	2.77
2	Moderate	Moderate	Mining	1.22
3	Moderate	Moderate	Not impacted	1.59
4	High	Moderate	Not impacted	1.00
5	Very high	Moderate	Not impacted, remote	0.75
6	Moderate	Moderate	Not impacted	0.80
7	Moderate	High	Not impacted, remote	2.91
8	Moderate	Moderate	Not impacted, remote	1.12
9	High	Very high	Not impacted, remote	0.48

Of the seven wetlands not impacted by operations, Nos 5, 7, 8 and 9 are remote from operational areas by at least several hundred metres (see Figure 8). Wetland No. 6 is some two hundred metres from the proposed dredge pond, and Wetland No. 3 is 75-100 metres from the pond. Wetlands Nos 5, 6, 7, 8 and 9 are so remote from operations as to require no special action to protect them (the draw-down in water table as a result of borefield operation would be imperceptible – see Section 4.3 below), and Wetland No. 3 would be fenced to protect the water body and surrounding buffer vegetation from inadvertent impact – some minor effects on water level might be experienced in Wetland No. 3, but these are likely to be restricted changes of less than one metre, of the same order as natural seasonal variations in water level (it should be noted that a high pond water level will be sought to ensure efficient operation of the dredge).

Wetland No. 4 lies adjacent to the proposed route for return of decant water from the settling pond. Thus, infiltration of water from the unlined return channel would ensure that borefield operation would not affect water level in this lake; in fact, slight groundwater mounding is more likely. No direct impacts on this wetland and its surrounding vegetation buffer are currently envisaged, and the area would be fenced to prevent inadvertent entry. The area of wetland No. 4 does contain ore resources, but their exploitation is not planned in the ten-year life of the current project model; should such exploitation become desirable, specific approval would be sought from the state.

In developing the project concept model to this stage, the potential for avoiding impacts on wetlands has been closely examined, because of the general ecological and conservation values ascribed to these areas. The impacts on Wetlands 1 and 2 (see above table) are unavoidable, since the ore located under and around them is pivotal to the commercial viability of the project, as is discussed below; forgoing this ore, which is of a unique quality and grade (a reflection of trace element composition) and thus commands a high price to be obtained at the start of the project, would make the project financially tenuous.

Given that the two wetlands which would be impacted by project operations have *moderate* ecological significance (see Table 1 and Appendix B), their disturbance is not considered significant in a regional conservation sense. Moreover, post-mining rehabilitation would re-establish, indeed even expand, areas of wetland, resulting in a net gain outcome on a life-of-project basis. As noted in Section 3.9.3, mine-planning would include the engineering of shallows and beaches and the establishment of vegetation to provide the habitats and conditions necessary for development of productive and diverse wetland ecosystems.

While recognising the importance of remaining wetlands on the Swan Coastal Plain, as reflected in the EPP for Coastal Plain Lakes, it is noted that the EPP does (in Part 3) allow for mining when the activity is authorised under the terms of the *Environmental Protection Act 1986*. The classification of these lakes as 'Category R' according to EPA Bulletins 374 and 686 also provides for such activity. In this context, the following considerations are relevant:

- Preliminary biological studies (Mattiske & Associates 1993 a,b, Ninox 1993), which will be expanded on by supplementary studies to be carried out in the spring of 1993 and by studies being carried progressively throughout 1993 to assess waterbird use, indicate a low regional significance of the lakes in question. While the lakes have moderate local significance, their regional values, particularly in terms of water-bird habitats, should be viewed in the context of those of Benger Swamp and Leschenault Inlet.

- To forgo the ore located under and around the lakes in question would hazard the viability of the project – some of the highest grade and best quality ore lies in this area, and its mining is necessary for the generation of the initial cash flow which is crucial to the long-term financial integrity of the project. Nearby areas of ore have been forgone because their mining would affect other EPP-wetlands, but the ore associated with wetlands 1 and 2 is pivotal to the project.

- Rehabilitation, as discussed in Section 3.9.3 above, is considered capable of reconstructing wetland values, possibly extending them (compared with the current situation), since a larger area of water will be created for the dredge pond. Shallows can be engineered as part of the mining plan, to provide for ecological productivity, and islands can be created to provide protection against predators. Topsoil and sediments would be salvaged during operations for subsequent use in rehabilitation (benefitting both plant and animal, especially invertebrate re-establishment), and re-vegetation would re-establish ecological values in lake-fringe areas.

- Thus, while there would be some temporary loss of habitat during operations, rehabilitation could replace, even enhance, conservation values. Biological studies indicate a prime function of the wetlands in the project area as summer drought refuge; even during operations, the seven unaffected lakes in the area could substantially meet this need – only about 30% of the total area of wetland on the project area would be disturbed, with the long-term situation (10 years) being one in which the total lake area would be increased from 12.6 hectares to more than 40 hectares – see Table 2 for detailed evaluation.

- Gwalia is committed to investigating the desirability and feasibility of ultimate vesting of rehabilitated areas, especially wetlands, with relevant authorities.

Table 2: Summary of Impacts of Ten-year Project on Areas of Wetlands of Different Types. (All figures in hectares.)

Wetland Type	Before	After			Total
		Lost	Created	Nett Gain	
Sumpland	8.5	4(1)	10(2)	+6	14.5
Lake	3.4	0	30(2)	+30	33.4
Sumpland/Palusplain	0.8	0	0	0	0.8
Total	12.7	4	40	+36	48.7

NOTES: (1) EPP-Wetlands Nos 1 &2 (see Table 1).
(2) Based on 40-hectare dredge pond, with 100-metre annulus of engineered shallows.

4.2 Rare and Endangered Flora and Fauna

The field investigations by E M Mattiske & Associates in December 1992 and April 1993 detected no plant species which have been declared as Rare Flora under the terms of Sub-section 23F of the *Wildlife Conservation Act 1950.* A total of 54 plant families and 238 vascular plant species were recorded in the project area.

Four priority species, as defined by the Department of Conservation and Land Management (1992) were recorded in these studies: *Boronia capitata* subsp. *gracilis* (P2), *Acacia semitrullata* and *Cartonema philydroides* (P3), and *Acacia flagelliformis* (P4). *Boronia juncea* - true type (DW184/EH304) was also recorded.

While no rare or endangered fauna species (as defined in Schedules 1 and 2 of the *Wildlife Conservation Act 1950*) were detected during a field survey in December 1992 by Ninox Wildlife Consulting, it has been predicted from the literature that up to ten such species might be found after extensive investigations over all seasons – if present, five of these would be resident (Red-eared Firetail *Emblema oculata*, Chuditch *Dasyurus geoffroii*, Western Ringtail Possum *Pseudocheirus peregrinus occidentalis*, Carpet Python *Morelia spilota imbricata*, Southern Brown Bandicoot *Isoodon obesulus fusciventer*) and five would occur as migrants and/or nomads (Australasian Bittern *Botaurus poiciloptilus*, Freckled Duck *Stictonetta naevosa*, Peregrine Falcon *Falco peregrinus*, Carnaby's Black Cockatoo *Calyptorhychnus funereus laterostris*, Baudin's Black Cockatoo *C. baudini*).

In a regional sense, the proposed mine area is described by Ninox as having no exceptional qualities or distinctive suites of fauna – all habitats are replicated elsewhere in this part of the Swan Coastal Plain. Wetlands in particular are seen to have comparatively minor significance in a regional context, since Benger Swamp to the south-east and Leschenault Estuary to the south-west are the dominant habitats (see Section 4.1 above) and are well-protected.

To further examine and facilitate management of environmental impacts of the project, Gwalia has commenced additional biological investigations. Seasonal factors demand that the bulk of these investigations be carried out in spring; plant phenology and fauna breeding and other activity cycles make studies in other seasons very much less productive, and less useful in the development of strategies to minimise and manage impacts on flora and fauna.

Additional flora and vegetation work is scheduled for October 1993, with all vascular plants being collected and identified. Declared Rare Flora and Priority Species will again be searched for, to supplement investigations made in December 1992 and April 1993.

A six-day fauna investigation is also scheduled for October 1993, co-ordinated with the flora and vegetation work. The fauna studies are designed to define more precisely:

- the vertebrate fauna of the area, particularly small mammals, amphibians and reptiles
- the status of gazetted rare fauna
- the relationships between vegetation communities and fauna populations
- fauna habitats of high conservation value
- aquatic fauna (including invertebrate) populations of the wetlands
- monitoring procedures to facilitate ongoing assessment and management of impacts on fauna

In addition to the October 1993 fauna work, one-day field trips are planned for April (completed), June (completed), August and December 1993, and February 1994. These short field trips are aimed at quantifying waterbird use of the wetland areas, and establishing the presence or absence of significant or rare species considered likely to be present in the area: the Freckled Duck *Stictonetta naevosa*, Southern Brown Bandicoot *Isoodon obesulus*, Western Ringtail Possum *Pseudocheirus occidentalis* and Chuditch *Dasyurus geoffroii.*

The April 1993 field trip (Ninox 1993b) added ten species to the list developed from the December 1993 field trip: four birds; one mammal; two frogs; two skinks and one snake. However, and surprisingly in view of detailed searching, none of the above-mentioned significant/rare species were either observed or their tracks, nests and diggings discovered. Searching will be continued in future field campaigns, although it had been expected that at least tracks, nests or diggings of the Southern Brown Bandicoot and the Western Ringtail Possum would have been observed during the first three campaigns (December 1992 and April and June1993) – the presence of foxes and/or feral cats is suspected.

4.3 Hydrological Impacts

Because the project would involve creation of an additional 65-80 hectares of evaporative surface (40-50 hectares for the dredge pond, 25-30 hectares for the Tailings Pond), impacts on local and regional hydrology have been assessed. Dames

& Moore carried out hydrological and geotechnical investigations at the project site in December 1992 and January 1993 (Dames & Moore 1993), and used the resultant data, together with existing information (e.g. from the Geological Survey of WA) to predict hydrological impacts and determine the feasibility and management of project water supply.

The schematic water balance for the project is shown in Figure 9.

The Dames & Moore study demonstrated the high permeabilities (average from 5 boreholes = 5.2 m/day) and high infiltration rates expected from the sandy soils of the project area. These data were used to model the potential impacts of the project, especially on water tables in wetlands which would not be disturbed by project activities. A number of scenarios were examined, to allow assessment of "worst cases" such as groundwater abstraction from a borefield located between the plant site and the tailings settling pond without the recharge of the unconfined surficial aquifers that would normally take place as process water was cycled between the dredge pond and the settling pond.

To place project water use into perspective, the annual groundwater throughflow in this (Myalup) are has been estimated at more than 19,000 ML per year (Deeney 1989). Gross water abstraction for the project at peak design capacity is estimated at some 5,000 ML per year; aquifer recharge from the tailings pond and decant return is expected to be at least 90% (reflecting the closed-loop nature of the operation's water management system), giving a net annual groundwater usage of about 500 ML, or 3% of the regional groundwater throughflow.

In the "worst case" (in terms of impacts on undisturbed wetlands), a maximum draw-down of 0.5 m is predicted for the nearest undisturbed wetland (No. 4) after 70 days of borefield abstraction without aquifer recharge – such a protracted period of no recharge is a highly improbable event since, after the establishment of operations, aquifer recharge will be a continuous occurence as tailings are deposited and decant water returned to process and the dredge pond *via* an unlined channel.

Under these more "normal" operational conditions, negligible groundwater draw-down is predicted at distances greater than 500 metres from the borefield, reflecting the high infiltration and permeability characteristics of the surficial soil profile in which mining and water abstraction will take place. Other than Wetland No. 4, lakes which will not be disturbed are located at distances greater than 500 metres from the borefield, and the water level in Wetland No. 4 will be maintained by recharge from the tailings pond and the decant return channel. The additional head provided by this groundwater mounding will both maintain water levels and accelerate flows of groundwater through the highly permeable soil profile towards the borefield.

Groundwater salinity, calculated from conductivity measurements during the Dames & Moore study, is around 600 mg/L Total Dissolved Solids. It is expected that this quality of groundwater would not be adversely affected by the operation of the project, since the operational water management system is a cyclic system from groundwater to process and then back to groundwater via infiltration, with evaporation (less than 500 ML per year at full design production) representing an extremely small component of the water balance in an area with a comparatively large groundwater resource (19,000 ML throughflow per year).

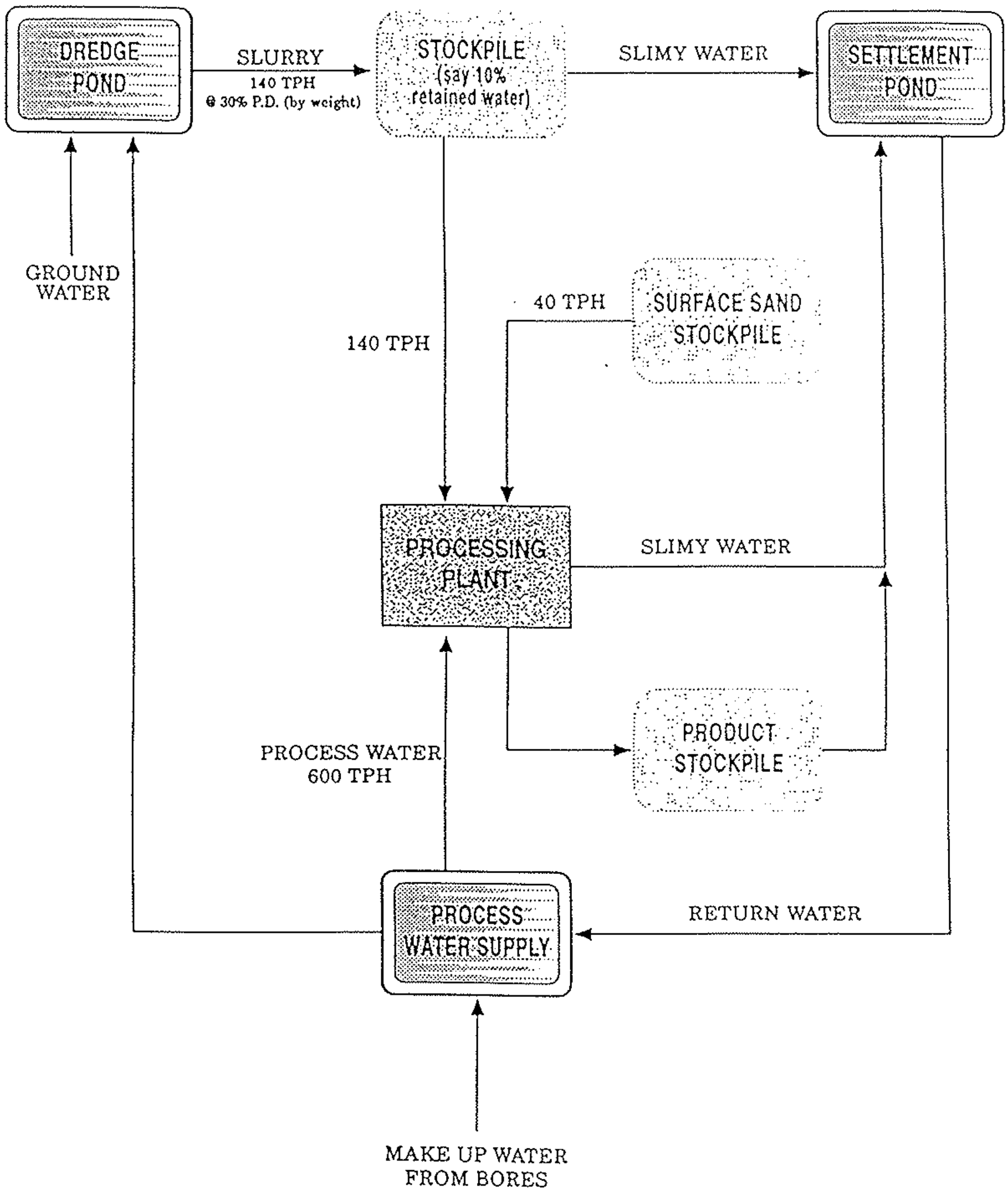


Figure 9

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SANDS

WATER BALANCE DIAGRAM

SCALE		LOCATED ON		1 : 250 000 SHEET
COMPILED	M. D. BALE	JUNE'93	LAST REVISION	
DRAWN	C. L. SCAFE	JUNE'93	ORIGINAL HELD	PERTH
CHECKED			DRAWING NUMBER : 0221 / 2 / 022	

DAMES & MOORE

JOB No. 21377-003-074		DATE
PREPARED BY	OC	12/02/93
APPROVED BY	RV	16/2/93

It is proposed that the bores used in the Dames & Moore study will be monitored on a regular basis in future, to confirm the findings of the recent study and to provide a pre-operations baseline against which project impacts can be assessed on an ongoing basis throughout the life of the project.

4.4 Dieback Management

The vegetation of the project area contains species susceptible to the Jarrah Dieback disease, and the disease may already be present in some areas of the property. Thus, an appropriate hygiene programme would be implemented for project development and operations, to practicably minimise the risk of disease movement to and from the project area. The hygiene programme would include workforce awareness and training, and be based primarily on ensuring the cleanliness of vehicles and equipment entering and leaving the project area. Movement into non-operational areas would be prevented through a combination of workforce education, signposting and fencing/gating.

4.5 Noise Impacts

4.5.1 General

Potential noise impacts of the proposal have been assessed with a rigorous technical approach. Sound and Vibration Technology Pty Ltd (SVT) were commissioned by Gwalia in May 1993 to determine background noise levels and likely impacts of the project at the mine-site and along the transport route to the Port of Bunbury. Copies of SVT's report to Gwalia are available to interested parties.

4.5.2 Noise Study Methodology

BACKGROUND NOISE MONITORING

For minimum periods of two days, continuous noise level recording was carried out at two locations in East Bunbury (Cantwell Crescent and Richmond Street); at the corner of Marriott and Old Coast Roads, Kemerton; and Lot 52 Ridgeview Road Wellesley. The Bunbury locations allowed assessment of road transport between the Eelup Rotary and the inner Harbour; the Marriott Road site allowed assessment of traffic noise along Old Coast Road (a site near Wellesley Road was not possible because of a lack of security for monitoring equipment); and the Ridgeview Road site is in the area of the mine-site and the transport route. The locations of monitoring sites are shown in Figure 10. The Bunbury (2) and Marriott sites were monitored continuously for 48 hours, and the Ridgeview site for seven days.

Background noise levels at these sites is summarised below in Table 3:

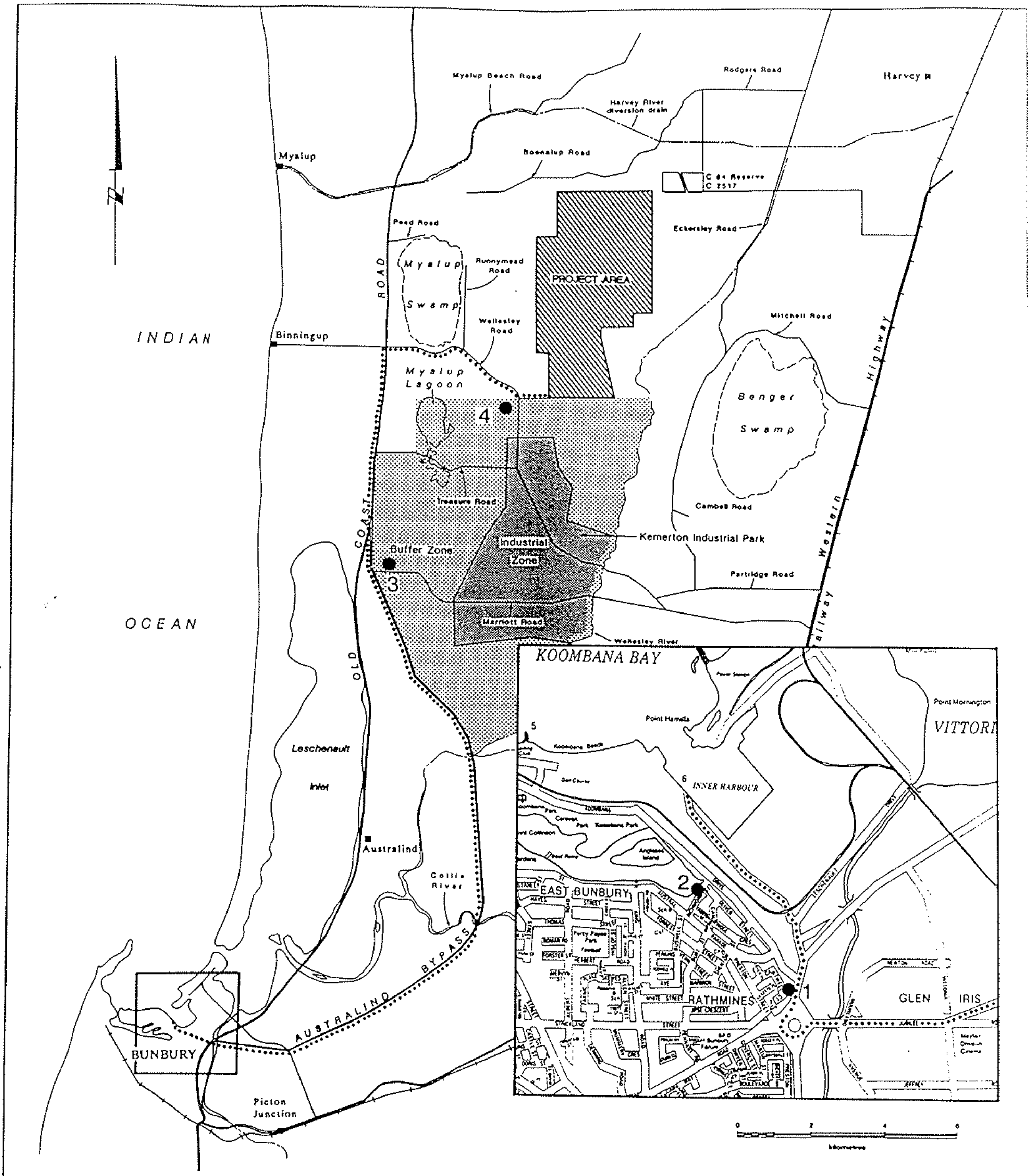


Figure 10

1. 25 Cantwell Crescent, Bunbury
2. 4B Richmond Street, Bunbury
3. Corner of Marriot Road
4. Lot 52 Ridgeview Way

•••••••••• Truck Route

MAP LOCATION

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SANDS

NOISE MONITORING SITES

SCALE			LOCATED ON		1 : 250 000 SHEET
COMPILED	T.M.	APR 92	LAST REVISION	M. D. BALE JULY '93	
DRAWN	C.R.S.	APR 92	ORIGINAL HELD	PERTH	
CHECKED			DRAWING NUMBER :	0221 / 2 / 023	

Table 3: Summary of results of background noise monitoring at Bunbury and Kemerton.

Site	L_{10} (day-night) (dB(A)) (15 min.)	L_{90}(day-night) (dB(A))	Monitoring Period (days)
Cantwell Cresc.	52-59	42-51	2
Richmond St	59-63	53	2
Marriott	49-59	35-42	2
Ridgeview	38-43	32-34	7

NOISE EMISSION MODELLING

To establish likely noise emission levels from the mine-site, sound power levels from plant and equipment were collated from manufacturers' data and/or from experience with equipment comparable with that contained in an equipment list provided by Gwalia: slurry pumps, ball mill, trommels, magnetic separators, conveyors, various pumps (including borefield pumps), diesel generator, dredge and front-end loader(both for processing plant feeding and for product loading into trucks). Noise levelsfrom dry mining operations were modelled at distances up to 1,200 m from the plant-site.
To address the influence of weather, five scenarios of wind-speed and direction were modelled. Wind-speeds of 3-5 m/s (11-18 km per hour), with winds from the E, SE, S, W and NW directions

For product transport, sound power levels were obtained from truck manufacturers, and noise decay modelled with standard techniques.

Locations of residences in the vicinity of the mine-site and the Wellesley Road section of the transport route are shown in Figure 11.

4.5.3 Results of Noise Modelling

NOISE EMISSIONS FROM THE PLANT-SITE/MINE-SITE

Modelling shows that, under the range of meteorological conditions examined, and with a background noise level of 28 dB(A), no existing residence would be expected to experience noise levels in excess of 37 dB(A) as a result of mining or plant operations.

Noise levels at all residences would be 35 dB(A) or less most of the time. However, under some circumstances – particular meteorological conditions at the time product is being loaded at the plant-site – some residences could experience noise levels of up to 37 dB(A).

These circumstances comply with proposed *Environmental Protection (Noise) Regulations,* which are currently in draft form and may come into force during 1993. The proposed new noise control legislation sets different standards for different times of the day, with 40 dB(A) covering the most sensitive period – from 10 p.m. to

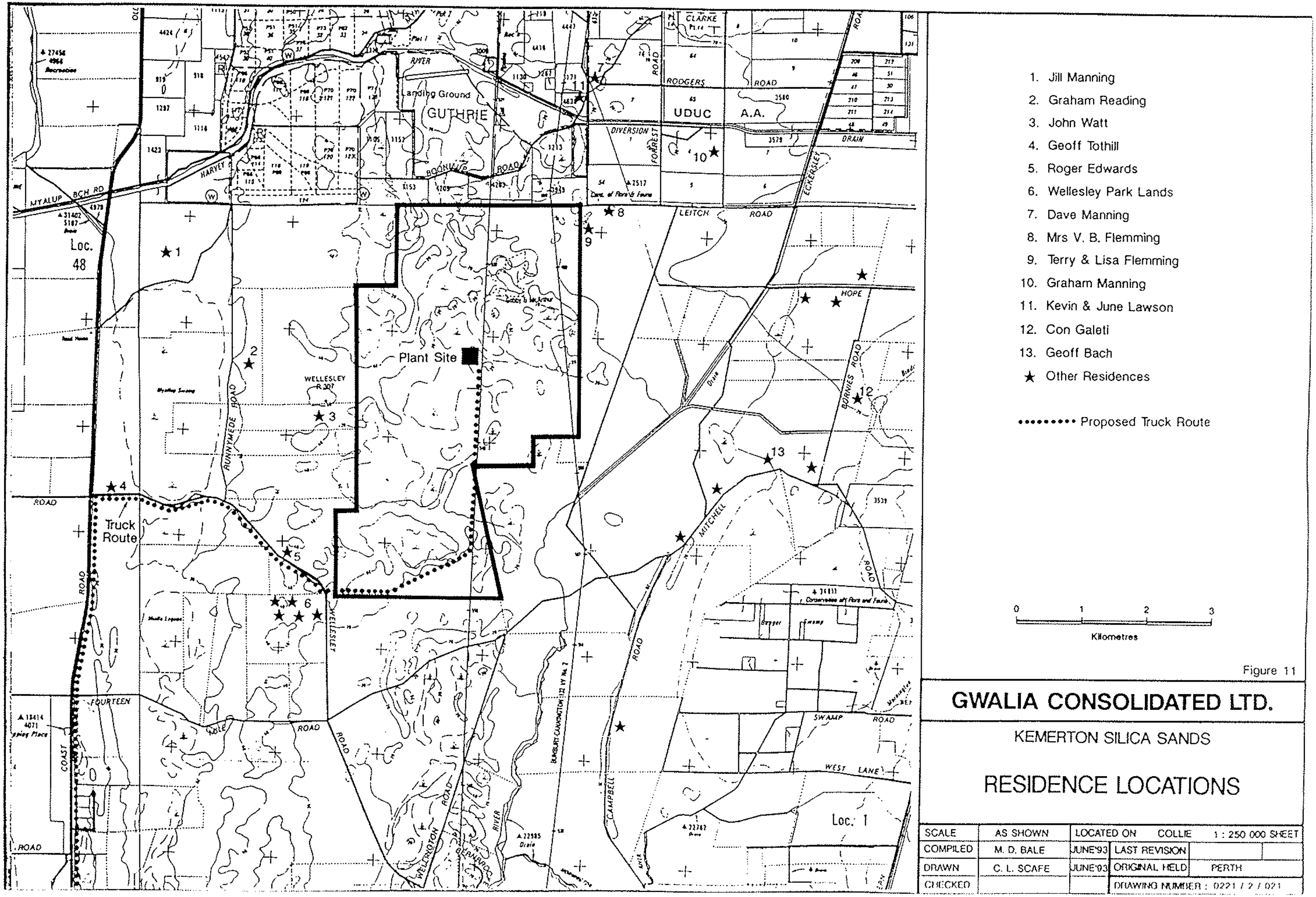


Figure 11

GWALIA CONSOLIDATED LTD.

KEMERTON SILICA SANDS

RESIDENCE LOCATIONS

SCALE	AS SHOWN	LOCATED ON	COLLIE	1 : 250 000 SHEET	
COMPILED	M. D. BALE	JUNE'93	LAST REVISION		
DRAWN	C. L. SCAFE	JUNE'93	ORIGINAL HELD	PERTH	
CHECKED			DRAWING NUMBER : 0221 / 2 / 021		

7 a.m. the following day. Moreover, the 40 dB(A) limit is an L_{10}: noise must be less than 40 dB(A) for 90% of the measuring period, which is a minimum of 15 minutes.

For noise in excess of 40 dB(A) in the measuring period – i.e. for a maximum of 10% of the time period (minimum 15 minutes) – the proposed new regulations allow for a maximum noise level of 50 dB(A). As noted above, the modelling carried out for this project indicates that no residence would experience noise levels above 37 dB(A).

The proposed new regulations also allow for tonal characteristics of noise emissions. On this basis, it is possible that a 5 dB(A) penalty could be imposed, reducing the above-mentioned L_{10} standard of 40 dB(A) to 35 dB(A).

However, modelling has shown that by reducing the noise emissions from all stationary plant outside the central processing building to a maximum noise level of 80 dB(A) at one metre, no residence would experience noise levels greater than 35 dB(A). On this basis, Gwalia will ensure, during the process of ordering and supply, that all such equipment meets this standard. Equipment located within the processing facility does not present a problem of noise emissions because of the noise control provided by the cladding of the structure surrounding this equipment.

NOISE FROM PRODUCT TRANSPORT

The attenuation of noise from trucks used to transport product to Bunbury is shown in Figure 12; data is expressed as L_{10} values for 20 truck movements per hour and are based on trucks emitting maximum noise levels of 95 dB(A) at 7.5 metres at a speed of 100 km per hour, and 88 dB(A) at 60 km per hour.

There are no statutory requirements in WA in relation to road traffic noise. However, based on current guidelines and procedures used by the MRD, a one-hour L_{10} of 63 dB(A) has been adopted for maximum permissible traffic noise. This standard is currently applied to both urban and rural areas.

On this basis, no residence in the project area or along the transport route between the plant-site and Bunbury would experience noise above standard levels. Along Wellesley Road, Gwalia will ensure maximum truck speeds of 90 km per hour – at this speed, the closest residence (approximately 85 metres from the edge of the road) would experience noise with an L_{10} of 63 dB(A).

4.6 Dust Management

The silica sand subjected to dry mining is inherently low in propensity to cause dust emissions, and the dredge and processing operations, being wet operations, would generate negligible dust. The Tailings Settling Pond would be wet for most of the time and would similarly not constitute a source of fugitive dust emissions.

The greatest potential for dust generation would be from the 4-kilometre unsealed access road along the SECWA easement. However, dust generation here would be easily and efficiently controlled through regular watering.

Predicted L10 noise levels due to the operation of haulage vehicle

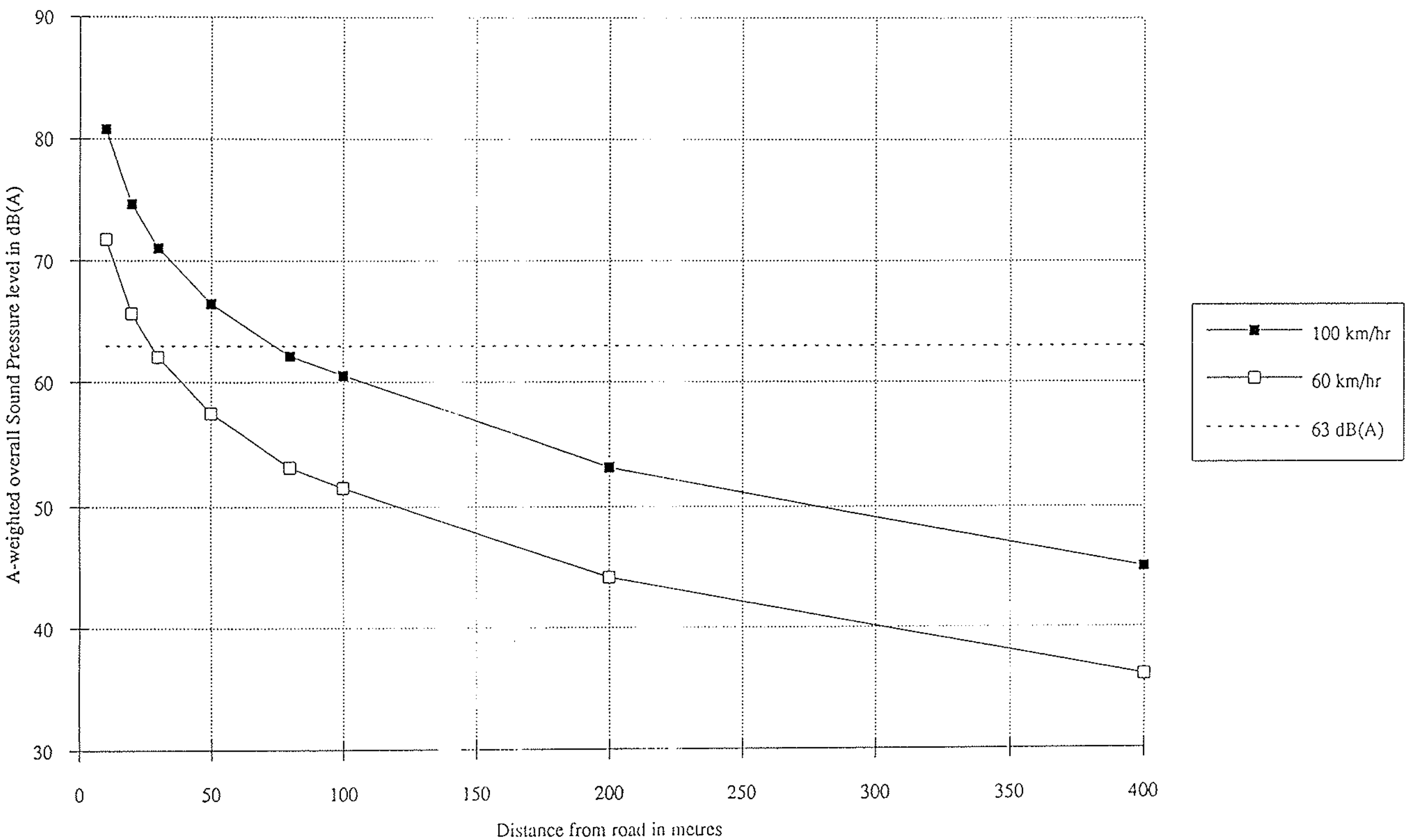


Figure 12

4.7 Light Spill

The remoteness of the operational area of the project makes problems of light spill from night-time operations unlikely. Nonetheless, attention would be paid to equipment selection and application to minimise risks of problems. In the unlikely event that problems developed, they would easily be managed through modification of operational procedures.

5. Public Consultation

In the period from December 1992 to February 1993, Gwalia initiated contacts with the following organisations and parties in relation to the environmental, social and infrastructure impacts of the project:

Environmental Protection Authority - Perth and Bunbury offices
Water Authority of WA - Bunbury
Department of Minerals and Energy
Shire of Harvey
City of Bunbury
Main Roads Department
South West Development Authority - Bunbury (incl. Kemerton Industry Community Liaison Committee)
Department of Conservation and Land Management - Bunbury and Como
Department of State Development
State Energy Commission of WA
Department of Planning and Urban Development - Bunbury
Landcorp
Conservation Council of WA
Australian Conservation Foundation
Residents near the project area
Newspapers in Bunbury and Harvey (favourable lead stories) and the *Heron* newsletter (SWDA)

These contacts will be continued as appropriate during the feasibility study and during operations, should the project go ahead, to allow reasonable input from interested and potentially affected parties, as well as the meeting of statutory requirements. It is the Company's intention to accommodate, where practicable and reasonable, the non-statutory requirements of other parties, within the constraints of fiscal feasibility and responsibility.

6. Summary of Environmental Commitments

Based on information presented in this PER, Gwalia is committed to responsible environmental management of the project. The following commitments represent the basis on which appropriate environmental management programmes will be developed and implemented.

6.1 Rehabilitation

6.1.1 Rehabilitation of Areas Subjected to Dry Mining

Areas subjected to dry mining and not subsequently included in dredge mining operations will progressively be rehabilitated to stable landforms, to the satisfaction of the EPA, on the advice of CALM. Rehabilitation will include:

- The battering down of slopes agreed with the Department of Minerals and Energy
- Where necessary, the provision of erosion-control facilities, to manage runoff and prevent sheet and gully erosion
- Scarifying, ripping or ploughing on contour of salvaged and replaced overburden and topsoil
- Planting and/or seeding of suitable plant species
- Maintenance of revegetation through fertiliser application, fire management and the like, to encourage a self-sustaining system

6.1.2 Rehabilitation of Dredged Areas

As part of a strategic plan to replace, if not enhance, the pre-mining wetland values of the mining area, areas subjected to dredge mining will be progressively reconstructed as wetlands, to the satisfaction of the EPA and as advised by CALM. This reconstruction will include:

- Establishment of shallows (no deeper than 2 metres) over a 100 metre-wide perimeter of the dredge pond
- Replacement of salvaged topsoil around the pond perimeter, to facilitate re-establishment of lake-side vegetation
- Planting and/or seeding of lake-side vegetation, based on flora and vegetation studies carried out in December 1992 and to be carried out in the spring of 1993 – both species diversity and vegetation structure will be accommodated, to re-establish representative flora and fauna habitat values
- Examination of the desirability and feasibility of establishment of floating islands, to provide protection to fauna (especially waterbirds) from predators

6.1.3 Re-use of Dried Process Tailings

Solar-dried tailings will be re-won from the tailings dam and used in rehabilitation programmes to enhance the water- and nutrient-holding properties of the sandy soils of areas being rehabilitated. Tailings will be blended into the sandy soils, by rotary hoeing or other means of tillage.

At the end of the project, remnant tailings on the floor of the tailings dam will be similarly incorporated into the sandy soils underlying the tailings dam, and the area re-vegetated, using relevant parts of the prescription described in Section 6.1.1 above.

6.1.4 Vesting of Rehabilitated and Other Areas

Investigate the feasibility and desirability of vesting rehabilitated and other areas with appropriate authorities, to ensure long-term management of ecological values either protected from disturbance during operations or created by rehabilitation programmes. Of particular interest are wetland areas: two such areas covered by the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* will be disturbed by project operations, and another seven such nearby areas will be protected from disturbance by project operations.

6.2 Protection of Wetlands

Seven of the nine wetlands in the project area covered by the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* will not be directly disturbed by project activities. These wetlands will be protected from indirect and/or inadvertent disturbance by fencing, signposting, access-control, workforce awareness and other appropriate means.

6.3 Biological Investigations

Building on the December 1992 studies, intensive flora and fauna studies will be carried out in the spring of 1993, and brief studies bi-monthly until February 1994, to :

- Define more precisely the status of any species on CALM's Declared Rare Flora and Priority Species List, and of any rare and endangered fauna
- Provide a quantitative baseline for the planning of rehabilitation/revegetation, especially in terms of habitat requirements
- Provide a basis for ongoing monitoring of biological impacts and the subsequent development of appropriate management plans
- Assess patterns and nature of waterbird use of wetland areas
- Delineate habitats of sensitive species and provide appropriate protection

6.4 Groundwater Monitoring

Maintain the bores used in initial hydrological investigations, monitor them six-monthly for water level and basic water chemistry, and report the data to the EPA and the Water Authority of WA within three months of each monitoring date, with a brief interpretive commentary.

6.5 Dieback Management

Develop and implement a dieback management programme aimed at minimising the risk of plant disease movement to and from the project area, to the satisfaction of the EPA on the advice of CALM.

6.6 Noise Management

6.6.1 Noise from Mining and Processing

Ensure that noise from mining and processing operations, including the loading of product for trucking to the Port of Bunbury, does not result in noise levels at existing residences in the vicinity of the project area in excess of 35 dB(A) (15-minute L_{10}), including allowance for tonal components.

6.6.2 Noise from Product Transport

Ensure that noise from transport of product to the Port of Bunbury does not exceed an L_{10} of 63 dB(A) at existing residences in the vicinity of the transport route.

6.7 Dust Management

Apply water or other treatments, and install appropriate dust control equipment on processing facilities, to ensure that vehicular movement and equipment operation does not cause dust nuisance.

6.8 Control of Light Spill

Design and operate lighting facilities so that light spill does not cause a nuisance to neighbours.

Appendix A

EPA Guidelines for this PER

PROPOSED KEMERTON SILICA SAND PROJECT

PUBLIC ENVIRONMENTAL REVIEW (PER) GUIDELINES

Overview

In Western Australia all environmental reviews are about protecting the environment. The fundamental requirement is for the proponent to describe what they propose to do, to discuss the potential environmental impacts of the proposal, and then to describe how those environmental impacts are going to be managed so that the environment is protected.

If the proponent can demonstrate that the environment will be protected then the proposal will be found environmentally acceptable; if the proponent cannot show that the environment would be protected then the Environmental Protection Authority (EPA) would recommend against the proposal.

Throughout the process it is the aim of the EPA to advise and assist the proponent to improve or modify the proposal in such a way that the environment is protected. Nonetheless, the environmental review in Western Australia is proponent driven, and it is up to the proponent to identify the potential environmental impacts and design and implement proposals which protect the environment.

For this proposal, protecting the environment means that the natural values associated with the Protected Lakes and the social values of the Bunbury area are retained. Where they cannot be protected, proposals to mitigate the impacts are required. It should be noted that the EPA regards the purpose of the regulations for the Lakes Policy as providing for the retention of those lakes in an undisturbed state. Hence there is a presumption against filling, mining or polluting these lakes. A decision by Government to allow development , after environmental assessment, would be regarded by the EPA as the exception rather than the rule.

Purpose of a PER

The primary function of a PER is to provide the basis for the Environmental Protection Authority to provide advice to Government on protecting the environment. An additional function is to communicate clearly with the public so that EPA can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process. The PER should set out the series of decisions taken to develop this proposal at this place and time and why.

Objectives of the Review

The PER should have the following objectives:

- to place this project in the context of the regional environment and the progressive development of resources in the region, including the cumulative impact of this development;
- to explain the issues and decisions which led to the choice of this project at this place at this time;
- to set out the environmental impacts that the project may have; and
- for each impact, to describe any environmental management steps the proponent believes would avoid, mitigate or ameliorate that impact.

The PER should focus on the major issues for the area and anticipate the questions that members of the public will raise. Data describing the environment should be directly related to the discussion of the potential impacts of the proposal. Both should then relate directly to the actions proposed to manage those impacts.

Key issues

The critical issues for the proposal are likely to be related to the proposal to mine Protected Lakes and associated disturbance of other wetlands in the area, and transportation of the product through urban areas. The conservation values of areas to be disturbed should be examined in detail. Any proposals the proponent has with respect to the potential locations of mining and development zones, their rehabilitation and routes for transportation should be indicated clearly.

The key issues for this project should be clearly identified and the content of succeeding sections determined by their relevance to these issues.

In this case the key issues should include.

- the reasons for selection of the preferred mine site and transport route, and the alternatives considered:
- wetland conservation or replacement:
- flora, fauna and ecosystems:
  - description of wetland biota;
  - rare and poorly known flora, fauna and communities;
  - inter-dependence of the biota and environment ;
- water management issues:
  - groundwater hydrology, predicted groundwater drawdowns or increases, zones of influence, impacts on Protected Lakes, flora, fauna and other wetland communities in the region and impacts on other users;
  - dewatering and discharges, erosion and siltation control;
  - surface water supplies, relationship to groundwater, protection of ground and surface water quantity and quality;
  - maintenance of surface water drainage patterns;
- mine operation management issues:
  - location and description of facilities;
  - protection of Lakes and wetlands ;
  - dust and noise control ;
  - dieback disease, presence and proposed management ;
  - rehabilitation and final land use;
  - description of affected communities;
  - construction and operational workforce;
- Transportation issues:
  - transport route, existing traffic flows, number of truck movements per day, comparison with similar producers;
  - impact on other road users from transportation of product;
  - description of affected communities;
  - noise impact on residences;
  - contingency plans for accidents such as fuel spills and discharges;

plus any other key issues raised during the preparation of the report.

Public participation and consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the PER. It should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management for the proposal which should clearly indicate how community concerns have been addressed. Where these concerns are dealt with via other departments or procedures, outside the Environmental Protection Authority process, these can be noted and referenced here.

Detailed list of environmental commitments

The commitments being made by the proponent to protect the environment should be clearly defined and separately listed. Where an environmental problem has the potential to occur, there should be a commitment to rectify it. They should be numbered and take the form of:

a) who will do the work;
b) what the work is;
c) when the work will be carried out; and
d) to whose satisfaction the work will be carried out.

All actionable and auditable commitments made in the body of the document should be numbered and summarised in this list.

Kem Silica guide 290493RGR

Appendix B

Detailed Botanical Descriptions
of Individual EPP Wetlands

(Extracted from Mattiske & Associates 1993a)

EPP-1: Sumpland – 11 300N 12 300E

This wetland is a sumpland of similar size and type to the sumpland situated at 10 600N 12 150E [*EPP-5*]. Areas of open water are edged by *Melaleuca rhaphiophylla* and *M. lateritia* over *Baumea articulata*. *Typha orientalis* is also present in the water-body itself. Pockets of *M. rhaphiophylla* and *Banksia littoralis* over mixed low shrubs and *Centella asiatica* are present on the eastern side of the wetland.

The sumpland falls into management category R (Resource Enhancement) as defined by the Environmental Protection Authority [*A Guide to Wetland Management in Perth. EPA Bulletin 374, November 1990*]. Wetlands in this category have been modified and do not have clearly defined human uses. Management objectives for these areas are to maintain and enhance existing ecological functions. A development may be recommended for approval around these wetlands provided that the wetland function is retained, or an equivalent area of wetland of a similar type is constructed or rehabilitated to fulfil equivalent functions. The term resource enhancement indicates that opportunities may exist for commercial developments to enhance the wetland resource.

EPP-2: Sumpland – 11 600N 12 350E

Although this wetland area is smaller than the sumplands surrounding it, similar vegetation types are present. The area of open water is edged by *M. rhaphiophylla* over *Baumea articulata* and *Centella asiatica*. A community of *M. preissiana* over *Hypocalymma angustifolium*, *Kunzea recurva* and *Calothamnus lateralis* is present in the drier areas surrounding the wetland itself.

This sumpland also falls into category R (Resource Enhancement). The existing ecological functions of the area should be maintained and enhanced.

EPP-3: Sumpland – 12 000N 12 250E

Although this wetland area is smaller than the sumplands surrounding it, similar vegetation types are present. The smaller area of open water is edged by stands of *M. rhaphiophylla* over low shrubs of the family Mrytaceae and a range of sedges including *Baumea juncea*.

This sumpland also falls into category R (Resource Enhancement). The existing ecological functions of the area should be maintained and enhanced.

EPP-4: Sumpland – 12 150N 10 950E

This small seasonally inundated sumpland supports a very different plant community when compared to the other sumplands in the area. Dense thickets of *M. viminea* almost completely surround the shallow water-body. Some *m. rhaphiophylla*, *Viminaria juncea*, *Pericalymma ellipticum* and *Calothamnus lateralis* are also present. The area has been disturbed by vehicles and brush-cutters but still has a moderate local and regional conservation value due to the lack of similar vegetation types in the area. In view of the lack of *Melaleuca viminea* wetlands in the area, the overall significance was upgraded to high.

The sumpland falls into Category C (Conservation) as the composition and structure of the vegetation community is significantly different to that found at nearby wetlands. The wetlands natural attributes and functions should therefore be maintained and enhanced.

EPP-5: Sumpland and Palusplain - 10600N 12 150E

This wetland consists of a small, seasonally inundated sumpland surrounded by seasonal waterlogged flats (palusplain), each of which support very different vegetation types. The open water in the sumpland is edged by *M. rhaphiophylla* over dense stands of *Baumea articulata* and *B. juncea* mixed with smaller proportions of *Leptocarpus scariosus* and *L. coangustatus*. In some areas *M. rhaphiophylla* is absent, resulting in sedgelands of *Baumea articulata*. These occur primarily on the southern edge of the water-body. The eastern side of the water-body is edged by *M. rhaphiophylla* over *M. Lateritia*, *M. incana* and *Astartea fascicularis*. Pockets of *M. cuticularis* are also present, indicating apparent sub-surface saline seepage. The palusplain supports three distinct vegetation communities. The largest of these is a fringing woodland of *M. preissiana* and *Banksia littoralis* over *M. lateritia*. A low closed heath of mixed Myrtaceae shrubs with occasional *Actinostrobus pyramidalis* is present on the northern side of the wetland with a tall shrubland of *Calothamnus lateralis* and *Viminaria juncea* occurring on the eastern side. The eastern side also has drier soil conditions supporting a low woodland of *Agonis flexuosa*. The upland vegetation surrounding the wetland is partially disturbed or cleared due to grazing.

The sumpland falls into Category C (Conservation) and should therefore be maintained and enhanced to protect its natural attributes.

EPP-6: Sumpland - 11 500N 12 600E

Although this wetland is smaller than the sumplands surrounding it, similar vegetation types are present. The small area of open water is edged by *M. rhaphiophylla* over *Baumea articulata* and *Centella asiatica*. A community of *M. preissiana* over *Hypocalymma angustifolium*, *Kunzea recurva* and *Calothamnus lateralis* is also present in the drier areas surrounding the wetland itself.

This sumpland falls into category R (Resource Enhancement). The existing ecological functions of the area should be maintained and enhanced.

EPP-7: Lake - 12 300N 12 600E

This wetland, situated on the eastern boundary of the survey area, is a large, deep (depth greater than 1m), tannin stained lake. The water-body is fringed by *Eucalyptus rudis* and *M. rhaphiophylla* over mixed *Melaleuca* species, *Astartea fascicularis* and *Hypocalymma angustifolium* over sedges. A woodland of *Agonis flexuosa* also exists on the north eastern side.

This wetland falls into management category C (Conservation) as defined by the EPA [Bulletin 374]. These wetlands possess a high degree of naturalness and as such management objectives should be to maintain and enhance natural attributes and functions.

EPP-8: Sumpland – 12 700N 11 950N

The wetland situated at 12 700N/11 950E is a seasonally waterlogged basin, or sumpland surrounded by dampland. At the time of survey [December 1992] no surface water was present. Vegetation was uniform over the entire basin and consists of scattered *M. rhaphiophylla* over a tall open heath of *M. lateritia*, *Pericalymma ellipticum* and *Calothamnus lateralis* over sedges. The density of the *M. rhaphiophylla* varies throughout the basin.

This sumpland falls into category R (Resource Enhancement). The existing function of the area should be maintained and enhanced although development is possible if requirements are met.

EPP-9: Lake – 13 050N 12 000E

This wetland is also a deep, tannin stained lake. It is fringed by dense vegetation consisting of *M. preissiana* over *Astartea fascicularis* and *M. lateritia-M.* spp. over pockets of *Baumea articulata* and *Leptocarpus scariosus*. *Kunzea ericifolia* is also present on the eastern side of the water-body. The conservation value of this lake is very high on a local scale due to the lack of disturbance of the diverse fringing vegetation. On a regional and overall scale its value is decreased as the wetland is almost completely surrounded by vehicle tracks and pine plantations, although it is protected from these by fringing vegetation.

This wetland falls into category C (Conservation). It therefore possesses a high degree of naturalness and the areas natural attributes should be maintained and enhanced.

7. References

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KEMERTON - BOTANICAL APPRAISAL

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JULY 1995

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1.0 SUMMARY

The vegetation of Cable Sands Pty Ltd Project Area at Kemerton was assessed during March 1995 and described in terms of characteristic species, structure and landscape attributes. Seven principal vegetation types occur within the Project Area, with most of the proposed mining activity being restricted to Jarrah-*Banksia* woodland vegetation.

The Project Area contains extensive areas of diverse native vegetation in good condition, and also areas that have been affected by clearing and grazing. An inventory of flora observed in the Project Area is provided in this report, most of these species are widely distributed on the Swan Coastal Plain. There are no known occurrences of gazetted rare flora in the vicinity of the Project Area, however, *Acacia semitrullata*, a priority three species was observed adjacent to the proposed mining area. The intrinsic conservation value of the vegetation relates to its attributes as a natural bushland remnant of the Karrakatta vegetation complex which is poorly conserved on the Swan Coastal Plain south of Perth. The vegetation is also adjacent to the regionally important Kemerton wetland chain within CALM land to the west.

2.0 OBJECTIVES

The objectives of this study are to:

- describe and appraise the vegetation and flora of the Project Area,
- assess the likely impacts of proposed mining on the vegetation and flora of the Project Area; both in a local and regional context, and
- provide recommendations which will minimise potentially adverse impacts on the vegetation and flora, and provide general criteria for the post mining rehabilitation.

3.0 VEGETATION AND FLORA

3.1 Vegetation

The vegetation of the Kemerton Project Area was assessed during March 1995. The vegetation of the Project Area was described in terms of seven vegetation/landscape types based on structural attributes and dominant character species of both the overstorey and the shrub stratum and on their location in the landscape. The distribution of vegetation and flora of the area reflects soil changes associated with a dune-swale topography typical of the Swan Coastal Plain north of Bunbury; this distribution is given in Plate 1. A description of the vegetation types follows:

a) Low forest of *Agonis flexuosa*, *Banksia attenuata* and *Eucalyptus marginata* (J-B-Ag)

A dune ridge composed of yellow calcareous sands overlying limestone to various depths is orientated in a north-south direction along the eastern edge of the proposed mining zone. Much of the upper slopes and crests of the ridge support a low forest of *Agonis flexuosa* (peppermint), *Banksia attenuata* and *Eucalyptus marginata* (jarrah); *Banksia grandis* is also present in the overstorey of upper slopes but at low densities. The shrub understorey is typically less than 1.0m in height, with *Hibbertia hypericoides* and *Melaleuca thyoides* being dominant; *Daviesia preissii*, *Hakea prostrata*, *Jacksonia furcellata*, *Leucopogon propinquus*, *Macrozamia riedlei*, *Petrophile linearis* and *Xanthorrhoea gracilis* are also common in the understorey of this vegetation type.

Eucalyptus decipiens is
is very
uncommon in the area. The most
Southerly population
of occurs just to
the South. This is
a significant
population

b) **Jarrah and peppermint tall open woodland with occasional marri (J-M-Ag)**

On the more shallow ridge soils, *Banksia attenuata* becomes sparse or absent, and jarrah and peppermint form a tall open woodland and overstorey, occasionally in association with marri. The soils supporting this vegetation type are also favoured for pasture production, and in the vicinity of the Project Area the understorey has been cleared and pasture established for grazing purposes. Remnant understorey includes *Xanthorrhoea gracilis* and *Macrozamia riedlei.*

c) **Jarrah and peppermint woodland (J-Ag)**

This vegetation also occurs on upper slope and dune ridge topography in the Project Area, however *Agonis* sp. becomes dominant and marri becomes scarce to absent. The understorey is similar to J-B-Ag vegetation.

d) ***Banksia attenuata* dominant woodland with emergent jarrah (J-B)**

On the lower dune slopes to the west of the ridge, deeper, less calcareous sands support a *Banksia attenuata* dominant woodland with associated emergent tall jarrah trees or stunted jarrah regrowth. There is a diverse shrub and sedge understorey which includes many of the shrub species common to the peppermint forest vegetation together with species typical of *Banksia attenuata* woodland. Commonly observed shrubs in this vegetation were *Allocasuarina humilis, Astroloma pallidum, Bossiaea eriocarpa, Calytrix flavescens, Conostephium preissii, Hibbertia spicata, Hibbertia vaginata, Leschenaultia floribunda, Leucopogon polymorphus, Leucopogon propinquus, Persoonia saccata* and *Stirlingia latifolia*; common sedges include *Dasypogon bromeliifolius, Lepidosperma angustatum, Loxocarya fascicularis, Loxocarya flexuosa, Lyginia barbata* and *Phlebocarya ciliatum.*

e) **Jarrah-Marri-*Banksia attenuata* woodland on lower dune slopes (J-M-B)**

On the lower dune slopes where silty or clay sub-soils associated with the water table are closer to the surface, the Jarrah-*Banksia attenuata* woodland stratum merges with Marri, *Banksia grandis, Banksia ilicifolia, Nytsia floribunda, Persoonia longifolia* and *Xylomelum occidentalis* in the overstorey. Within the Project Area this vegetation type has the most diverse overstorey. Characteristic species of the understorey include *Acacia extensa, Acacia pulchella, Adenanthos meisneri, Calytrix fraseri, Daviesia divaricata, Daviesia pectinata, Dianella revoluta, Haemodorum spicatum, Platysace compressa, Phyllanthus calycinus* and *Thysanotus dichotomus.*

f) ***Eucalyptus decipiens*, mixed woodland (E)**

Other vegetation types that occur adjacent to the proposed mining area include a small stand of *Eucalyptus decipiens*, marri, peppermint and *Banksia grandis* woodland associated with the shallow sands over limestone on the ridge crest, and the wetland complex vegetation which lies within the dune swale to the west. The small area of *Eucalyptus decipiens* vegetation on the ridge crest has a sparse understorey of species common to the Jarrah-*Banksia-Agonis* vegetation further downslope except for some calcicolous adventive species such as *Olearia axillaris* and *Melaleuca scabra.*

g) **Wetland complex vegetation - flooded gum (*Eucalyptus rudis*) and paperbark (*Melaleuca preissiana*) forest with tall shrub/sedge understorey and sedgelands of *Baumea* and *Juncus* species (W)**

The wetland fringe overstorey is typically flooded gum (*Eucalyptus rudis*) and paperbark (*Melaleuca preissiana*) with a tall shrub sedge understorey of *Acacia saligna, Aotus* sp., *Astartea fascicularis, Melaleuca teretifolia, Oxylobium lanceolatum* and the sedges *Baumea articulata, Baumea juncea, Juncus pallidus*, with *Typha orientalis* occurring in the wettest areas.

3.2 Flora

3.2.1 General

Flora was identified opportunistically along traverses taken throughout the Project Area, and an inventory of flora observed during these traverses is given in Table 1. Most of the perennial species occurring in the Project Area have a wide distribution on the Swan Coastal Plain. Many of the species are also common on sands and sandy gravels to the east of the Darling Scarp in the Jarrah Forest region.

The vegetation of the ungrazed sections of the Project Area has a diverse perennial shrub and sedge flora, however the timing of the survey during the late summer period co-incided with the dormant phase of ephemeral species. The vegetation could be expected to contain a range of *Droseraceae*, *Liliaceae*, *Orchidaceae* and *Stylidaceae* and also annual ephemerals during the winter-spring period.

3.2.2 Declared rare and priority listed flora

There are no known occurrences of gazetted rare flora in the vicinity of the Project Area. There are several taxa on the Department of Conservation and Land Management priority flora list that have known distribution in the general region. These include:

SPECIES	PRIORITY	LOCATION
Acacia flagelliformis	Priority 4	Bunbury-Eaton region
Acacia horridus	Priority 3	Serpentine-Bunbury region
Acacia semitrullata	Priority 3	Yallingup, Donnybrook, Harvey, Yarloop region
Boronia capita subsp. *gracilis*	Priority 2	Harvey-Eaton region
Caladenia speciosa M.S.	Priority 4	Myalup-Eaton region

Of these, *Acacia semitrullata* was observed to occur in the Jarrah-*Agonis* vegetation upslope of the proposed mining area. A detailed survey of the distribution of this taxa was not carried out.

3.2.3 Exotic flora

There were no declared exotic species observed in the Project Area. Few annual weed species have invaded the jarrah, *Banksia*, or peppermint woodland types that have not been subject to grazing. Weedy annuals that have established are non-aggressive naturalised species which are common on the Swan Coastal Plain and they include *Ursinia* and *Hypochaeris* species.

3.3 Vegetation condition

The ungrazed vegetation of the Project Area is in good condition with a healthy overstorey with few recent deaths, and a diverse and representative perennial understorey. No expression of dieback disease *Phytophthora cinnamomi* was observed in the overstorey of the jarrah *Banksia* woodland types at the time of the survey, which coincided with a long dry summer period. The most appropriate time to assess the presence of dieback disease would be in May to June.

3.4.2 The study should also place the area in a regional perspective by referring to

- Heddle et al (1983)
- Gibson et al (1994)

Gibson et al. has sites adjacent to this area. PTO

5.1.2 Should also consider the need for buffers around the wetland see Davies and Lane (1995)

3.4 Conservation aspects

3.4.1 Local significance of the vegetation

The local significance of the vegetation relates particularly to its interaction and continuity with the immediate surrounding landscape. The principal feature of the landscape in the vicinity of the Project Area is the close proximity of a diversity of habitat types. The Kemerton wetland chain immediately west of the Project Area contains dense sedgelands, thickets, and closed forest types, and these are linked to peripheral forest-woodlands which are described in this survey. The continuum of vegetation which prevails between wetland and upland habitats supports a considerable diversity of fauna and avifauna, and provides refuge sites for nesting and feeding, especially after fire events in drier, upland remnant woodlands. The wetland chain provides an important habitat for avifauna, and the adjacent woodlands form an important ecological component of the landscape system. Collectivly, this entire area is likely to form a valuable regional habitat of a range of fauna.

3.4.2 Regional conservation significance

There are few conservation reserves in the vicinity of the Project Area which lies between Bunbury and Mandurah other than reserves located in the coastal Quindalup and Vasse Dune Systems. The jarrah-*Banksia-Agonis* woodland types that occur in older phase dune systems in the vicinity of the Project Area are typical of the Karrakatta Complex - central and south (D.C.E., 1980). Representative vegetation of this vegetation complex has not been conserved in the most southern section of the Swan Coastal Plain, therefore the intrinsic value of the vegetation is of importance.

4.0 POTENTIAL IMPACTS OF PROPOSED MINING OPERATIONS

At this stage it is difficult to assess the total impact of the proposed mining operations because the exact mine path and the infrastructure needs have not been determined. However, it can be assumed that the vegetation of the entire orebody will be cleared for mining. The area of vegetation which will have to be cleared will be determined upon completion of the mine plan.

Currently, exploratory drilling has required drill lines to be cleared at fifty metre intervals across the proposed mining area. Understorey shrubs have been flattened and occasional *Banksia* trees have been removed. Most of the impact of exploration has occurred within the Jarrah-*Banksia* vegetation, and the extent of the proposed mining zone coincides largely with this vegetation type (see Plate 1). The Jarrah-Marri-*Banksia* vegetation and the wetland vegetation downslope of the likely mining area, and also the Jarrah-*Agonis* and Jarrah-*Banksia-Agonis* vegetation upslope will be mostly unaffected.

5.0 RECOMMENDATIONS

5.1 Planning of operations

5.1.1 Land clearing

Principal objectives of mine planning should endeavour to minimise clearing of the natural vegetation, particularly overstorey species. There are areas of partly cleared or degraded vegetation to the south of the likely mining area; if possible, these should be used for infrastructure purposes.

5.1.2 Protection of adjacent wetlands

As the mining area is likely to intercept subsurface drainage between the ridge and the adjacent wetlands to the west, there will be a need to assess the potential impact and, if required, to plan for compensatory drainage. There is a need to maintain an adequate vegetation buffer between the wetlands and the mining operation.

5.3
NO examples of being able to ~~resto~~ revegetate to Banksia woodland.

5.1.3 Dieback hygiene

Dieback hygiene methods need to be introduced during the earliest phase of exploration and mine planning. This is important in order to preserve vegetation not included in the land clearing programme, and it is also important to maintain uncontaminated topsoil for rehabilitation.

5.2 Mining phase

Conservation and management of topsoil during mining is central to avoiding long-term impact on the area. Ideally, the stripping and replacement of topsoil during mining should be integrated to minimise the need for stockpiling. The shorter the period of stockpiling of topsoil, the better the condition of the soil will be for replanting and regeneration of plants.

Also important during the mining phase is to monitor the effectiveness of dieback hygiene measures and also the impacts, if any, of mining on the health of adjacent vegetation. Every effort should also be made to protect adjacent vegetation from weed encroachment and accidental burning.

5.3 Rehabilitation

The principal objective of land rehabilitation after mining is to restore landforms compatible with the surrounding terrain, and to recognise conservation requirements for the site. The planned landuse for the restored area should be compatible with the land capability of the site as well as being compatible with that of the surrounding area. The soils of the proposed mining area are not suitable for pasture and livestock production, therefore the land would most appropriately be restored with perennial vegetation such as native woodland systems or timber plantations.

Banksia woodland systems similar to those currently on the site are known to be difficult to re-establish, therefore a revegetation programme with the objective of re-establishing a *Banksia* woodland would require detailed planning before the commencement of mining. In particular, topsoil management, species selection, seed collection and treatment, method of propagation and planting are important. Plant species observed to commonly occur in the Project Area are listed in Table 1, and these would provide a basis for revegetation planning.

6.0 CONCLUSIONS

The Project Area contains diverse stands of native vegetation typical of the Karrakatta Complex vegetation system. This vegetation system is poorly represented in conservation reserves, and consequently it has an intrinsic conservation value. Substantial efforts should thus be made to minimise impacts associated with exploration and mining. Areas of particular concern relate to the loss of natural vegetation through clearing and the risk of introducting dieback disease into the surrounding vegetation. This has the potential to impact on the conservation value of the vegetation as a natural bushland remnant, a wildlife corridor and as a greenbelt. These impacts would be reduced by a rehabilitation programme which has a restoration of natural woodland as its primary objective.

7.0 STUDY TEAM

The study was undertaken by the following:

- **Dr Dennis Backshall - Botanist**

Attended to field survey and report preparation.

- **Dr Wolf Martinick - Environmental Scientist**

Report preparation and editing.

TABLE 1

PLANT SPECIES OBSERVED ON OR NEAR THE KEMERTON PROJECT AREA

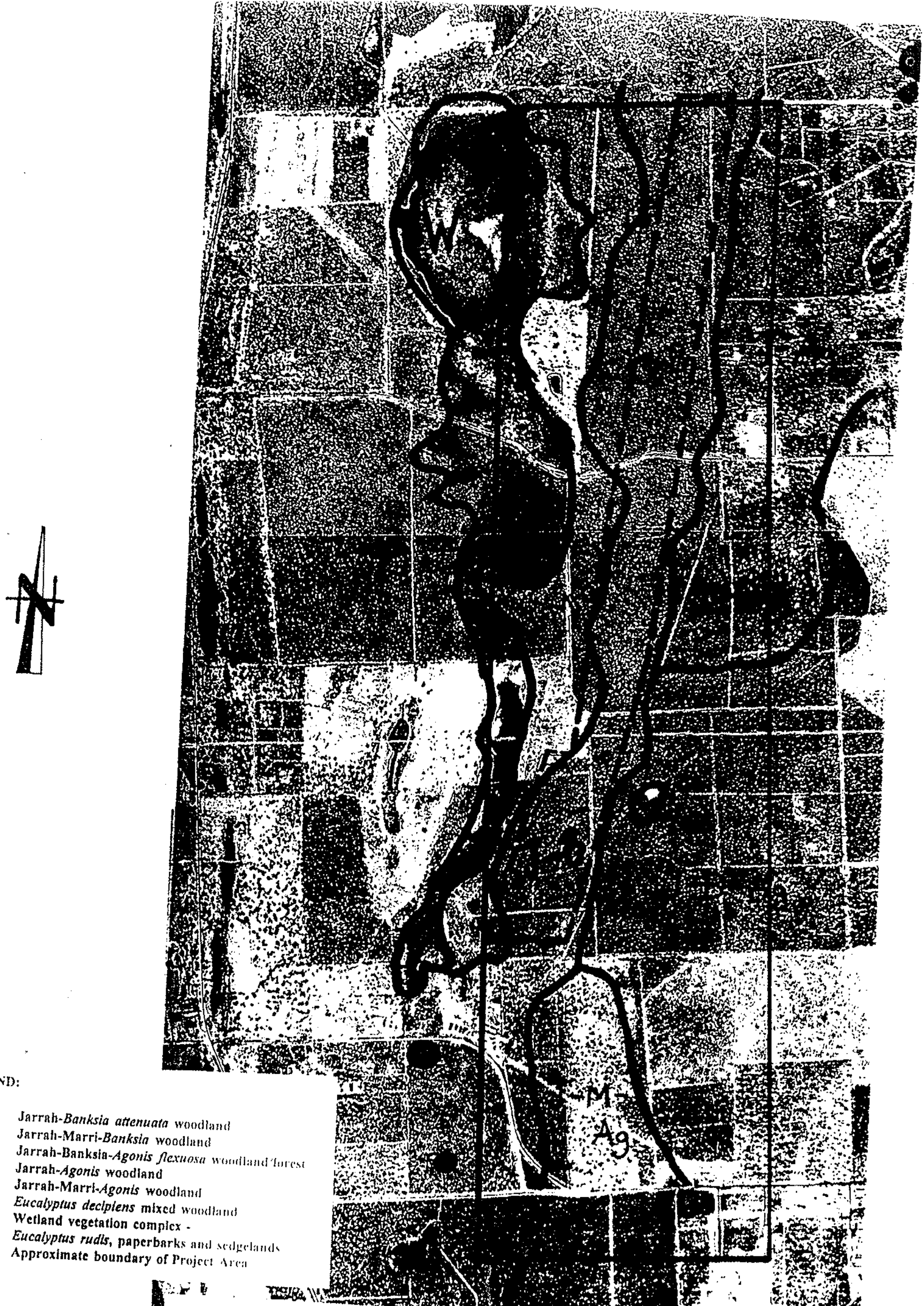
Species	Family
Trees	
Agonis flexuosa	Myrtaceae
Banksia attenuata	Proteaceae
Banksia grandis	Proteaceae
Banksia ilicifolia	Proteaceae
Eucalyptus calophylla	Myrtaceae
Eucalyptus decipiens	Myrtaceae
Eucalyptus marginata	Myrtaceae
Eucalyptus rudis	Myrtaceae
Melaleuca preissiana	Myrtaceae
Nuytsia floribunda	Proteaceae
Persoonia longifolia	Proteaceae
Xylomelum occidentale	Proteaceae
Grass trees	
Xanthorrhoea brunonis	Xanthorrhoeaceae
Xanthorrhoea gracilis	Xanthorrhoeaceae
Cycads	
Macrozamia riedlei	Xamiaceae
Tall shrubs	
Acacia extensa	Mimosaceae
Acacia saligna	Mimosaceae
Aotus gracillima	Papilionaceae
Hakea prostrata	Proteaceae
Jacksonia furcellata	Papilionaceae
Jacksonia sternbergiana	Papilionaceae
Melaleuca radula	Myrtaceae
Melaleuca scabra	Myrtaceae
Viminaria juncea	Papilionaceae
Medium shrubs	
Acacia hastata	Mimosaceae
Acacia pulchella	Mimosaceae

Species	Family
Acacia semitrullata	Mimosaceae
Allocasuarina humilis	Allocasuarinaseae
Adenanthos meisneri	Proteaceae
Astroloma pallidum	Epacridaceae
Bossiaea eriocarpa	Papilunaceae
Calytrix flavescens	Myrtaceae
Calytrix fraseri	Myrtaceae
Conostephium preissii	Epacridaceae
Dampiera linearis	Goodenaceae
Daviesia divaricata	Papilionaceae
Daviesia incrassata	Papilionaceae
Daviesia pectinata	Papilionaceae
Daviesia physodes	Papilionaceae
Gompholobium tomentosum	Papilionaceae
Hemiandra pungens	Lamiaceae
Hibbertia huegelii	Dillenaceae
Hibbertia hypericoides	Dillenaceae
Hibbertia racemosa	Dillenaceae
Hibbertia vaginata	Dillenaceae
Leucopogon polymorphus	Epacridaceae
Leucopogon propinquus	Epacridaceae
Leschenaultia floribunda	Goodenaceae
Melaleuca thyoides	Myrtaceae
Olearia axillaris	Asteraceae
Olearia? elaeophila	Asteraceae
Persoonia saccata	Proteaceae
Petrophile linearis	Proteaceae
Stirlingia latifolia	Proteaceae
Herbaceous perennials	
Burchardia umbellata	Liliaceae
Conostylis aculeata	Haemodoraceae
Cassytha racemosa	Lauraceae
Centella cordifolia	Apiaceae
Danthonia? occidentalis	Poaceae

Species	Family
Dasypogon bromeliifolius	Dasypoganaceae
Hardenbergia comptoniana	Papilionaceae
Haemodorum laxum	Haemodoraceae
Lomandra suaveolens	Dasypoganaceae
Opercularia vaginata	Rubiaceae
Patersonia occidentalis	Iridaceae
Patersonia rudis	Iridaceae
Platysace compressa	Apiaceae
Pteridium esculentum	Dennstaediaceae
Phlebocarya ciliata	Haemodoraceae
Stipa elegantissima	Poaceae
Sedges	
Baumea articulata	Cyperaceae
Baumea juncea	Cyperaceae
Juncus pallidus	Juncaceae
Lepidosperma angustatum	Cyperacea
Loxocarya fascicularis	Restionaceae
Loxocarya flexuosa	Restionaceae
Lyginia barbata	Restionaceae
Schoenus? subbulbosus	Cyperaceae
Tetraria octandra	Cyperaceae
Typha orientalis	Tyrpaceae

TABLE
Stipa elegantissima is an unusual occurrence in this vegetation.

TABLE 1
Xanthorrhoea gracilis is VERY unlikely to occur here. If it does it is the only known occurrence on sands derived from Tamala limestone.



END:

Jarrah-*Banksia attenuata* woodland
3 Jarrah-Marri-*Banksia* woodland
g Jarrah-Banksia-*Agonis flexuosa* woodland/forest
Jarrah-*Agonis* woodland
-g Jarrah-Marri-*Agonis* woodland
Eucalyptus decipiens mixed woodland
Wetland vegetation complex -
Eucalyptus rudis, paperbarks and sedgelands
Approximate boundary of Project Area

PLATE 1: DISTRIBUTION OF VEGETATION TYPES OF THE PROJECT AREA TAKEN FROM AERIAL PHOTOGRAPH RUN 11 (5088-5107, PHOTO 5105) AND RUN 12 (5108-5136, PHOTO 5110)

SCALE: 1:25 000

Department of
Environment and Conservation

ENVIRONMENTAL MANAGEMENT BRANCH

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To: **Manager, Mining and Industrial Assessment Branch (Att: John Güld)**

From: **Manager, Environmental Management Branch (Att: Chris Bishop)**

Date: **10 November 2008**

Subject: **Internal Advice Request – Extension of Kemerton Silica Sand, Dredge Mining, Draft PER – Kemerton Silica Sand Pty Ltd (October 2008)**

I refer to your request for advice of the 24 October 2008, concerning Extension of Kemerton Silica Sand, Dredge Mining, Draft PER – Kemerton Silica Sand Pty Ltd (October 2008). The following advice has been prepared by the Environmental Management Branch (EMB) on behalf of the Nature Conservation Division of the Department of Environment and Conservation (DEC). This advice incorporates the input of Species and Communities Branch (including the Wetland Section) and South West Region, and relates to the adequacy of the information provided in the document pursuant to the Department's responsibilities under the *Conservation and Land Management Act 1984* and the *Wildlife Conservation Act 1950* (WC Act).

Summary

The Kemerton Silica Sands (KSS) proposed western extension lies near the interface of three major landform units including the Spearwood Dunes and the Bassendean (Central and South) and Guildford Complexes, and contains a floristically diverse assemblage of wetland communities and conservation significant flora. A suite of floristic community types are represented, however, a number of these communities are considered to be poorly represented in a regional context. A number of the floristic communities identified, closely align with existing threatened and priority ecological communities (TECs and PECs).

The proposal involves the clearing of 262 ha of vegetation and reinstating 170 ha of permanent lakes and 113 ha of rehabilitated vegetation, resulting in a net loss of vegetation. Given the high conservation value of the native vegetation and wetlands in the proposal area, the Department considers the Draft PER to be deficient in the following areas:

- Flora survey methodology;
- Definition of floristic community types;
- Relationship between mine-site flora communities and the Muchea Limestone TEC;
- Identification of DRF orchids in the project area;
- Wetland classification methodology;
- Pre and post-mining wetland monitoring and management programme;
- Description of post-mining permanent lakes and potential impacts;
- Wetland rehabilitation risk and management;
- Fauna findings; and
- Offset proposal.

Attachment 1 discusses these issues in detail, and provides recommendations to address these issues.

Attachment 1

Floristic Community Types

Issue: There is insufficient information in the Draft PER to provide an adequate understanding of the survey and analysis methods used for determining floristic community types (FCTs) and possible TEC occurrences.

Recommendation 1: *The proponent should provide raw data, in the form of detailed species lists, from all flora surveys undertaken in the project area.*

Recommendation 2: *The proponent should provide more detail on the flora survey methodologies used.*

Recommendation 3: *The proponent should collect data from permanent plots that are scored at least twice in appropriate seasons. Statistical analysis should then be applied to allow comparison with the relevant FCTs described in Gibson et al. (1994).*

Recommendation 4: *The proponent should provide additional information on the type of TEC or priority ecological community list database search that occurred, and how this information was used.*

Recommendation 5: *Information discussing potential impacts to TECs and PECs in a regional context should be provided.*

Issue: There is insufficient discussion on the relationship between some of the listed plant communities and the '*Shrubland and Woodlands on Muchea Limestone*' (Muchea Limestone) TEC.

Recommendation 6: *The proponent should provide more discussion on the relationship of the Mattiske plant communities listed below and the Muchea Limestone TEC.*

Discussion

Flora Survey Methodologies

Raw data in the form of full species lists from relevees and other flora surveys included in the Draft PER have not been provided. This data is required to allow the Department to assess data quality, survey adequacy, species richness and compatibility with relevant references such as Gibson *et al.* (1994).

For the flora survey data used in the Draft PER to be acceptable for statistical comparison to that acquired by Gibson *et al.* (1994), plots should be surveyed in vegetation of best condition, and scored more than once at appropriate times (usually spring and late spring). Given the significance of the vegetation in the project area, this is considered appropriate, and it is not evident from the information provided that this has occurred.

Floristic Community Types

Mattiske (2003) identified 24 plant communities that were considered common in the wider region and well reserved. This list appears in Table 9 of the report. The Department compared the vegetation communities as described by the Mattiske with the key species and community structure of the Swan Coastal Plain FCTs as described by Gibson *et al* (1994), and TECs as defined by English and Blyth (1997). Based on this comparison, Table 1 lists the vegetation communities described by Mattiske that DEC identified as having similarities to FCTs that are listed TECs and PECs.

Table 1 Mattiske Vegetation codes analogous with TECs and PECs

Mattiske Vegetation Community	Potential TEC/PEC
F-2 and G-4	Type 07 *Herb rich saline shrublands in clay pans*: TEC - Vulnerable (VU)
B-1 and C-3	Type 1b *Southern Eucalyptus calophylla woodlands on heavy soils* - TEC: Vulnerable (VU)
A-1, A-2 and A-3	Type 21a Central *Banksia attenuata – Eucalyptus marginata woodlands*: Priority 3 PEC
C-1 and C-2	Type 21b Southern Banksia attenuata woodlands: Priority 3 PEC

The Draft PER does not reference PECs and this should be rectified. One TEC (floristic community type 7) and both PECs (type 21a and 21b) are within the proposed mine extension area, however no information presenting the impacts in a regional context is presented. The Department notes that TEC type 02 (*Southern wet shrublands*) was not identified to align or show similarities with any Mattiske plant communities listed in Table 9, but given the location and habitat of the proposal, the Department considers it likely to be found in the project area. It is not clear if the consultant requested a search of the TEC database, or scrutinised the priority ecological community list prior to the work.

Muchea Limestone TEC

Keighery (1998) identified an occurrence of the *Shrubland and Woodlands on Muchea Limestone* (Muchea Limestone) TEC wetland mosaic, which is associated with four broad vegetation units in close proximity to the mining proposal. The Muchea Limestone TEC is of very high conservation value. Further studies in 2003 and 2004 defined the area and extent of this community. The Muchea Limestone TEC is currently listed as Critically Endangered (CR) in Western Australia and Endangered (EN) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The known occurrence lies within Kemerton Nature Reserve and is not directly subject to the proposed western extension, however given the proximity of the proposal to this TEC, the proponent must consider risks for the conservation of the TEC from indirect mining activity impacts.

Subsequent survey by Muir and Mattiske within the KSS western extension area did not result in a range extension of the Muchea Limestone TEC. However, Mattiske based their interpretations on coarse scale geological records, which indicated that limestone did not occur within the survey area. Muchea limestone is very rare on the eastern side of the Swan Coastal Plain, and is not likely to present in coarse scale geological mapping. However, the Muchea limestone TEC is comprised of discrete vegetation units linked with specific plant communities, and Keighery identified four of these vegetation units in the Kemerton Nature Reserve (Table 2) and therefore potentially present in the project area.

Table 2 Vegetation Communities of the *Shrubland and Woodlands on Muchea Limestone* TEC[1]

Vegetation Unit*	Description
Eucalyptus decipiens	This woodland to open forest is dominated by combinations of *Eucalyptus decipiens*, *E. calophylla*, *Banksia littoralis* and *Agonis flexuosa* on the eastern rise and *Eucalyptus decipiens* and *Agonis flexuosa* on the central southern rise
***Melaleuca rhaphiophylla* and *Eucalyptus decipiens* Low Forest**	This unit fringes the rises
***Melaleuca* species Shrublands/Sedgeland/Herbland wetland mosaic**	This unit is dominated by a complex suite of *Melaleuca* species associated with a series of sedges, rushes and herbs. At times the sedges, rushes and herbs occur without the *Melaleuca* layer
***Melaleuca rhaphiophylla* Low Forest**	This unit is associated with the deeper wetland areas, some of which contain areas of EPP lakes and areas of *Baumea articulata*

* As described in Keighery (1998)

The Department has determined there to be three vegetation communities identified in the Mattiske report that may be associated with limestone areas and therefore, based on Keighery (1998), potentially analogous with the Muchea Limestone TEC. These communities are listed in Table 3.

In relation to Keighery (1998), the Draft PER suggests that some of the conclusions are questionable and that there is a need for further investigation and that it is '*open to interpretation whether or not the presence of Eucalyptus decipiens reflects this community*' (Mattiske 2003). It should be noted that *E. decipiens* and a group of other species, are generally associated with the presence of limestone and occur within the Muchea Limestone TEC. *E. decipiens* occurs on the well developed rises surrounded by a wetland mosaic of associated species.

Importantly, wherever *E. decipiens* occurs in wetlands on the eastern side of the Swan Coastal Plain, it is known to be associated with the presence of the Muchea Limestone TEC. The basis of these differences of opinion requires clarification in the PER.

Table 3 Mattiske Vegetation Communities analogous with the Muchea Limestone TEC

Mattiske Vegetation Community	Description
D-2	Woodland of *Eucalyptus rudis* – *Melaleuca preissiana* and occasional *Banksia littoralis* over Myrtaceae spp. over mixed sedges
F-1	Seasonally inundated Low Closed Forest of *Melaleuca rhaphiophylla* over Myrtaceae spp. over mixed sedges
F-3	Waterlogged, Low Woodland of *Melaleuca rhaphiophylla* over *Baumea articulata*

DRF Orchids

Issue: The Draft PER flora surveys did not find any DRF taxa, in particular orchids that are likely to be present given the habitat.

Recommendation 7: *The proponent should carry out targeted surveys for DRF orchids, and describe the outcome relative to the relevant environmental factors (e.g. presence/absence of fire).*

Discussion
The potential for flora species of conservation significance to be present on the KSS property was assessed (Table 8 on p 49) by the proponent. However, no DRF was found in the western extension survey area out of a potential 8 listed taxa, and only one DRF (*Caladenia procera*) was found in the survey of the adjacent KSS landholding. This low occurrence of DRF requires further investigation and clarification.

The DRF orchids listed in Table 8, and at least one other unlisted DRF orchid *Diuris drummondii* in particular, would be expected within the western extension but were not found. These are all found in similar wetland vegetation communities to those found on the KSS property at nearby locations. The absence of these taxa could be related to flora survey timing and methodology, or an absence of specific environmental factors such as fire. For example, *Diuris drummondii* flowers late, being November through to January. *Diuris purdiei* requires fire to express itself, and some reference to fire history is required.

Wetland mapping and identification

Issue: The Draft PER does not adequately outline which of the three referenced wetland inventories was used in the determination of impacts and management actions.

Recommendation 8: *The Draft PER should indicate which of the three referenced wetland inventories referenced was used in the determination of impacts and management actions.*

Issue: The Draft PER does not adequately address the high conservation values of the Conservation category wetlands identified in the dataset.

Recommendation 9: *The proponent should provide information on the current values of all wetlands within the KSS property, and where necessary make recommendations regarding redefining of the wetlands' boundary, classification and management categories. To reduce the potential for delays, the request to modify the dataset should be submitted to DEC's Wetlands Section immediately.*

Issue: The methodology for classification of wetlands in section 4.8.1 is unclear.

Recommendation 10: *The Draft PER should provide the location, boundary, classification, management category and unique feature identifier (UFI) for each geomorphic wetland located in the KSS property, in a consolidated manner that reflects the information given in the discussion below.*

Discussion

Wetland Inventories

The Draft PER identifies the wetlands in the KSS property using the following:

- Wetlands identified under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1999* (EPP Lakes);
- Wetlands identified in the DEC *Geomorphic Wetlands Swan Coastal Plain* dataset (the dataset); and
- Wetlands mapping and inventory conducted by Bennett (2004).

The Draft PER does not adequately outline which of these three wetland inventories was used in the determination of impacts and management actions. Further, DEC considers that the Draft PER does not adequately address the high conservation values of the Conservation category wetlands identified in the dataset. It should also be noted that the EPP Lakes are portions of larger geomorphic wetlands (identified in the dataset), and therefore should not be considered in isolation of the surrounding wetland community.

DEC notes that the proponent intends to submit a request to modify the dataset in relation to a portion of wetland currently identified as Multiple Use dampland (seasonally waterlogged basin wetland), with the unique feature identifier (UFI) 1907. It is proposed in the Draft PER that this portion is 'upland Bassendean Dune' (pages 6 and 65). Furthermore, the wetlands assessment conducted by Bennett (2004) differs from the information in the dataset. It is also noted that this wetland assessment identifies the proposed 'upland Bassendean Dune' as being a portion of WC5.

Protocol for Proposing Modifications

The '*Protocol for proposing modifications to the Geomorphic Wetlands Swan Coastal Plain dataset*' (DEC 2007; available at www.dec.wa.gov.au/management-and-protection/wetlands/wetlands-data.html) outlines the information that should be provided to DEC when requesting a modification to the dataset. Correct mapping will ensure that the Department can consider the level of impact to the wetlands in relation to their current values, functions and attributes.

It should be noted that this protocol states that dataset modification requests should be submitted *'prior to any application to develop, subdivide or rezone land, or any outline development plan or structure plan'*. This is to ensure consideration of the current wetland extent, values and condition. The proponent also should note that the protocol also states *'that DEC undertakes a comprehensive review of requests to modify the dataset and, depending upon the complexity of the request and the number of requests waiting to be actioned, this may take time to complete'*.

Wetland Classification

The methodology used for the classification of wetlands in section 4.8.1 is not clear. The information contained within the relevant wetland dataset was originally digitised from the *Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas* (Hill et al. 1996).

It should be noted that the management categories are not the geomorphic wetland classification system. The management categories assigned to each geomorphic wetland are based upon wetland evaluation, which is the process of assessing the level of significance of a wetland (WRC 2001, and Hill et al. 1996a). The Draft PER correctly identifies that each management category provides guidance on the nature of the management and protection the wetland should be afforded (WRC 2001).

The geomorphic wetland classification system relates to the wetland types. The wetlands of the Swan Coastal Plain have been classified using the characteristics of landform and water permanence. The geomorphic wetland classification system is outlined in Table 12, however the classifications for the specific wetlands located in the KSS property have not been provided. The unique feature identifier (UFI) for each geomorphic wetland located in KSS property should be provided. DEC and planning agencies use the UFI for ease of identification.

Wetlands management and monitoring programme

Issue: The Draft PER does not clearly commit to a consolidated, detailed and on-going wetlands monitoring and management programme.

Recommendation 11: *The proponent should provide further information on the wetlands monitoring program to be implemented at wetland locations in the existing mining area, proposed extension area (pre- and post-mining), remaining portion of KSS property and the Kemerton Nature Reserve.*

Issue: The description of wetland fauna sample sites and on-going monitoring is unclear and lacks detail.

Recommendation 12: *The Draft PER should provide more information regarding on-going wetlands management, including post-mining and rehabilitation.*

Discussion

The Draft PER provides some information on current weed management, but does not adequately outline a proposed on-going wetlands monitoring and management program. The purpose of the wetlands monitoring should be to identify impacts and assist with adaptive rehabilitation and management. A level of detail similar to Table 6 in Appendix 9 of Volume 2 should be provided. The list of factors should be increased above that of Table 6 to include vegetation and groundwater monitoring. This should also be reflected in Table 1 *Summary of Environmental Factors and Management* and Table 43 *Environmental Commitments.*

Comprehensive background information is important to provide a context for any monitoring program. The sampling proposal should provide a discussion of why the monitoring will be undertaken (e.g. due to potential threats from development) and the objectives and expected outcomes of the sampling program. Timeframes (e.g. how long monitoring will continue) and responsibilities (e.g. who will undertake the sampling, analysis and reporting requirements) should also be provided.

The sampling proposal should describe site selection criteria (i.e. why and how particular sites were chosen) and maps of the proposed sites. In addition, the geomorphic classification of the wetlands to be sampled, as identified in the *Geomorphic Wetlands Swan Coastal Plain* dataset (DEC 2006), should be included. Photo points of the monitoring sites are also useful for the future comparison of wetland condition.

It is recommended that the requirement for one survey only in seasonal wetlands mentioned in Table 6 of Appendix 9 be reconsidered. In order to provide the best possible chance of gathering valuable data, monitoring should ideally be undertaken in early spring when water levels are at their peak and again in late spring after some drying has occurred when wetlands are at about 30% capacity. DEC is currently undertaking a wetland monitoring program (including macroinvertebrates) for the South West Catchments Council using this frequency of sampling.

Monitoring plans should contain a detailed methodology of sampling techniques in order to allow for replication. For example, insufficient detail in regard to live picking of macroinvertebrates has been given in Table 6 of Appendix 9. DEC generally uses 250μm mesh sweep nets in macroinvertebrate monitoring programs, in order to capture the best possible diversity of macroinvertebrates. The proposed sample net size should be given.

Section 4.8.5 initially outlines that wetlands in the extension area, as well as adjacent EPP Lakes and the rehabilitated dredge pond lake were surveyed. However, it also outlines that the sampling did not include sites within the extension area due to there being no surface water expressions in wetlands, which is consistent with the current mapping as damplands. However, Bennett (2004) identifies that the wetlands located in the extension area (WC4 and WC5) include sumplands (Table 14). Therefore, interpreting this information, the extension area should have areas of seasonal inundation for monitoring. Figure 14 indicates two wetland monitoring locations in the extension area.

Relevant wetland standards and legislation

Issue: Relevant wetland standards are not referenced.

Recommendation 13:
The proponent should refer to the Environmental Protection Authority's *Guidance Statement 33: Environmental Guidance for Planning and Development* (EPA 2008), and *Position Statement No. 4: Environmental Protection of Wetlands* (EPA 2004) in section 7.5.2.

EPP4 and UFI 13254

Issue: The impact of mining on EPP4 and the buffering Conservation category sumpland UFI 13254 has not been adequately considered and described, in section 7.5.4.

Recommendation 14: *The proponent should consider the geomorphic wetland boundary, values and functions (including hydrological connectivity) of EPP4 when determining management actions, including buffers. This should take into account the buffering provided by associated sumpland UFI 13254.*

Discussion
A buffer has been determined for EPP4, however this does not address the associated geomorphic wetland (that is, Conservation category sumpland UFI 13254). The proposed boundary of the extension area is adjacent to the boundary of sumpland UFI 13254. Alterations

and impacts to this geomorphic wetland will affect EPP4. Furthermore, because of the groundwater flows, actions within the extension area are likely to impact sumpland UFI 13254.

Post-mining landform

Issue: The direct, indirect and cumulative impact of proposed and current mining on wetland health is not adequately described.

Recommendation 15: *The proponent should adequately identify and acknowledge the extent of the wetlands, and the direct and indirect impacts to wetlands within the KSS property and Kemerton Nature Reserve (including cumulative impacts from both the existing and proposed extension mining areas). This should include adequate identification of the altered wetland values, functions and attributes as a result of the rehabilitation and creation of permanently inundated lakes.*

Recommendation 16: *The proponent should commit to a groundwater monitoring program for the wetlands within the KSS property and Kemerton Nature Reserve, to ensure consideration of the direct and indirect impacts from alteration of the groundwater regime.*

Recommendation 17: *Section 3.11 should provide further clarity to the proposed modifications to the landform, including the reduction in area of ephemeral wetlands.*

Recommendation 18: *Section 3.11 should provide quantification of the amount of overburden and reject material available to provide the proposed graded beaches and shallow areas, given removal of '80 % of the sand'.*

Issue: The risk of rehabilitation failure has not been addressed.

Recommendation 19: *Section 3.11 should provide (or reference provision elsewhere) relevant examples of successful and sustainable rehabilitated wetland ecosystems, post mining, on the Swan Coastal Plain. Reference should be made to potential impacts of permanent water bodies on survival of the Black-striped Jollytail.*

Recommendation 20: *The risk of rehabilitation failure should be addressed.*

Discussion
It is noted that the Draft PER identifies direct impacts to Conservation category wetlands in the extension area (that is, altered local topography and creation of permanently inundated lakes), and indirect impacts to wetlands outside the extension area (that is, potential impacts to groundwater quality and quantity, and intersection of the groundwater table).

However, the direct impacts should also identify that the significant change in the local topography (that is, geomorphology) will potentially impact the local surface and groundwater flows, therefore directly impacting the wetland hydrological regimes. In particular, the wetlands within the extension area are currently mapped as damplands (that is, seasonally waterlogged basin wetlands), and the proposal for rehabilitation is the creation of a number of lakes (that is, permanently inundated basin wetlands), therefore altering the water permanence characteristics. Rehabilitation strategies will also directly alter the wetland functions and attributes relating to the vegetation communities and fauna habitat provision (as referred to in Section 6.1 Environmental Impacts).

This hydrological alteration may also impact the hydrological regimes of the wetlands within the remaining area of the KSS property outside of this proposal and the Kemerton Nature Reserve, due to the likely connectivity of groundwater (moving southeast). It should also be acknowledged that wetlands may be altered as a result of the cumulative impact of the existing and proposed extension mining areas.

It should also be noted that altering the hydrological regime can impact wetland values by:

- reducing the vegetation condition;
- reducing biodiversity;
- impacting fauna habitat;
- disrupting fauna life cycles (e.g. birds, frogs and invertebrates); and
- modifying soil chemical processes (e.g. acid sulphate soils).

Furthermore, the vegetation clearing associated with the dredge mining is likely to affect surface and groundwater. Ecological corridors will be fragmented and consequently disrupt fauna migration patterns north-south and between dryland and wetland areas, and separate wetlands. It is noted that these impacts are covered in the corresponding sections, however it should also be summarised in Section 7.5.3 'Potential Issues'. This will assist in consideration of the level of impacts to the wetlands.

Section 3.11 and elsewhere identifies the creation of permanent lakes, but also outlines that '*post mining landform will retain the low lying (wetland) aspect of the property, separated by elevated land, which will be lower than pre-mining height*'. However, this does not convey the detail provided in Section 7.5 Wetlands (specifically Table 34), which outlines that only 40% of ephemeral wetlands will be retained post mining.

The wetland rehabilitation section (pg.174 onwards) seems reliant on the success of the current mine rehabilitation work. The reviews of this work (e.g. pg.176) reference mixed success with an inherent risk of failure. The risk of rehabilitation failure should be addressed.

The Black-striped Jollytail (fish) (pg.86 and pg.99) require an ephemeral wetland cycle and an open water body final landform will likely cause increased competition and predation from introduced gambusia.

<u>Fauna</u>

Issue: There is a high potential that fauna species of conservation significance exist in the project area, but were not detected in the fauna surveys undertaken to date.

Recommendation 21: *The proponent should provide information detailing fauna survey methodologies and constraints to enable the Department to examine survey completeness and adequacy in its ability to detect the Chuditch, Western Ringtail Possum, Quokka and Australasian Bittern (and possibly the Little and Black Bitterns) in the project area.*

Discussion

Fauna survey reports confirm that the project area supports a rich fauna, with a high number of conservation significant fauna species of regional importance, largely due to the greater Kemerton area being '*one of the largest contiguous areas of native vegetation on the Swan Coastal Plain between Bunbury and Perth*' (pg.85).

Appendix 5 (Vol 2) provides a summary of fauna studies undertaken to date relevant to the project area. In particular, Table 3 and 4 list the recorded and expected conservation significant fauna in the Kemerton Region. This list should contain the aforementioned Bittern species. They are present in nearby Benger Swamp and comparable Baumea wetland habitat occurs on the KSS property.

Chuditch and Western Ringtail Possums (see pg.163 Vol 1) could also be expected in habitat on KSS property given suitable habitat (*Agonis flexuosa* in the case of WRP), and known nearby populations. An abutting property owner has previously provided information indicating the presence of WRP in the northern parts of Kemerton Nature Reserve. This habitat (Mattiske vegetation community types C1 and C2) is also the most impacted by the proposal. Quokka could reasonably be expected in and around the wetlands given that suitable habitat in vegetation communities F1, G3, G4 are found on the KSS property.

Environmental Offsets

The following general advice is provided to assist the proponent to develop its offset package. It does not suggest or imply acceptance of any impact or offset component.

Issue: The offset proposal was not developed according to the principles outlined in both EPA Position Statement 9 and Guidance Statement 19.

Issue: The offset proposal does not demonstrate 'like for like or better' or a net environmental benefit.

Recommendation 22: *The offset proposal should be developed according to the principles outlined in both EPA Position Statement 9 and Guidance Statement 19.*

Recommendation 23: *The proponent should utilise an environmental offsets reporting form, as suggested in Guidance Statement No.19, to address the principles as outlined in Guidance Statement No.19.*

Recommendation 24: *The offset proposal should consider the current values held by wetlands to be impacted and propose offsets that provide the same wetland characteristics, values and functions (that is, wetland type, management category, vegetation community, habitat provision, wetland processes, hydrology, etc),in order to demonstrate 'like for like or better'.*

Recommendation 25: *Given the net loss of native vegetation by the creation of permanent lakes, land acquisition should attempt to demonstrate a no net loss or net environmental benefit through the application of positive ratios*

Recommendation 26: *Prior to proposing offsets, the proponent should adequately describe the biodiversity conservation values of the site as outlined in recommendation 1-7, 9, 15 and 21. Only then can the offset proposal consider the appropriate offsetting of residual impacts.*

Discussion

Offset proposal

It is the view of DEC that the offset proposal was not developed according to the principles outlined in both EPA Position Statement 9 and Guidance Statement 19, particularly the proposal:

- does not address both direct and contributing offsets;
- does not propose 'like for like or better' offsets;
- does not provide clearly defined, publicly registered, transparent, auditable and enforceable offsets;
- does not meet all statutory requirements;
- does not provide a long lasting benefit; and
- does not entail a robust and consistent assessment process.

DEC recommends the proponent utilise an environmental offsets reporting form, as suggested in Guidance Statement No.19, to address the above-mentioned principles and to define the:

- aim of the offset;
- type of offset;
- governance requirements;
- feasibility/risk assessment; and
- consultation.

Offsetting Critical Assets

The Department considers it likely that through further investigation of the floristic communities that TECs, PECs, DRF and priority flora will be confirmed in the area to be impacted, thereby increasing the 'critical assets' to be impacted to those already identified in Figure 24 in the Draft PER.

Land Acquisition

The proposal includes the disturbance of 262 ha of vegetation and the creation of 170 ha of permanent lakes. While 48 ha of ephemeral wetland and 65 ha of upland rehabilitation is proposed, there is no guarantee on the success and revegetation is not considered to be of the same environmental value as pre-mined vegetation. Land acquisition should be considered in order to help address this deficit and positive offset ratios should apply.

The acquisition of 13 ha of rehabilitated existing swamp land is noted and it is unclear if this represents proponent's re-instated swamp vegetation post-mining. If so, there maybe some residual liability to the Department in accepting vegetation that has not met completion criteria and this should be identified. Further mining rehabilitation is not considered to be of the same value as pre-existing vegetation.

References

Department of Environment and Conservation (2007) *Protocol for proposing modifications to the 'Geomorphic Wetlands Swan Coastal Plain' dataset*, Department of Environment and Conservation, Perth.

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Keighery B. (1998). Vegetation and Flora Conservation Values of the Kemerton Silica Sands Project Area. Unpublished report to Department of Conservation and Environment.

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DEC 9560-01
DOC 67252

Department of Water
Government of Western Australia

SW5331

Richard Watson

9726 4111

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Attention : John Güld

Dear John

Re : Draft Public Environmental Review - Kemerton Silica Sand Pty Ltd
Extension of Kemerton Silica Sand Dredge Mining

Thank you the opportunity to comment on the Draft PER for this project. Sections relevant to the licensing and monitoring of groundwater extraction at the site have been reviewed by South West Region staff and the following points have been raised.

- **Section 3.6 Extraction Method**
  The Department of Water is currently reviewing its policy regarding the licensing of dewatering operations. It is therefore possible that licensing of the dredge mining may be required once a policy position on these mining activities has been finalised.

- **Section 3.7 Groundwater Usage**
  This section gives the process groundwater extraction licence number as GWL60367(**2**), while the current version is GWL60367(**3**), which was issued on 20 August 2007, with a reduced Annual Water Entitlement (AWE) of 660,000kL. The new version of the licence also contains updated groundwater monitoring conditions, but the expiry date of 30 June 2013 remains unchanged.

  The wording " . . . *and at the request of the Department of Water (DoW), due to over allocation in the local Kemerton sub region*" is not strictly correct. A reduction in the AWE was proposed to reflect water efficiency gains at a time when allocation limits were being revised in the area due to changes to groundwater subarea boundaries. The actual figure of 660,000kL was nominated by KSS.

- **Section 4.3.2 Acid Sulphate Soils** ?
  This section does not include the reference in **Section 7.1.2.4** to the increasing acidity of the dredge pond reported as ranging from pH 6.5 to 8.0 from 1996 to 2004, but from pH 5.0 to 6.4 since 2004. It is stated that the reasons for this are unknown but several possibilities are mentioned including ". . . *acid generation from the dredge pond itself*".

  Check this aspect closely.

  The Management and Mitigation Measures outlined in **Section 7.1.2.5** indicate that an Acid Sulphate Soils Management Plan (AASMP) will only be prepared " *If acid generation occurs due to mining . . . to address any acidity generated (Commitment 3b)*". Given that the possibility exists that this is already the case, the Department of

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Water recommends that an AASMP be prepared and implemented immediately to ensure the on-going protection of the surrounding environment.

Other questions this raises are, for example, what parameters are to be used to determine if any future reductions in pH are due to mining? What happens if the pH in the dredge pond continues to fall but the chosen parameters suggest it is not due to mining? The AASMP must include, but not be limited to, contingency measures which address these issues.

- **Sections 4.5.1 & 4.5.2 Groundwater**
  The PER notes here that the groundwater flow from the Mialla mound, which lies beneath the KSS site, is indicated to be south-eastwards towards the Wellesley River. Deeney's 1989 report "*Geology and Groundwater Resources of the Superficial Formations between Pinjarra and Bunbury, Perth Basin*", contains plans which indicate that the western extensions may lie on the west side of the mound's crest and groundwater in this area may flow to the west or southwest.

  This is an area without any monitoring bore coverage and it is recommended that additional bores be provided along the western boundary of the property and to the north and south of the western extensions to accurately assess hydraulic gradients and potential effects off-site.

  The Mialla mound is an important recharge area for the Superficial aquifer. Groundwater throughflow is towards the Wellesley River and associated drains in the east but also west and southwest towards coastal lakes and horticultural properties where it is used for the irrigation of vegetable crops (refer attached plan). Water quality in recently drilled horticultural bores only 2.5km west of the western boundary of the mine was reported to be less than 600mg/l TDS, while bores just west of Old Coast Road contain water with salinity of around 800mg/l TDS. Modelling suggesting that post mining groundwater salinity under the mound is expected to increase from 300mg/l to about 1000mg/l TDS after 85 years raises concerns about potential effects on the water quality of these users down gradient of the mound in the west (Section 7.3.4.2).

- **Section 4.5.3 Groundwater Quality**
  The comment "*. . . these results all fall within historical ranges that could be expected for groundwater in the superficial aquifer in the area (Deeney, 1989)*" may be misleading as the Deeney study covered all the Harvey Shallow Project bores drilled over a wide range of environments including the Tamala Limestone, Guildford clay and Jandakot Beds. For example, monitoring bores KMB6 and KMB10 both contain low pH water, the latest results (01/06/2008) being pH 3.9 and 3.7 respectively with historical lows of pH 3.1 in KMB6 and pH 3.4 in KMB10. These values are lower than any recorded by Deeney (lowest was pH 4.0). This provides additional impetus for the preparation and implementation of an AASMP.

- **Section 7.3.4 Groundwater Impact Assessment**
  This section refers to Rockwater (2007), but a more recent report entitled "*Groundwater Monitoring Review, July 2005 to June 2008 (GWL60367(2&3)*", dated September 2008 is now available and consideration should be given to its inclusion.

- **Section 11 Environmental Management Commitments**
  Commitment 5 proposes two new monitoring bores within 100m of EPP4. The Department of Water recommends that the monitoring locations should be set back as far as practically possible upstream of EPP4 for early detection of pollutants or changes in water levels. As mentioned above, it is also recommended that additional

monitoring sites be identified on the western boundary of the property and north and south of the western extension.

The provision of two new production bores within 200m of KMB6 should be reviewed in light of KMB6 having been identified as having the lowest pH of any monitoring bore. It is desirable that groundwater extraction is spread over several bore sites, but it must be without the risk of mobilising low pH groundwater, as may be the case if new bores are established near KMB6.

In general, the PER gives strong commitments to the maintenance of surface and ground water quality, and mitigation measures are outlined to reduce the risk of adverse effects. However, no contingency plans are provided to address any adverse effects on groundwater, surface water and wetlands, which may be identified in monitoring data.

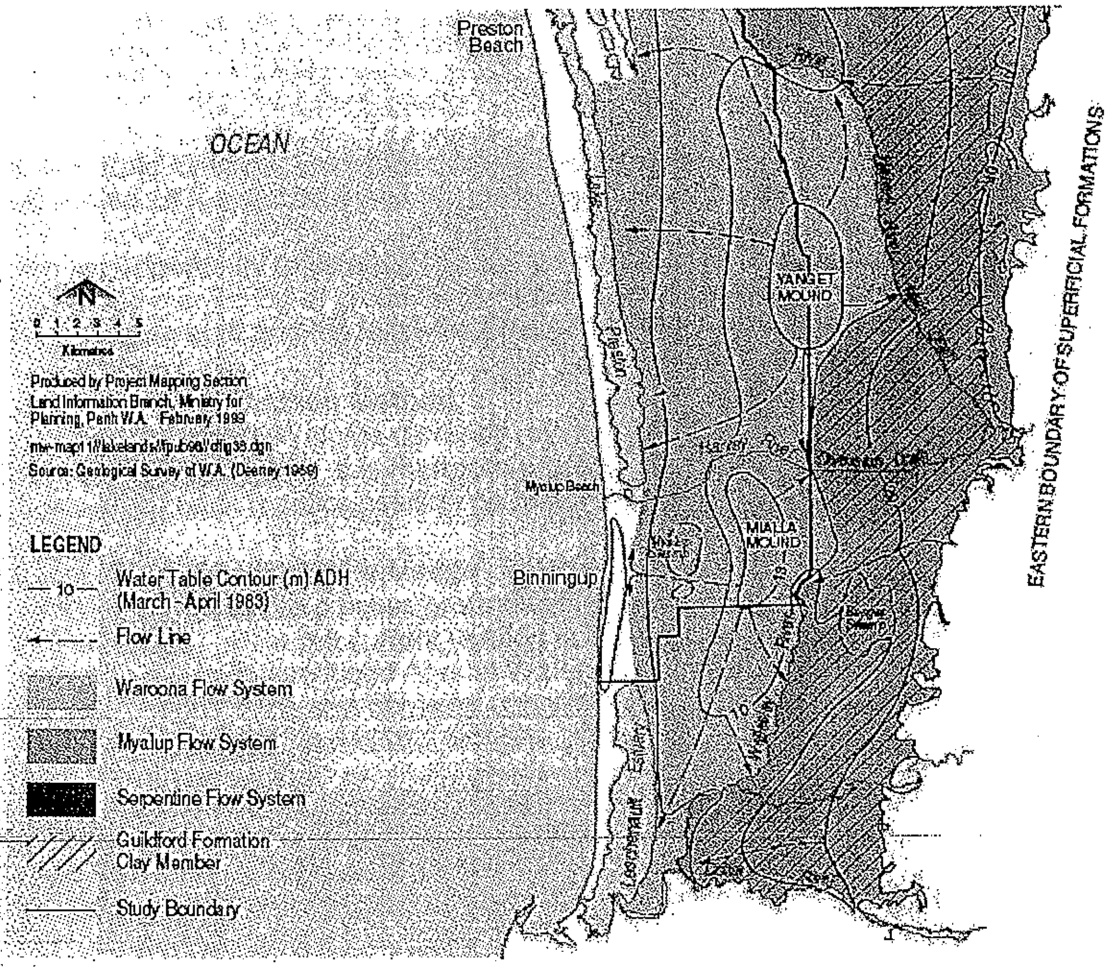
For example, modelling (Section 7.3.4.2) suggests that post mining groundwater salinity is expected to increase from 300mg/l to about 1000mg/l TDS after 85 years and concludes that impacts "*are likely to be minor*" because TDS in groundwater varies across the property. However, this variability is likely to be compromised by the dredge mining operations and contingency plans should be provided in case the effects turn out to be greater than modelling suggests.

Yours sincerely,

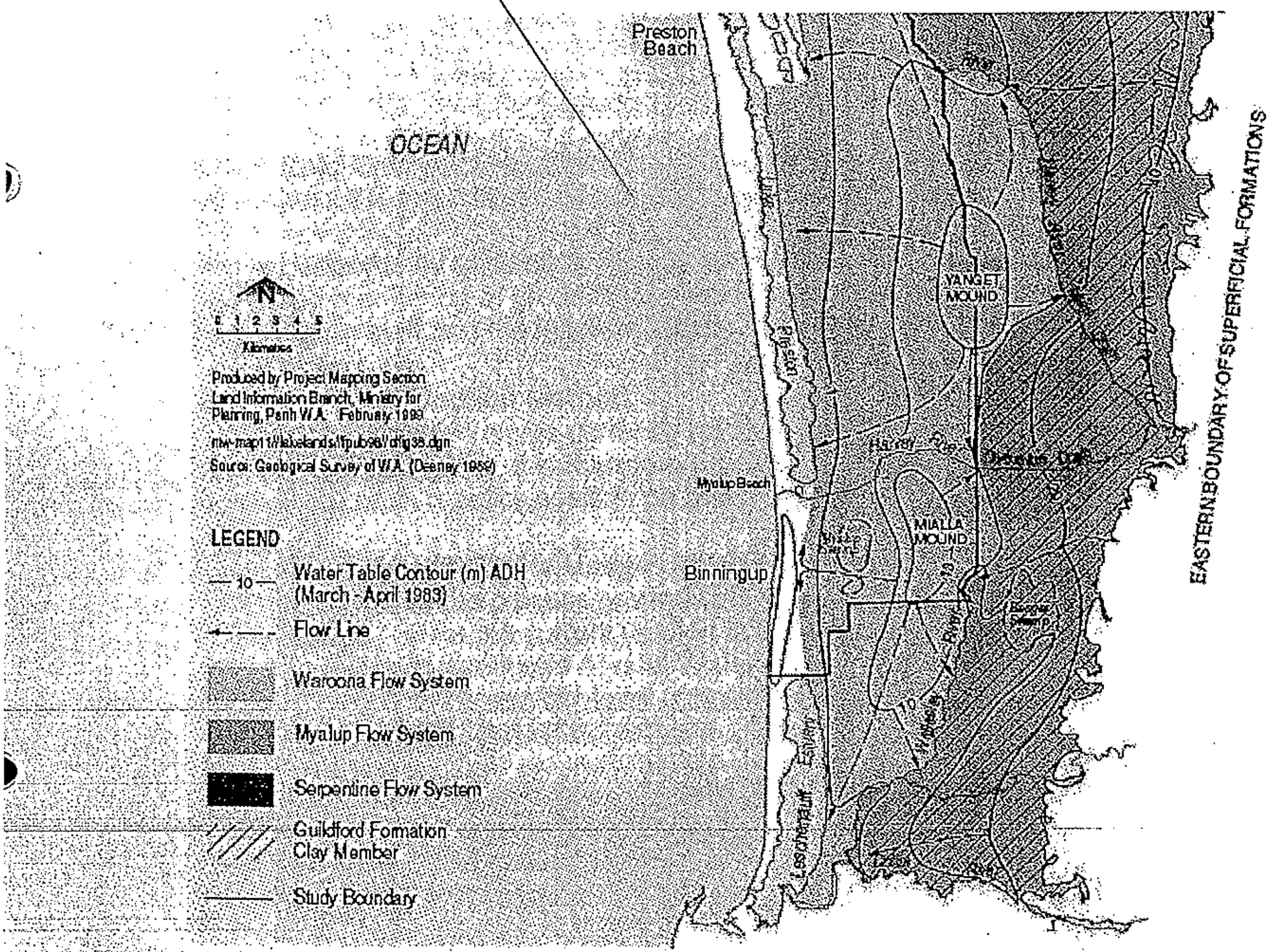
Mike McKenna
District Manager
Leschenault-Collie District
South West Region

Richard Watson
Senior Natural Resource Management Officer
South West Region

4 November 2008



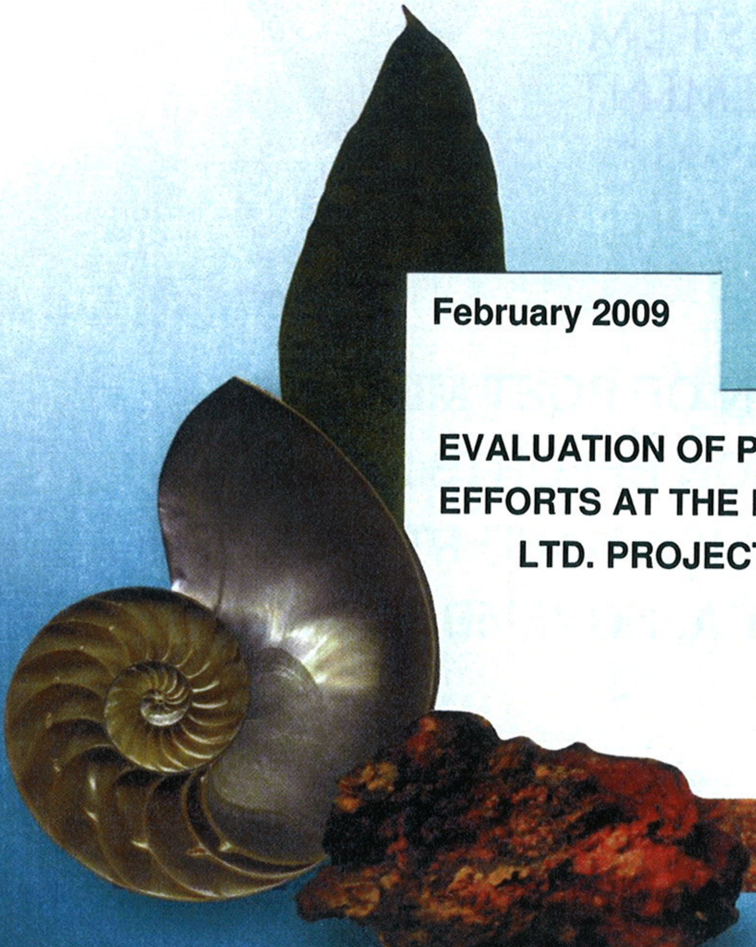
Westward Groundwater Throughflow from Yanget and Mialla Mounds



Westward Groundwater Throughflow from Yanget and Mialla Mounds

Centre for ecosystem management

EDITH COWAN
UNIVERSITY
PERTH WESTERN AUSTRALIA



February 2009

EVALUATION OF POST MINING REHABILITATION EFFORTS AT THE KEMERTON SILICA SAND PTY. LTD. PROJECT AREA, NOVEMBER 2008

By, Dr. Eddie van Etten
Dr. Clint McCullough
Assoc. Prof. Mark Lund

CENTRE FOR ECOSYSTEM MANAGEMENT

CENTRE *for* ECOSYSTEM MANAGEMENT
EDITH COWAN UNIVERSITY

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EVALUATION OF POST MINING REHABILITATION EFFORTS AT THE KEMERTON SILICA SAND PTY. LTD. PROJECT AREA, NOVEMBER 2008

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Frontispiece

Plate 1:. Rehabilitated edge of 'North Lake' dredge pond near transect 7 looking east (November 2008).

1 Executive Summary

- Eddie van Etten and colleagues at ECU's Centre for Ecosystem Management (CEM) were engaged to evaluate rehabilitation at the KSS minesite at Kemerton in mid 2007 and to provide recommendation to help improve restoration success of post-mining environments. In early November 2008, KSS contracted the CEM to report on changes to rehabilitation since 2007 and to evaluate their most recent rehabilitation.

- Overall, the monitoring has revealed a slight to modest improvement in rehabilitation since the previous monitoring in mid 2007. Plant cover showed the most marked increase from 2007, with plant abundance and species richness generally stable overall

- Generally plant cover increased more substantially in low-lying areas closer to lake, with new species appearing more readily in such areas. Areas higher in the topographic profile have experience a decline in fringing/flooded zone species such as Melaleucas, rushes and sedges. Therefore it is apparent that some degree of species sorting according to moisture and flooding preferences is occurring. This is encouraging, as is the seemingly natural recolonisation in lower areas by sedges, melaleucas and other wetland species.

- Differences between rehabilitation sectors revealed in previously monitoring were mostly maintained and can be clearly related to differences in rehabilitation technique and topographic position in relation to lake levels. This and previous monitoring confirm that good to excellent ecological restoration can be achieved at post-mining landscape at Kemerton through use of fresh topsoil. Matching of topsoil to topographic position should improve overall rehabilitation success. Recent rehabilitation of low-lying areas using topsoil has achieved excellent results at the Kemerton mine site. The challenge now is to improve upland restoration so it achieves similar success in terms of return of plant cover, species richness and resemblance to nearby native upland communities.

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3 Study Area, Monitoring Sites & Methods

3.1 Location & Study Area

The Kemerton Silica Sand Pty Ltd (KSS) project area occupies some 1 600 ha of land at the northern end of Kemerton Industrial Park, 20 km north of Bunbury (Figure). The KSS Project Area is located in the Swan Coastal Plain, primarily on gently undulating Bassendean Sands, with vegetation comprising *Eucalypt-Banksia* woodland on uplands and wetlands on lower parts of the landscape.

Feldspathic silica sands are extracted from below the water table using dredge ponds. The resource generally lies beneath <1 m of topsoil and 4 to 7 m of overburden (which generally contains a band of coffee rock at the inter-phase between high and low groundwater levels). The overburden is removed by earth moving equipment. The ore resource is then extracted from a 30 m deep superficial aquifer using a surface floating dredge to a maximum permitted depth of 15 m. Once ore extraction is complete, the dredge pond is approximately 10 m deep. As the dredge pond is essentially an expression of the groundwater, the results are permanently inundated lakes. Fines, overburden and topsoil are available for sculpting and landscaping of the dredge ponds and surrounds.

The study has focussed on the main rehabilitation area around the northern most dredge pond of the Kemerton active mining area, hereafter referred to as "North Lake" (Figure 1). This area was mined and the pond created in the late 1990's. Rehabilitation of the surrounding slopes commenced in 2001 and progressively implemented until 2007 with different techniques used in different areas (known as rehab 'sectors'). Active mining is currently occurring in dredge ponds immediately south of North Lake, with the southern edge of the dredge ponds rehabilitated in 2007. This rehabilitation was monitored for the first time in this study.

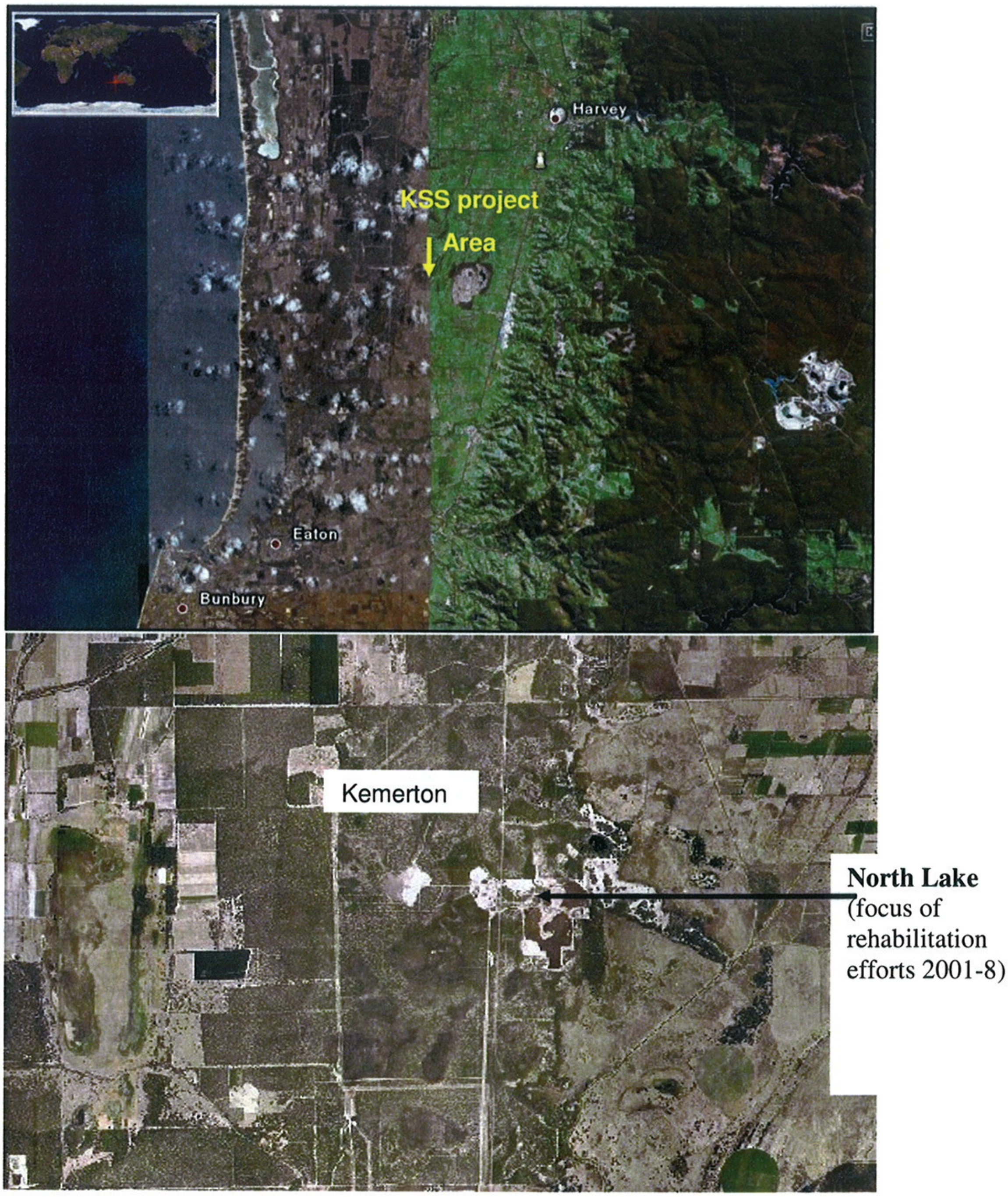


Figure 1. Location of Kemerton wetlands and mine site in south-western Australia.

3.2 Rehabilitation History & Sectors

The slopes of North Lake have been progressively rehabilitated between 2001 and 2007. We have identified six distinct rehabilitation areas or 'sectors' delineated by different histories of soil treatments and revegetation techniques, as well as fundamental environmental differences. These are described in Table 1 and are mapped in Figure 2.

Table 1. Summary of rehabilitation history and monitoring around North Lake.

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History
1 (north-east)	Mattiske #1	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags **Autumn 2006:** ripped, hand-seeded, brushed, herbicide and fertilised/limed	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
2 (east)	Mattiske #4	~2	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: minor ripping on contour, herbicide treatment and planting of seedlings (in gaps only); fertilised and covered with tree bags	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
3 (south-east)	Mattiske #5	~1	**Feb 2001**: contoured and spread with topsoil (and understorey debris) **Autumn/winter 2002**: major ripping on contour, herbicide treatment, planting of seedlings' fertilised and covered with tree bags **Autumn 2006:** hand-seeded and fertilised/limed	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
4 (west)	Mattiske #7	~4	**April 2003**: contoured and spread with 20cm topsoil (and understorey debris)	**March 2004**: Mattiske Consulting **August 2005**: Mattiske Consulting **June 2007**: CEM **November 2008**: CEM
5 (north)	New Transect (#10)	~2	**Autumn 2006**: contoured and spread with 10 year old, stored topsoil (with some understorey debris)	**June 2007**: CEM **November 2008**: CEM
6 (south)	New Transect (#9)	~2	**Autumn 2006:** contoured and spread with direct fresh topsoil return (understorey debris). Most topsoil from dampland Area. Upland soil placed on higher ground	**June 2007**: CEM **November 2008**: CEM

Sector	Monitoring Transect	Area (ha)	Treatment(s)	Monitoring History

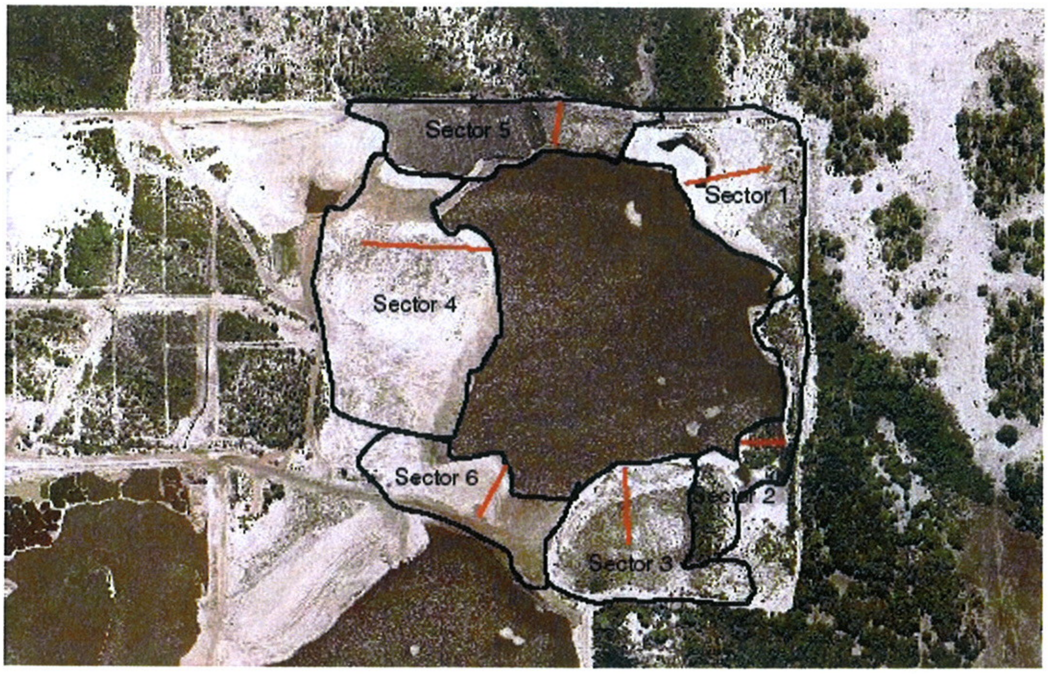


Figure 2. Aerial photograph from 2006 showing Sectors around North Lake. Topsoil has been recently applied to Sector 5 in the photo. Position of monitoring transects are shown by red lines.

3.3 Climate

Average rainfall in the Kemerton Area is around 900 mm per year (based on interpolation of Bureau of Meteorology records from Bunbury, some 20 km to the south, and Wokalup, some 10 km to the north-east). Rainfall is distinctly Mediterranean in distribution, with the vast majority of precipitation falling in winter and spring (

Figure). Summers are typically very dry and warm to hot, whereas winters are cool and wet (Figure). Frosts are rare, with an average of 1 day per year with minimum ground temperatures below -1°C recorded at Wokalup, although this seems to be increasing with dry winters.

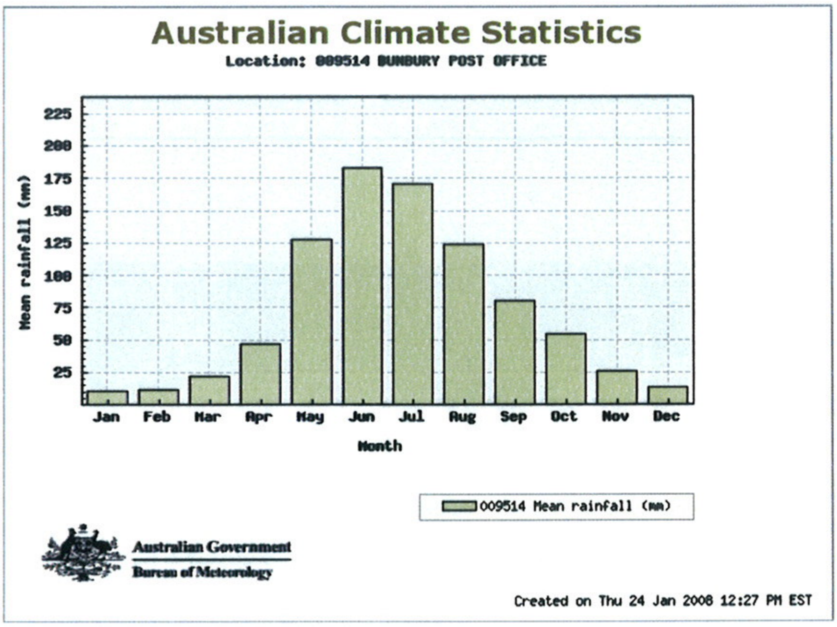


Figure 3. Average monthly rainfall for Bunbury P.O. (1880-1985) (Source: Bureau of Meteorology 2008).

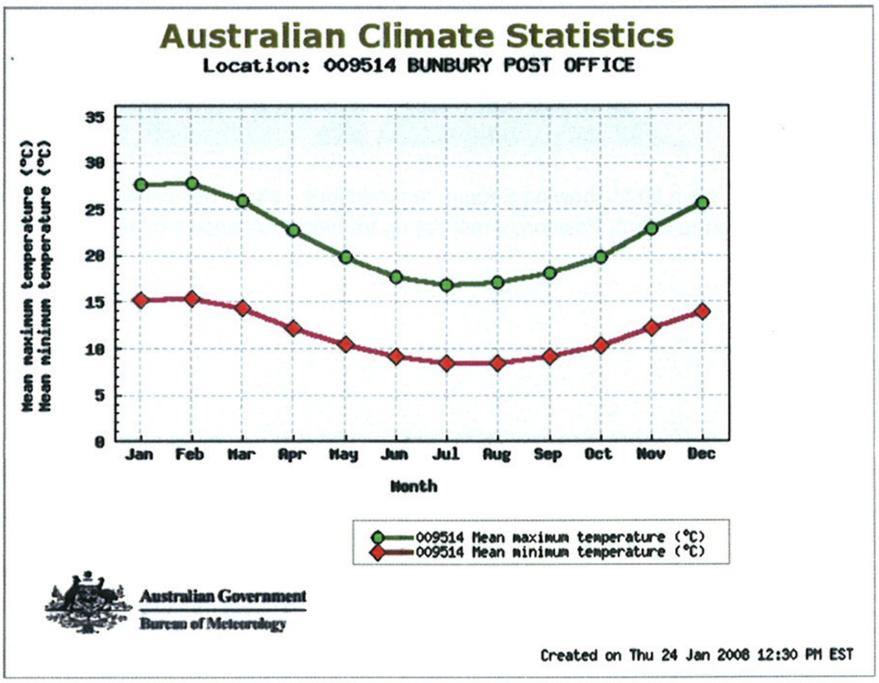


Figure 4. Average monthly maximum and minimum temperatures for Bunbury P.O. (1880-1985). (Source: Bureau of Meteorology 2008).

The rehabilitation period 2001–2008 was one of the driest periods on record (Figure). Each year was below the long term average, with many below the recent (1996–2006) average. The year 2006 was very close to the lowest annual rainfall on record. Since then, two years (2007-8) just under the long-term average have occurred.

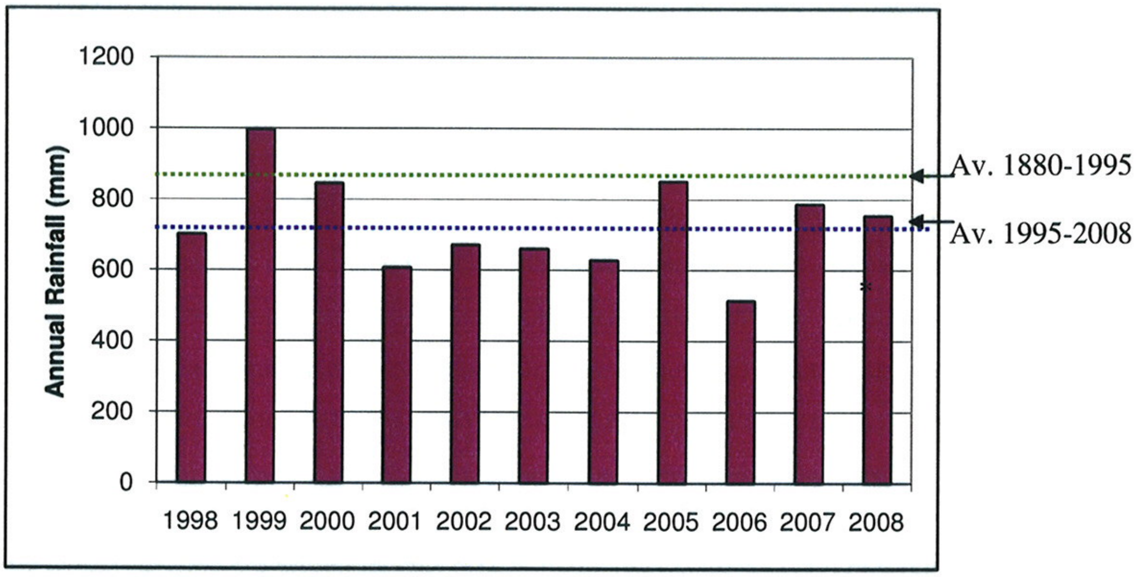


Figure 5. Annual rainfall for Bunbury for the period 1998-2008 compared against average annual rainfall for 1880-1995 (long-term; green broken line) and 1995-2006 (recent; blue broken line

3.4 Rehabilitation Monitoring Methods

Assessment of exiting rehabilitation was made through re-measurement of existing permanent monitoring transects established by Mattiske Consulting P/L in 2004-5 and the Centre for Ecosystem Management in 2007. One monitoring transect was measured in each of the six distinct rehabilitation sectors (as defined above). In addition a new transect was established in recent rehabilitation on the southern edge of the dredge ponds. Field measurements took place on 6^{th} and 7^{th} November 2008.

Each monitoring transect was positioned transverse to the slope and extended from the lake shoreline to the end of the rehabilitation at the top of the slope. They varied in length from 80 to 200 m. At each 5 m interval along transects a 2 m x 2 m sampling quadrat was established and the cover and abundance of each plant species was recorded. Notes on plant size, particularly the number of seedlings, and condition were made.

Plant species were identified using a combination of prior experience, published keys, Florabase (DEC website), herbarium records and other resources. Nomenclature follows that of Florabase as of January 2009. The focus was on native species, although total weed cover was recorded in quadrats. Some plant species names have changed or are more certain since the last monitoring for a number of reasons. Firstly, seedlings in newer rehab are now larger and are thereby easier to correctly identify. Also many species were in flower during this (spring) monitoring period, even in recent rehab, whereas previous monitoring was completed in early winter. Lastly, some species names were changed to reflect recent changes in taxonomy. Examples of key changes since last monitoring include: *Desmocladus* (*Loxocarya*) *flexuosa* is now *Empodisma gracillimum*, *Baumea articulata* is now *Juncus pallidus*, *Kunzea ericifolia* is now *K. glaucescens* and *Gompholobium* sp is now *G. aristatum*.

Data analysis involved calculating the mean and standard error of quadrat cover, density (number of plants per quadrat) and richness (number of species per quadrat) for each transect. The mean values of these parameters were then compared between transects and between monitoring periods. Analysis was conducted on perennial species only to enable fair comparison between monitoring periods given previous monitoring has occurred over different seasons. Differences in species composition between transects and quadrats were explored using ordinations. Ordination techniques attempt to arrange surveyed sites so that the degree of similarity in plant species composition is represented in the physical spacing of the sites when the data are plotted i.e., similar sites sit close to one another. Differences between sites were then tested using ANOSIM which can be considered to be similar to analysis of variance (ANOVA) for this type of analysis. Similarities were determined using the Bray-Curtis measure (based on square root transformed cover values of species). Ordination and ANOSIM were then performed using the Primer (v6) software (PRIMER-E Ltd, 2006).

4 Summary of Rehabilitation Trends by Sectors

4.1 Sector 1: North-East Corner (Transect #1)

History:

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: Ripping between existing plants with 3 tyne ripper to 30 cm depth, hand-seeded (with ~9 common understorey species), limed (2t/ha) and fertilised (incl. trace elements). Also hand spread with brush to avoid re-compacting the area;
- June 2007: 3rd monitoring by CEM
- November 2008: 4th monitoring by CEM

Sector 1 has experienced little change since 2007 (Figure 6). Most quadrats along the monitoring transect have experienced growth of more well established and larger plants, and this has been more pronounced closer to the lake edge where sedges and sedge-like species such as *Juncus pallidus* and *Lepidosperma longitudinale* have proliferated at lower elevations where soils were waterlogged or partially flooded at time of monitoring. Seedlings of several species not previously recorded in quadrats were also found in these lower areas closer to the lake. This rehabilitation sector was one of the first attempted in 2001 and was initially poor in terms of native plant cover and species diversity. Soil remediation measures implemented in autumn 2006 (ripping, seeding, fertilising) made a significant difference to native species cover and diversity, and this improvement has been sustained over the last 16 months. However, although lower areas are improving, loss of some species and individual plants, particularly legumes such as *Viminaria juncea, Hardenbergia comptoniana* and *Acacia* spp, in upper parts of this area is a concern. Some of these species are relatively short-lived and declines in cover may represent loss of individuals established in initial rehab of the site in 2001. Some loss of young *Melaleuca* spp. in the middle of the quadrat is also of concern –

these seedlings established following direct seeding in Autumn 2006 and appear to be drought impacted. In contrast, new shrub species such as *Aotus gracillima, Astartea scoparia* and *Pericalymma ellipticum* have established in middle to lower reaches of the sector; these most likely represent delayed germination from the 2006 seeding presumably responding to good winter rainfall in 2008. It is recommended that more planting and/or seeding of typical upland species of the local area be conducted, with accompanying weed control, in areas >2m above the lake height.

Plate 2 a,b. Rehabilitation in Sector 1 (along transect #1) showing patchy native shrub cover and abundant weeds.

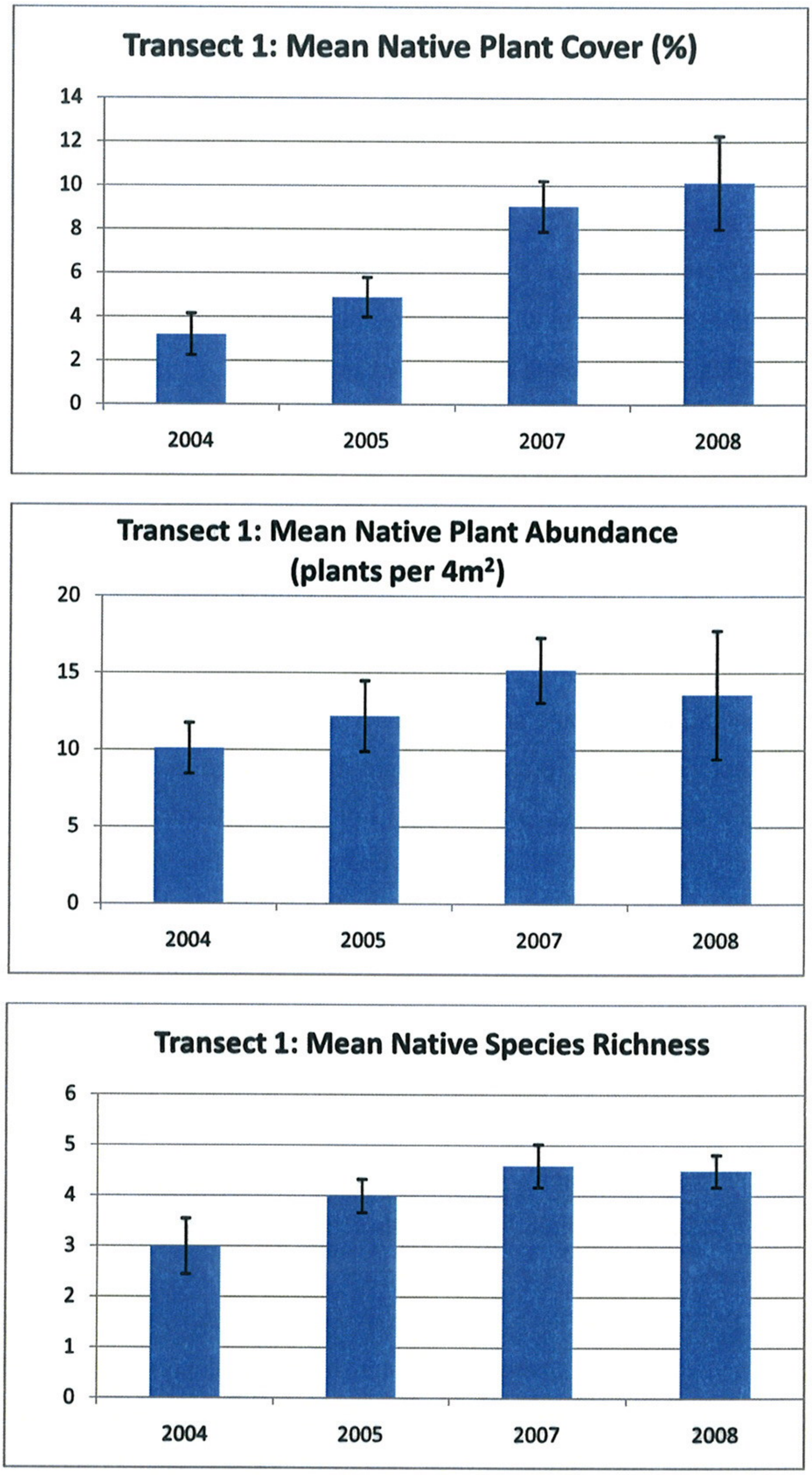


Figure 6. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 1 within rehab Sector 1. Error bars are ±standard errors.

4.2 Sector 2: East Side Lowlands (Transect #4)

4.2.1.1 History

- February 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM
- Oct 2008: 4th monitoring (this report)

Sector 2 has been the most successful area in terms of restoration of plant cover at Kemerton, as well being most similar to native wetland communities of the study area in terms of species composition and structure. It is dominated by several tall *Melaleuca* tree species (i.e., 'paperbarks') and tall Myrtaceous shrubs such as *Astartea scoparia.* It also has good cover of native sedges and sedge-like plants as would be expected in such fringing wetland communities. The success of this Sector in terms of rehabilitation is due to low lying nature of the land and appropriate species selection in terms of topsoiling and seeding. There is also evidence of natural recolonisation in areas closest to the lake.

Even though very successful, this area continues to improve, with a significant increase in number of native plant species recorded (Figure). Also most quadrats experienced an increase in plant abundance and cover (Figure). Most of this improvement can be attributed to colonisation by new understorey species and growth of existing plants. There has been some loss (death) of individuals in dense stands of shrubs (most likely due to competition), but this has been more than counter-balanced by recruitment of seedlings and colonisation by new species. Species such as *Astartea scoparia, Acacia pulchella, Hypocalymma angustifolium,* and *Kunzea glaucescens* appeared to have colonised upper reaches of this sector. Some of the improvement in species diversity can also be attributed to different seasons of monitoring; for instance several geophytes species, such as sundews (*Drosera*) and orchids (*Caladenia*), recorded for first time in this monitoring period, are only detectable in spring and survive underground as tubers in other seasons (the previous monitoring was in June 2007).

In summary, the most recent monitoring confirms that excellent restoration can be achieved in lowlands surrounding the lake if appropriate species selection and/or topsoil matching is practiced.

Plate 3 a,b: showing dense and tall rehabilitation in Sector 2 (along transect #4).

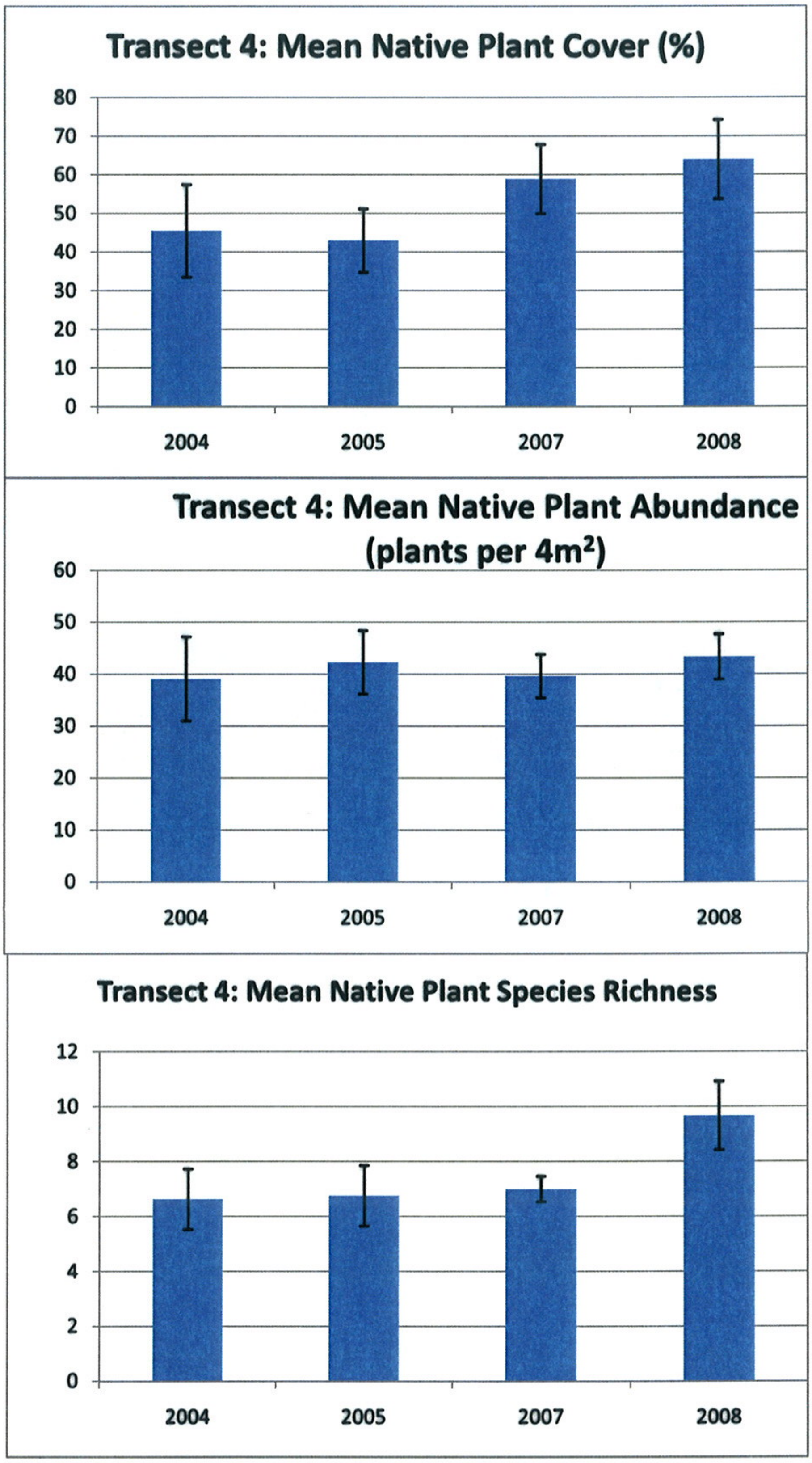


Figure 7: Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 4 within rehab Sector 2. Error bars are ±standard error.

4.3 Sector 3: South-East Side Uplands (Transect #5)

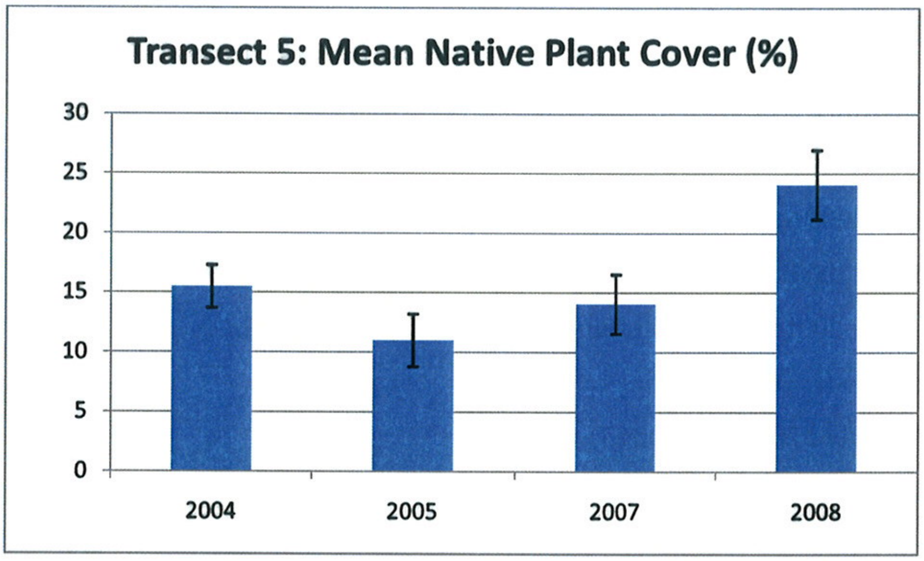
4.3.1.1 History

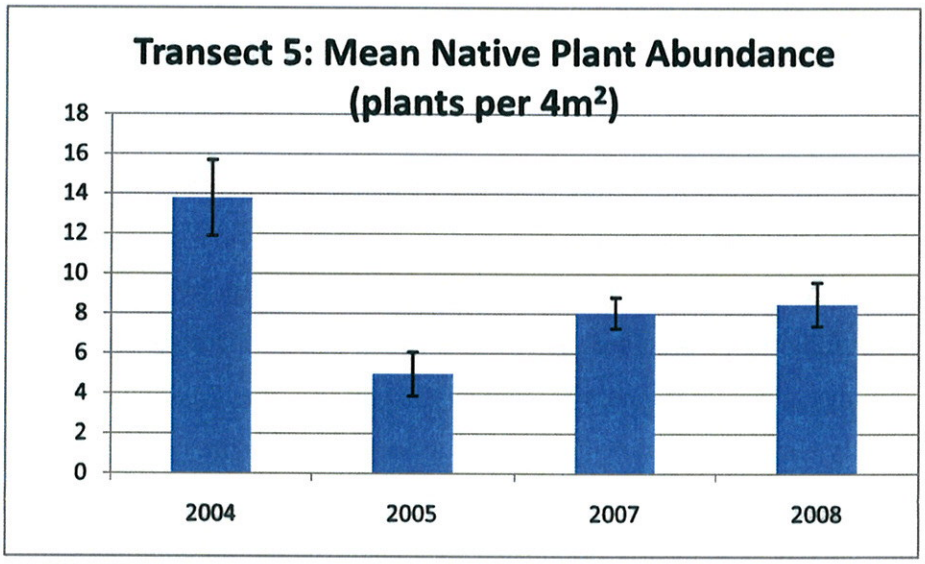
- Feb 2001: contoured and spread with topsoil (and understorey debris);
- Autumn/winter 2002: ripped on contour, herbicide treatment and planting of seedlings; fertilised and covered with tree bags;
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- Autumn 2006: hand-seeded (with ~9 common species), fertilised (including trace elements), limed (2t/ha) and (apparently) treated with herbicide;
- June 2007: 3rd monitoring by CEM
- Oct 2008: 4th monitoring (this report)

Sector 3 has experience a significant increase in plant cover since previous monitoring in 2007 (**Figure 1**) mostly attributable to growth of existing large plants, particularly legumes such as *Acacia pulchella* and *Acacia saligna*, and in Myrtaceous shrubs such as *Kunzea recurva* and *Hypocalymma angustifolium*. These species were seeded in autumn 2006, so this treatment was relatively successful. Plant abundance and species richness have stayed relatively constant over the last 16 months on average (Fig 8); however this masks a dynamic where dying shrubs have been more-or less balanced by new recruitment and colonisation. New germinants of perennial native species is encouraging which demonstrates viable seed of such remains in the topsoil. Such recent recruitment has included species such as *Acacia pulchella, Hypocalymma angustifolium, Pericalymma ellipticum* and *Kunzea glaucescens* –all except the first of these were seeded in 2006. A higher than average winter rainfall no doubt contributed to recruitment. Some legumes have been lost or are dying (eg *Juncea viminaria*) which is perhaps indicative of individuals reaching the end of their life span. Some *Melaleuca* seedlings which established after the 2006 direct seeding have not survived.

Despite the improvements in rehabilitation, this area remains species poor and structurally simple for 7 year old rehabilitation, especially compared to Sector 2 adjacent. The higher topography is likely to be cause with most of Sector 3 greater than 2 m above high lake levels. It is recommended that ongoing work in seeding/planting of upland species and weed control occurs in this Sector. If any excess upland topsoil is available, it should be spread on this Sector.

Plate 3 a,b: showing typical plant cover of Sector 3 (transect 5) showing dominance of weeds and stunted tree and shrub growth.





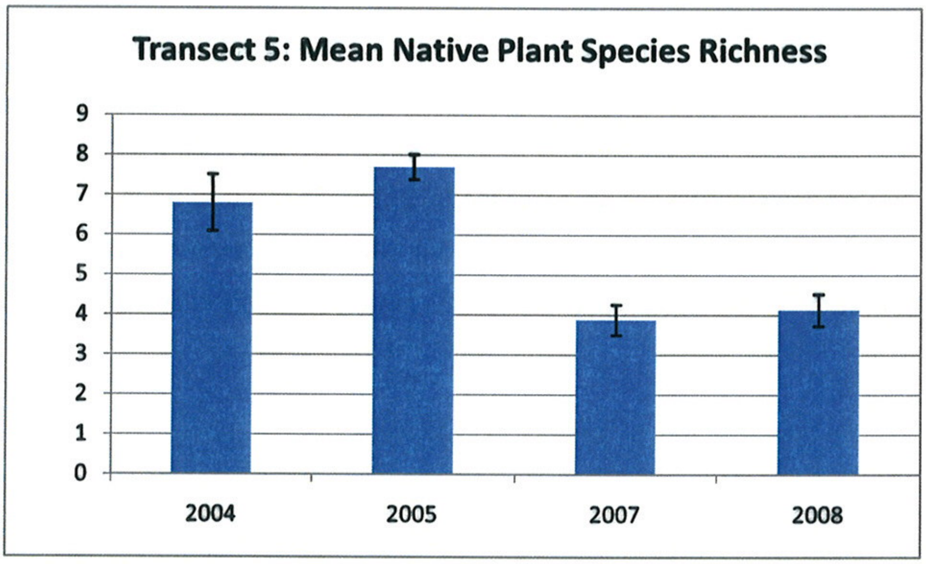


Figure 1. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 5 with rehab Sector 3. Error bars are ±standard error.

4.4 Sector 4: West Side (Transect #7)

4.4.1.1 History

- April 2003: contoured and spread with topsoil (and understorey debris);
- March 2004: monitored by Mattiske Consulting P/L;
- August 2005: 2nd monitoring by Mattiske Consulting P/L;
- June 2007: 3rd monitoring by CEM
- November 2008 (this report).

Sector 4 received topsoil treatment later than those described above but is generally superior in terms of plant cover and species diversity (Figs 6-9). Cover is continuing to increase on average (Fig 9) with quadrats closer to the lake experiencing increased cover and abundance. Encouragingly, many seedlings were recorded in monitoring quadrats; these included both existing plant species and species not recorded in quadrats previously. Such colonisation by new species has resulted in average species richness significantly increasing since 2007 and is now approaching the peak in species richness found in 2005. Despite significant increases in species numbers, species richness is relatively low at just over 7 per quadrat, although this value is actually similar to that of the successful Sector 2. Of more concern is the simplicity of structure and unevenness of species dominance; although cover is reasonable for 5 year old rehabilitation, Sector 4 is clearly dominated by *Lepidosperma longitudinale* and some low shrubs like *Hypocalymma angustifolium* and *Kunzea recurva.* The absence of taller shrubs and trees like tea trees and paperbarks (*Melaleuca* spp.) is a concern especially in low lying areas close to the lake. The presence of very young *Melaleuca rhaphiophylla* near the lake edge is therefore encouraging especially as they seem to the result of washed-up and/or wind-blown seed. If such seedlings do not establish into trees, consideration needs to be given to planting, brushing and/or seeding with *Melaleuca* close to the lake edge.

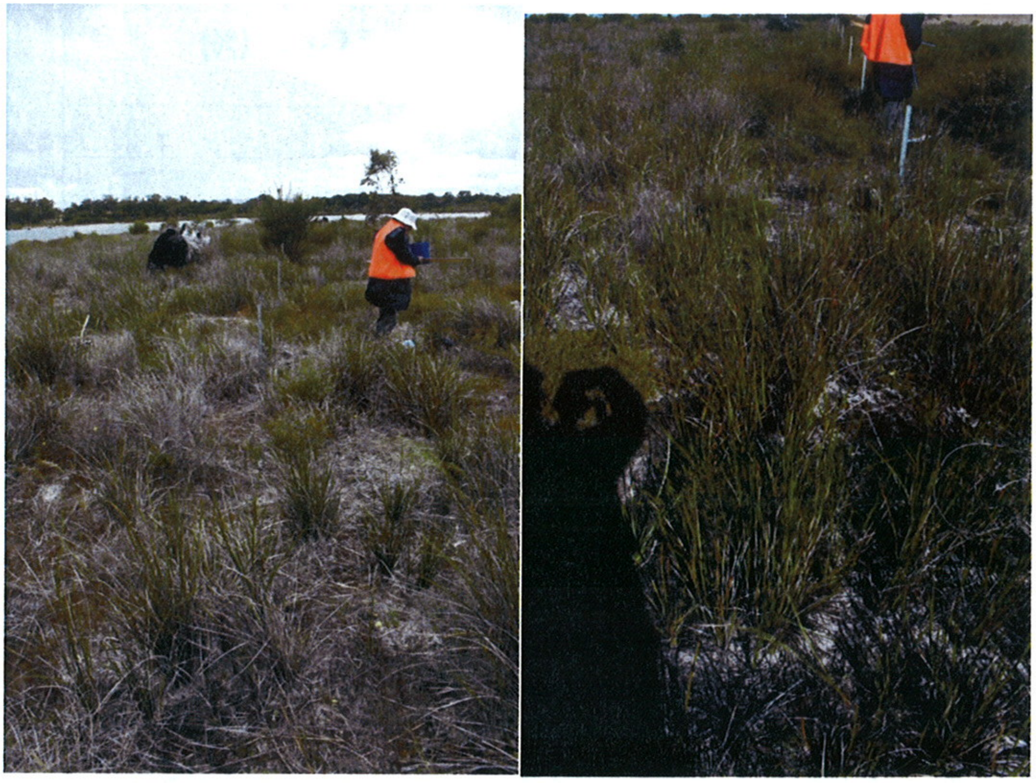


Plate 4 a,b. showing typical plant cover of Sector 4 (along transect 7) showing dominance of *Lepidosperma longitudinale*.

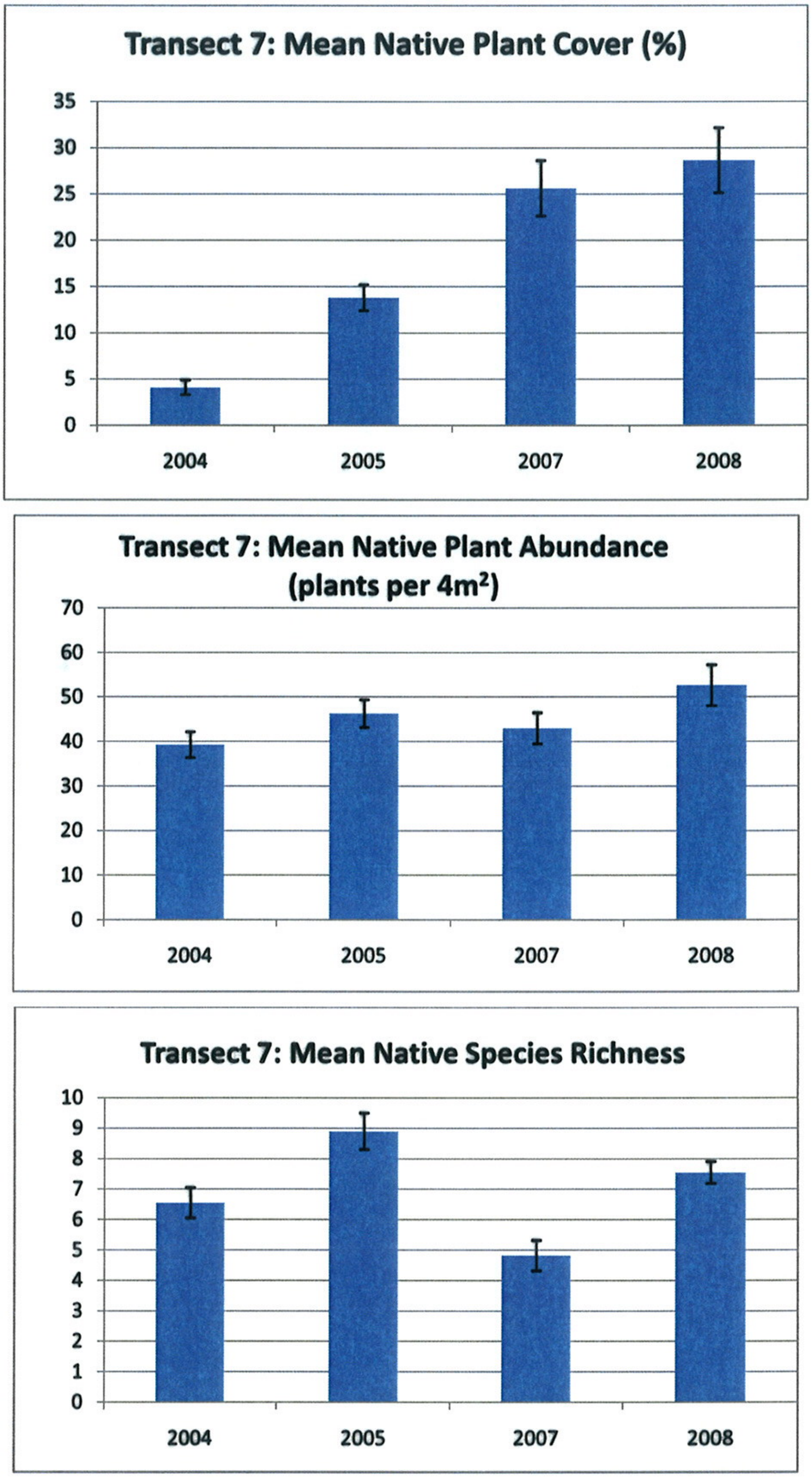


Figure 2. Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 7 within rehab Sector 4. Error bars are ±standard errors.

4.5 Sectors 5 & 6: North & South Sides of Lake (Both New Rehabilitation Areas)

(Transects 9 &10)

4.5.1.1 History

- Autumn 2006: contoured and spread with topsoil (with some understorey debris); Sector 5 used 10 year old, stored topsoil, whereas Sector 6 used fresh topsoil.
- June 2007: Initial monitoring by CEM.
- November 2008: 2nd Monitoring by CEM (this report).

These two rehabilitation sectors are clumped together as they were both rehabilitated using topsoil two and half years previously. In terms of all measures, this treatment has been highly successful with good initial cover and diversity achieved. This monitoring has demonstrated improvements in rehabilitation success since previous monitoring in 2007 (Fig 10; Appendix 3). In particular, significant increases in cover have occurred with Sector 5 increasing from 8 to 45% cover on average, and Sector 6 from 9 % to 27% (Fig 10). A relatively severe summer drought resulted in loss of individuals at this site, especially more typical wetland species in quadrats higher in the topographic profile. This loss has been more than balanced by recruitment of new individuals, most likely from soil stored seed, in the wetter than average winter.

Species richness, on average, increased only slightly from 2007 to 2008 (Fig 10); however this masks a dynamic which saw increased abundance of fringing wetland species such as sedges and *Melaleuca* lower in the profile and decline of such species in higher areas. Species richness is still relatively high (8-13 species per 4 m^2 quadrat) which compares favourably with some of the most species-rich wetland margins and damplands in the surrounding area. Figure 11 shows the gradient in species composition across transects with upland quadrats on the left side and lower quadrats closer to lake edge towards the right. This ordination also show the shift in species composition between June 2007 and November 2008 with quadrats towards the lake developing more typical wetland characteristics with increase in sedges/rushes (e.g., *Lepidosperma longitudinale*, *Juncus pallidus* and *Baumea articulata*) and Melaleuca species and cover (Appendix 3). Upper quadrats have shifted in the opposite direction with more typical upland species such as *Calytrix* sp., *Acacia pulchella*, *Gompholobium aristatum* and *Hakea* sp increasing in cover. Quadrats in the middle of the profile have changed relatively little in terms of species composition (1). The species mostly contributing to overall differences between the 2007 and 2008 are *Acacia pulchella, Lepidosperma longitudinale, Kunzea glaucescens, Hypocalymma angustifolium* and *Calothamnus lateralis*, all of which have increased in cover (Appendix 3).

Sector 6 received fresh topsoil in 2005, whereas Sector 5 received topsoil which was stored for many years. The significantly higher species richness and plant abundance in areas receiving fresh topsoil has been maintained, however the increase in plant cover has been more substantial in areas receiving older topsoil. This is due to prolific growth of a small number of shrub species in Sector 5, which may be a result lower overall inter-specific competition in this area. Species differences between sector 5 and 6 are shown in Appendix 3. Main differences are: *Lepidosperma longitudinale, Acacia pulchella, Euchilopsis linearis, Hypolaena exsulca, Melaleuca preissiana* and *Empodisma gracillimum* being more common in Sector 6; whilst *Aotus gracillima, Calothamnus lateralis, Juncus pallidus, Viminaria juncea* and *Baumea articulata* are more common in Sector 5.

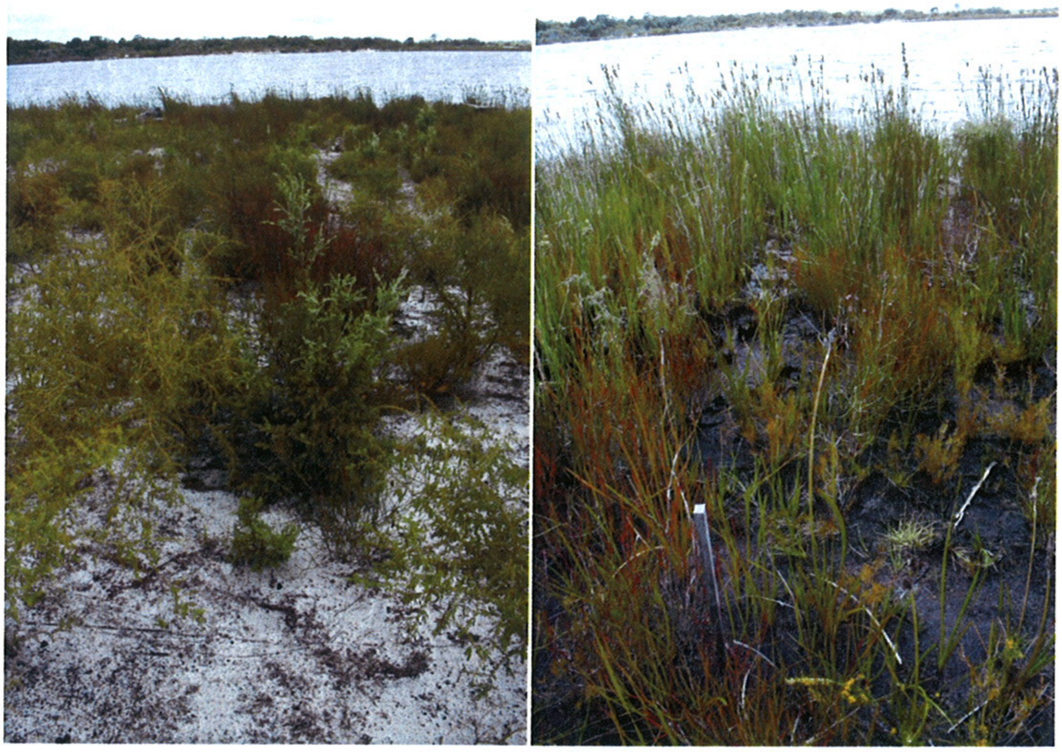
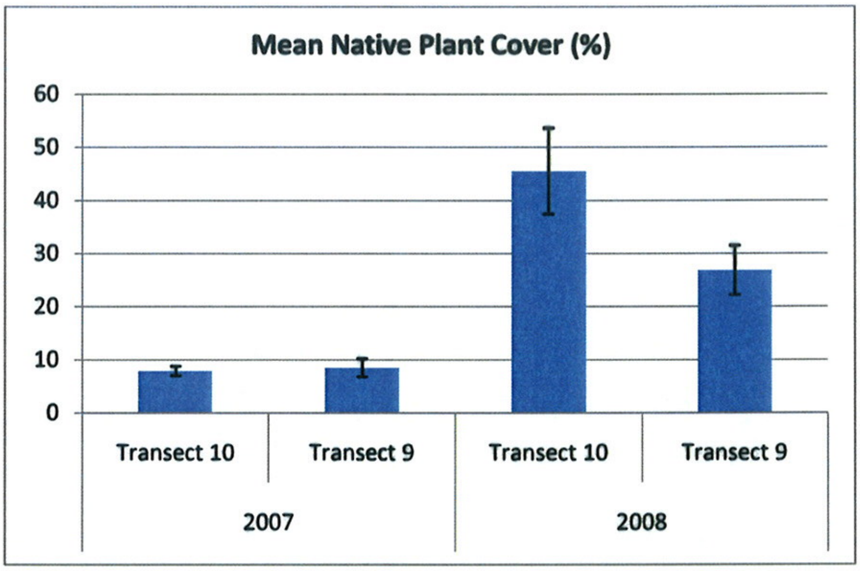
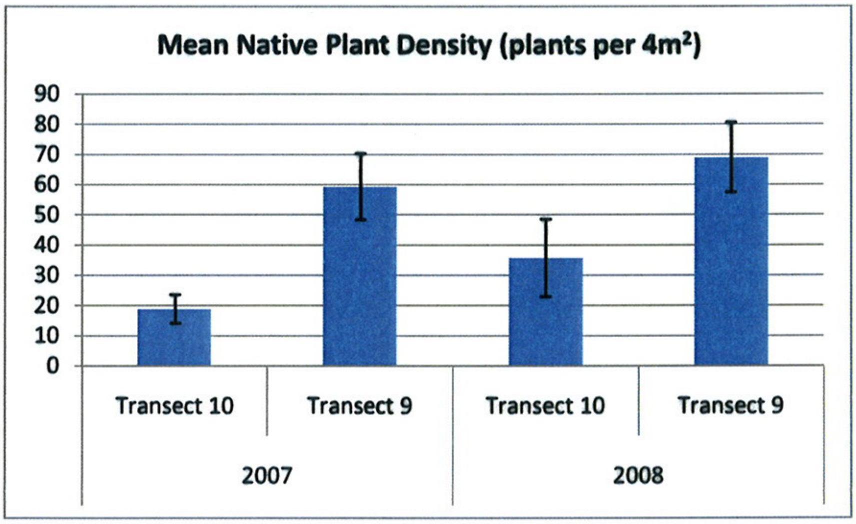


Plate 5 a,b. Rehabilitation in Sector 5 (along transect 10).

Plate 6 a,b: showing typical cover of rehabilitation in Sector 6 (transect #9).





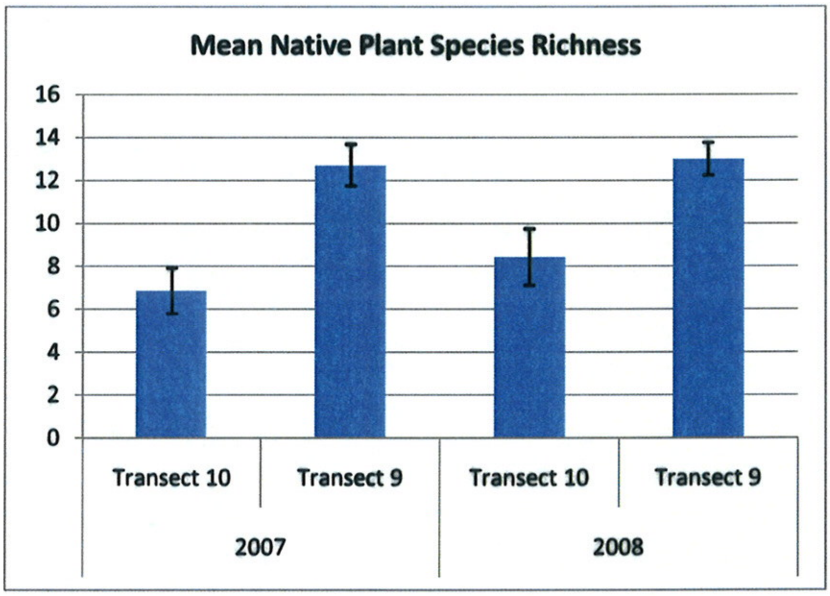


Figure 10: Trend in mean plant cover (top), native plant density (middle) and species richness (bottom) across monitoring periods for Transect 9 (Sector 6) and Transect 10 (Sector 5). Error bars are ±standard error.

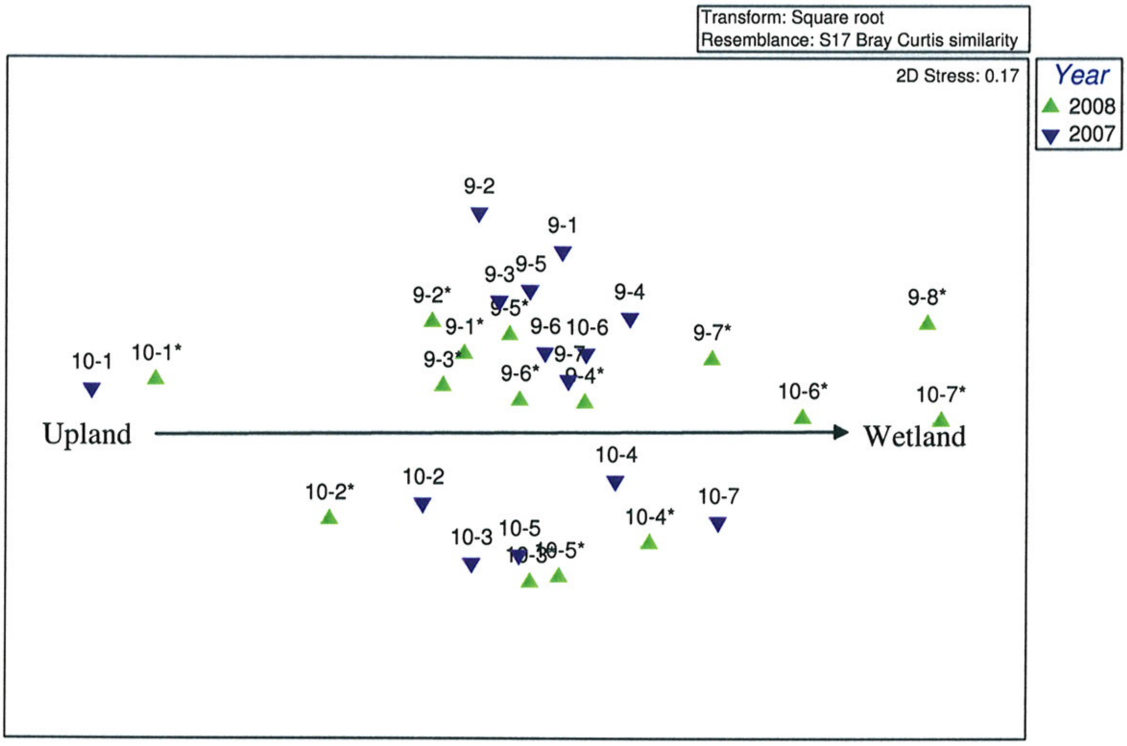


Figure 11. Ordination showing differences in species composition between quadrats of transects 9 and 10 and relative shifts in composition from June 2007 (blue triangles) to November 2008 (green triangles).

5 Recent Rehabilitation of Wetland Area

In mid 2007, a new area south of North Lake was rehabilitated using topsoil and spreading of brushing and logs. A new monitoring transect was established in this area (Transect #11) and monitored for the first time in November 2008.

This area was low lying and at November 2008 contained large areas submerged by water (see Plate 7–Plate). Areas under shallow water or waterlogged had very high plant cover in the order of 60-100%. This represents prolific growth over just over one year post rehabilitation and confirms the readiness for plant establishment in low lying areas which are flooded or waterlogged for most of the years as long as appropriate (i.e., wetland or fringing wetland) topsoil is used. This area did not contain any upland areas, i.e. areas >2m above water table.

Although the area appeared visually to be dominated by a single species (*Juncus pallidus*), the species richness was relatively high with an average of 8 species per 4 m^2 quadrat (highest of 10 per quadrat). Most of the species were rushes, sedges and related species (Appendix 1). *Juncus pallidus* was indeed the most common and widespread species occurring in every quadrat and averaging 22%. Other common species were *Juncus planifolius, Isolepis sp, Meeboldina scariosa* and *Lepidosperma longitudinale*. Encouragingly many seedlings of *Melaleuca* and other Myrtaceous shrubs typical of fringing wetlands were found, particularly in quadrats close to the deep water edge. This suggests that more diverse structure and typical fringing wetland structure of paperbarks and other shrubs may develop over time. Seedlings were mostly of *Melaleuca preissiana* with many of these were growing close to or amongst brushing which suggest this may have been a valuable source of seed.

Plate 7. This panorama shows rehabilitated wetland in early 2008, whereas the photo below show wetland at time of monitoring in November 2008 showing high cover and dominance by *Juncus pallidus*.. Photos by Clint McCullough.

Plate 8 a,b. Extensive cover of rushes and sedges in new rehabilitation south of dredge pond (transect 11).

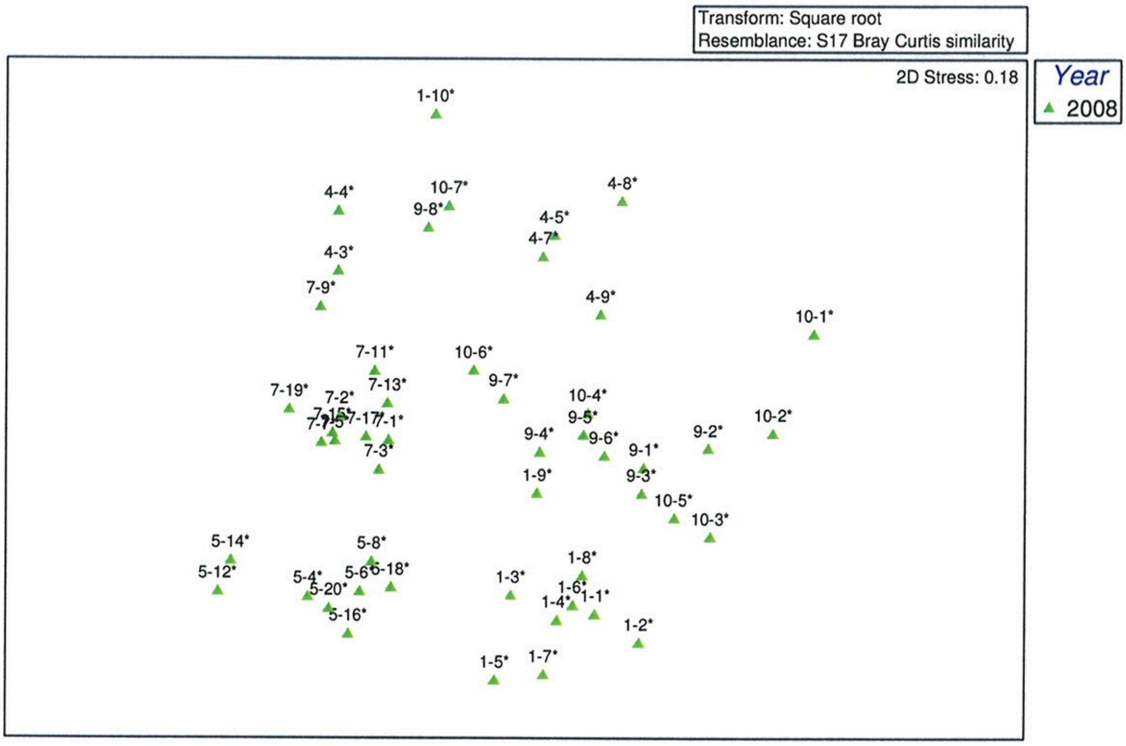
6 Summary & Conclusions

Monitoring in November 2008 has revealed an overall slight to modest improvement in rehabilitation since the previous monitoring in mid 2007. This improvement can be generally attributed to moist conditions provided by above average late autumn and early winter rains in 2008. This improvement was despite observations of drought death over a particularly dry summer in the previous year. Plant cover showed most marked increase from the previous year, with plant abundance and species richness generally stable overall.

This slight to modest improvement generally masks quite significant dynamics in plant species composition both within quadrats and across the rehabilitated landscape. Generally plant cover increased more substantially in low-lying areas closer to lake, with new species appearing more readily in such areas. Some of these species appear to have arisen by seeds dispersed by seed or water as they appear on areas without topsoil or rehabilitated. Areas higher in topographic profile have seen the loss of typically fringing/flooded zone species and although becoming floristically more simple (ie fewer species) are at least maintaining plant cover with some individuals growing substantially over the intervening period. Therefore it is apparent that some degree of species sorting according to moisture and flooding preferences is occurring. This is encouraging, as is the seemingly natural recolonisation in lower areas by sedges, Melaleucas and other wetland species. Upland areas of recent rehabilitation by topsoiling however need to be carefully monitored as they may trend toward that experienced in the older upland rehabilitation where growth is limited and species diversity low. Remediation is recommended in upland areas with poor rehabilitation success; spreading upland topsoil would be preferred approach if such resource is available, otherwise seeding, brushing and planting (using upland and transitional species) should occur.

Each rehabilitation sector remains distinct in terms of species composition (Fig 12 and ANOSIM results at Appendix 4). As outlined in previous reports, this reflects the different timing and techniques for rehabilitation, as well as contrasting topographic/edaphic/hydrological conditions. Older rehabilitation areas above ~2m of the high (spring) lake level (vertical distance) are generally the poorest in terms of species cover/diversity and therefore restoration success. It is believed the initial treatment of topsoil application was inappropriate (not matched to site characteristics) and subsequent remedial efforts have met with limited success. Future rehabilitation of such sites greater than 2 m above high water mark should ideally be sourced from upland sites (eg Jarrah-Marri woodland).

Restoration success in lower sections is generally good to excellent, especially in areas flooded or waterlogged close to the lake edge where extensive coverage of sedges and rushes have developed. Some young paperbarks are also well established in many shoreline sections. Success of the most recent rehabilitation in 2006 and 2007, although still in its infancy, is promising with diversity remaining relatively high despite hot and dry summer in 2007-8. These results confirm the potential benefits of using relatively fresh topsoil applied to similar environments from which it is sourced. Sector 4 is currently the most successful in terms of plant cover and its close resemblance to local fringing wetland communities. It is also clear that species composition in low-lying areas of other rehab sectors is shifting towards that of Sector 4 and hence are on a satisfactory trajectory in terms of resembling analogue (reference) sites found in native vegetation (Plate 3). Some of these species may be colonising shoreline or near-shore areas by seed dispersed by wind from nearby wetlands and hence may reflect the relative ease of restoring these lower parts of the rehabilitation. This is supported by the results of monitoring the most recent rehab south of the dredge ponds where extensive cover and relatively high diversity have developed in flooded and waterlogged areas in less than two years.



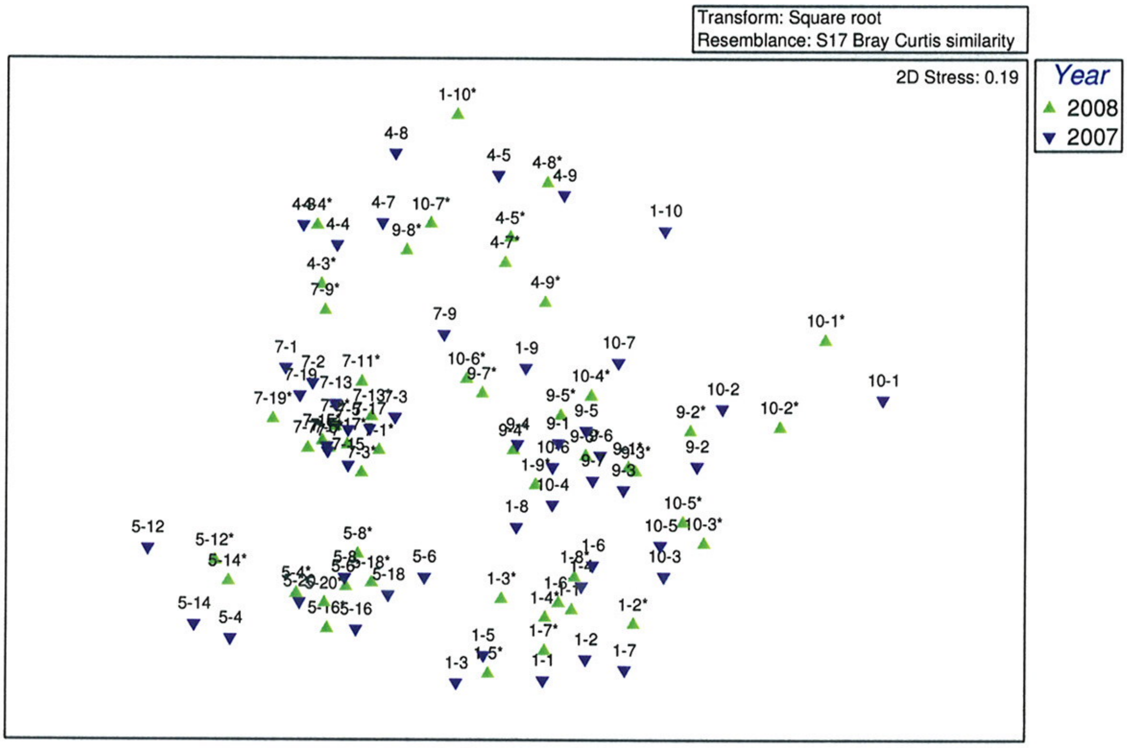


Figure 12 a,b. Ordination of 2008 monitoring quadrats (top) showing general distinction between transects in terms of species composition, with shifts in species composition from 2007 to 2008 monitoring shown below. First number of labels refers to transect #, with 2nd number referring to quadrat sequence along transects.

7 Appendices

Appendix 1: Raw Data for Each Quadrat Measured Oct/Nov 2008.

Transect	Quadrat	Species	% Cover	Abundance (plants per $4m^2$)	Notes
5	20	*Kunzea recurva*	8	4	
		Hypocalymma angustifolium	2	3	
		Jacksonia furcellata	2	2	
		Corymbia calophylla	2	1	2.4 m high
		*Grassy weeds	80	100's	
		*Other weeds	1	10	
5	18	*Hypocalymma angustifolium*	6	5	
		Kunzea recurva	8	3	
		Empodisma gracillimum	2	1	
		*Grassy weeds	15	100's	
		*Other weeds	1	10	
5	16	*Hypocalymma angustifolium*	7	4	
		Kunzea recurva	6	1	
		Acacia saligna	15	1	
		Jacksonia furcellata	3	2	
		Microtis media	<1	2	
		*Grassy weeds	60	100's	
		*Other weeds	1	20	
5	14	*Jacksonia furcellata*	3	4	2 seedlings
		Microtis media	<1	6	
		Acacia pulchella	<1	1	new
		Kunzea recurva	15	2	
		*Grassy weeds	30	100's	
		*Other weeds	1	15	
5	12	*Acacia saligna*	4	1	
		Melaleuca osullivanii	1.5	1	
		Kunzea recurva	30	2	
		Cytogonidium leptocarpoides	1	1	
		Hypocalymma angustifolium	<1	1	
		Microtis media	<1	3	
		*Grassy weeds	60	100's	
5	8	*Kunzea recurva*	16	3	
		Hypocalymma angustifolium	9	2	
		Lepidosperma longitudinale	<1	1	
		*Grassy weeds	20	100's	
		*Other weeds	1	20	
5	6	*Kunzea recurva*	22	6	
		Hypocalymma angustifolium	5	6	
		Daviesia physodes	4	1	
		Euchilopsis linearis	1	1	
		Jacksonia furcellata	<1	1	

		*Grassy weeds	2	100	
		*Other weeds	<1	5	
5	4	*Viminaria juncea*	5	1	2.5 m high
		Jacksonia furcellata	2	1	
		Acacia saligna	3	1	
		Kunzea recurva	9	2	
		Empodisma gracillimum	2	2	
		Hypocalymma angustifolium	1	1	
		*Grassy weeds	30	100's	
		*Other weeds	<1	5	
4	3	*Lepidosperma longitudinale*	10	15	
		Meeboldina scariosa	5	5	
		Juncus pallidus	1	5	
		Melaleuca rhaphiophylla	12	1	
		Kunzea recurva	3	3	
		Melaleuca incana ssp. *incana*	20	1	
		Hypolaena exsulca	2	7	
		Kunzea glaucescens	<1	1	
4	4	*Melaleuca rhaphiophylla*	20	1	
		Meeboldina scariosa	10	6	
		Lepidosperma longitudinale	4	15	
		Melaleuca lateriflora	40	1	
		Hypolaena exsulca	1	5	
		Astartea scoparia	2	2	
		Kunzea recurva	3	1	
		Philotheca sp.*icata*	<1	2	
		Drosera glanduligera	1	100	
		Juncus pallidus	1	2	
		Centella asiatica	<1	1	
4	5	*Lepidosperma longitudinale*	2	12	
		Meeboldina scariosa	20	10	
		Melaleuca lateriflora	40	1	
		Juncus pallidus	1	3	
		Acacia saligna	<1	1	
		Kunzea glaucescens	2	2	
		Astartea scoparia	2	12	
		Ptilotus? s.	<1	5	
		Microtis media	<1	5	
		Acacia pulchella	<1	1	seedling
		Hypocalymma angustifolium	<1	1	
		Drosera glanduligera	<1	20	
		Centella asiatica	<1	2	
4	7	*Astartea scoparia*	4	1	
		Meeboldina scariosa	10	9	
		Melaleuca lateriflora	6	1	
		Lepidosperma longitudinale	2	20	
		Kunzea glaucescens	1	2	
		Philotheca sp.*icata*	<1	1	
		Siloxerus filifolius	<1	20	

		Hypocalymma angustifolium	<1	1	
		Acacia pulchella	<1	1	seedling
		Drosera glanduligera	<1	5	
		Ptilotus sp.	<1	5	
4	8	*Meeboldina scariosa*	10	10	
		Astartea scoparia	27	14	
		Lepidosperma longitudinale	2	10	
		Melaleuca lateriflora	1	1	
		Kunzea glaucescens	20	3	
		Caladenia ?paludosa	<1	2	
		Ptilotus sp.	<1	10	
4	9	*Astartea scoparia*	20	10	
		Lepidosperma longitudinale	2	5	
		Viminaria juncea	10	1	
		Meeboldina scariosa	2	10	
		Melaleuca osullivanii	2	2	
		Melaleuca preissiana	3	4	
		Kunzea glaucescens	25	10	
		Hypocalymma angustifolium	2	5	
9	1	*Acacia pulchella*	5	5	
		Hypocalymma angustifolium	1	2	
		Euchilopsis linearis	1	1	
		Lepidosperma longitudinale	<1	1	
		Kunzea glaucescens	2	5	
		Melaleuca preissiana	2	2	
		Pericalymma ellipticum	<1	2	
		Siloxerus filifolius	1	50	
		Empodisma gracillimum	<1	5	
		Aotus gracillima	<1	1	
9	2	*Acacia pulchella*	10	11	
		Hypolaena exsulca	1	1	
		Hypocalymma angustifolium	<1	5	
		Empodisma gracillimum	1	3	
		Kunzea glaucescens	1.5	6	
		Pericalymma ellipticum	1	1	
		Melaleuca ?thymoides	<1	2	1 seedling
		Melaleuca preissiana	<1	1	
		Lomandra sp..	<1	1	
		Bossiaea eriocarpa	<1	2	
		Euchilopsis linearis	<1	1	
		Gompholobium aristatum	<1	6	2 seedlings
		Lepidosperma longitudinale	<1	4	
		Hakea sp.	<1	1	seedling
		Epacridaceae	<1	1	
		Calytrix fraseri	1	1	
9	3	*Acacia pulchella*	10	3	
		Hypocalymma angustifolium	5	10	
		Kunzea glaucescens	8	7	
		Lepidosperma longitudinale	<1	3	

		Pericalymma ellipticum	2	1	
		Euchilopsis linearis	1	2	
		Platysace filiformis	1	2	
		Empodisma gracillimum	<1	3	
		Hibbertia huegelii	<1	1	
		Hypolaena exsulca	<1	1	
		Hakea sp.	<1	1	seedling
		Gompholobium aristatum	<1	4	2 seedlings
9	4	*Lepidosperma longitudinale*	5	30	
		Acacia pulchella	15	4	
		Pericalymma ellipticum	1	3	
		Platysace filiformis	1	1	
		Calothamnus lateralis	1	3	
		Hypocalymma angustifolium	5	5	
		Kunzea recurva	1	2	
		Hypolaena exsulca	<1	2	
		Aotus gracillima	<1	1	
		Gompholobium aristatum	1	1	
		Pericalymma ellipticum	<1	2	
		Melaleuca preissiana	<1	1	
		Euchilopsis linearis	1	2	
		Kunzea glaucescens	1	5	
		Empodisma gracillimum	<1	2	
		Siloxerus filifolius	<1	30	
9	5	*Acacia pulchella*	15	5	
		Lepidosperma longitudinale	5	23	
		Hypolaena exsulca	1	7	
		Pericalymma ellipticum	2	5	
		Kunzea glaucescens	2	6	
		Empodisma gracillimum	3	25	
		Hypocalymma angustifolium	2	20	
		Hypolaena exsulca	1	6	
		Dasypogon bromeliifolius	<1	1	
		Melaleuca ?thymoides	<1	1	
		Euchilopsis linearis	2	2	
9	6	*Acacia pulchella*	8	4	
		Hypocalymma angustifolium	2	17	
		Lepidosperma longitudinale	2	25	
		Pericalymma ellipticum	1	7	
		Aotus gracillima	<1	1	
		Kunzea glaucescens	1	5	
		Acacia semitrullata	1	1	
		Euchilopsis linearis	1	1	
		Gompholobium aristatum	1	2	
		Empodisma gracillimum	<1	2	
		Lomandra sp..	<1	1	
		Viminaria juncea	<1	1	
		Drosera macrantha	1	1	
9	7	*Euchilopsis linearis*	1	1	
		Lepidosperma longitudinale	17	40	

		Empodisma gracillimum	1	2	
		Acacia pulchella	<1	1	dying
		Kunzea glaucescens	1	1	
		Calothamnus lateralis	3	9	
		Hypocalymma angustifolium	23	40	
		Pericalymma ellipticum	<1	3	
		Melaleuca preissiana	<1	1	
		Astartea scoparia	1	4	
		Meeboldina scariosa	1	2	
9	8	*Calothamnus lateralis*	3	5	
		Astartea scoparia	3	2	
		Lepidosperma longitudinale	60	100's	
		Acacia pulchella	<1	1	dying
		Juncus pallidus	10	15	
		Baumea articulata	2	10	
		Meeboldina scariosa	1	10	
		Melaleuca preissiana	<1	2	young plants
1	1	*Hypocalymma angustifolium*	2	1	
		Kunzea glaucescens	1	1	
		Viminaria juncea	3	1	
		Hakea sp.	<1	1	seedling
		Pericalymma ellipticum	<1	1	seedling
		Microtis media	<1	1	
		*Grassy weeds	5	20	
		*Other weeds	1	20	
1	2	*Acacia pulchella*	<1	1	
		Eucalyptus marginata	<1	1	
		Hypocalymma angustifolium	1	1	
		Corymbia calophylla	1	1	
		Kunzea glaucescens	1	1	
		Podotheca angustifolia	1	2	
		*Grassy weeds	10	50	
		*Other weeds	5	10	
1	3	*Hypocalymma angustifolium*	8	9	
		Viminaria juncea	2	1	
		Astartea scoparia	1	1	
		Pericalymma ellipticum	1	1	
		*Grassy weeds	5	20	
		*Other weeds	5	20	
1	4	*Hypocalymma angustifolium*	8	5	
		Kunzea glaucescens	2	2	
		?*Melaleuca* sp.	<1	1	
		*Grassy weeds	20	100	
		*Other weeds	2	10	
1	5	*Hypocalymma angustifolium*	6	5	
		*Grassy weeds	5	50	
		*Other weeds	5	20	

1	7	*Hypocalymma angustifolium*	1	1	
		Kunzea	2	3	
		Empodisma gracillimum	<1	1	
		Pericalymma ellipticum	1	1	
		Viminaria juncea	1	1	
		*Grassy weeds	1	10	
		*Other weeds	1	10	
1	9	*Pultenaea ochreata*	1	1	
		Juncus pallidus	3	3	
		Lepidosperma longitudinale	1	6	
		Hypocalymma angustifolium	6	8	
		Aotus gracillima	12	1	
		Pericalymma ellipticum	1	1	
		Empodisma gracillimum	<1	1	
		Hypolaena exsulca	<1	1	
1	10	*Juncus pallidus*	15	34	
		Astartea scoparia	1	2	
		Lepidosperma longitudinale	1	8	
		Baumea articulata	1	4	
10	1	*Kunzea glaucescens*	20	2	
		*Other weeds	2	10	
		*Grassy weeds	50	100's	
		Acacia pulchella	<1	1	
10	2	*Kunzea glaucescens*	8	3	
		Acacia pulchella	12	4	
		Aotus gracillima	3	1	
		Pericalymma ellipticum	<1	1	seedling
		Siloxerus filifolius	<1	1	
		Gompholobium aristatum	1	3	
		Stirlingia latifolia	<1	1	
		Daviesia physodes	5	6	5 seedling
		Hakea sp.	1	1	
		Calytrix fraseri	2	2	
		*Other weeds	1	5	
10	3	*Acacia pulchella*	25	5	
		Hypocalymma angustifolium	2	1	
		Aotus gracillima	10	7	
		Gompholobium aristatum	<1	1	
		Pericalymma ellipticum	2	1	
		Calytrix fraseri	1	1	
		Calytrix flavescens	<1	1	
		Gonocarpus paniculatus	<1	1	
		Calothamnus lateralis	1	1	
10	4	*Hypocalymma angustifolium*	32	5	
		Acacia pulchella	4	2	
		Pericalymma ellipticum	6	1	
		Lepidosperma longitudinale	5	11	
		Viminaria juncea	12	1	

		Aotus gracillima	20	1	
		Calothamnus lateralis	8	1	
		Kunzea glaucescens	1	1	
		Unknown #5	1	1	
10	5	*Calothamnus lateralis*	30	7	
		Kunzea glaucescens	3	2	
		Acacia pulchella	2	3	
		Hypocalymma angustifolium	3	4	
		Microtis media	<1	1	
		Aotus gracillima	8	1	
		Siloxerus filifolius	<1	3	
		Pericalymma ellipticum	<1	1	
		Stipa sp.	<1	3	
10	6	*Lepidosperma longitudinale*	15	3	
		Astartea scoparia	<1	2	
		Hypocalymma angustifolium	6	15	
		Melaleuca preissiana	2	3	
		Pericalymma ellipticum	<1	1	
		Restionaceae sp..	<1	1	
		Empodisma gracillimum	<1	1	
		Aotus gracillima	1		
		Calothamnus lateralis	10	11	
		Juncus pallidus	2	1	
		Baumea articulata	3	20	many seedlings
10	7	*Calothamnus lateralis*	4	5	
		Melaleuca lateriflora	4	1	
		Pericalymma ellipticum	1	1	
		Astartea scoparia	1	2	
		Lepidosperma longitudinale	10	8	
		Juncus pallidus	20	12	
		Baumea articulata	10	10	
7	1	*Kunzea recurva*	5	26	24 seedlings
		Lepidosperma longitudinale	2	12	
		Meeboldina scariosa	1	2	
		Hypocalymma angustifolium	2	2	
		Astartea scoparia	1	3	
		Melaleuca rhaphiophylla	1	2	seedlings
7	2	*Lepidosperma longitudinale*	15	40	
		Hypocalymma angustifolium	1	3	
		Kunzea recurva	4	2	
		Melaleuca rhaphiophylla	1	1	seedling
		Unknown #5	<1	2	
		Platysace sp.	<1	2	
		Siloxerus filifolius	<1	10	
7	3	*Kunzea recurva*	10	7	
		Lepidosperma longitudinale	13	40	
		Hypocalymma angustifolium	6	12	

		Meeboldina scariosa	<1	1	
		unknown #5	<1	10	seelings
		Stipa sp.	1	13	
		Siloxerus filifolius	<1	10	
		Aotus gracillima	<1	2	
7	5	*Lepidosperma longitudinale*	15	30	
		Hypocalymma angustifolium	1	5	
		Kunzea recurva	8	2	
		Platysace sp.	<1	1	
		unknown #5	<1	10	seedlings
		*Other weeds	<1	1	
7	7	*Lepidosperma longitudinale*	15	40	
		Hypocalymma angustifolium	1	1	
		Unknown #5	<1	1	
		Siloxerus filifolius	1	50	
		Platysace sp.	<1	4	
		Stipa sp.	1	20	
		Kunzea recurva	15	6	5 seedlings
7	9	*Lepidosperma longitudinale*	5	30	
		Melaleuca rhaphiophylla	1	1	
		Podotheca angustifolia	<1	5	
		Acacia pulchella	<1	1	seedling
		Unknown #5	<1	4	seedlings
		Daviesia physodes	<1	1	
		Siloxerus filifolius	<1	1	
		Platysace sp.	<1	3	
		Kunzea recurva	<1	5	4 seedlings
7	11	*Lepidosperma longitudinale*	30	40	
		Kunzea recurva	<1	2	1 seedling
		Hypocalymma angustifolium	1	2	
		Empodisma gracillimum	1	2	
		Stipa sp.	1	20	
		Unknown #5	<1	1	seedling
		Podotheca angustifolia	<1	5	
		Platysace sp.	<1	3	
7	13	*Lepidosperma longitudinale*	30	16	
		Hypocalymma angustifolium	2	7	
		Kunzea recurva	3	3	
		Astartea scoparia	2	2	
		Gompholobium aristatum	<1	1	
		Aotus gracillima	<1	1	seedling
		Platysace sp.	<1	1	
7	15	*Lepidosperma longitudinale*	20	40	
		Kunzea recurva	20	5	
		Hypocalymma angustifolium	1	5	
		Astartea scoparia	<1	2	
		Daviesia physodes	<1	2	
		Aotus gracillima	2	1	

		unknown #5	<1	1	
7	17	*Lepidosperma longitudinale*	15	25	
		Kunzea recurva	10	5	3 seedlings
		Hypocalymma angustifolium	2	1	
		Astartea scoparia	2	1	
		Unknown #5	<1	1	seedling
		Platysace sp.	<1	2	
		Viminaria juncea	4	1	
7	19	*Lepidosperma longitudinale*	25	30	
		Kunzea recurva	15	15	10 seedlings
		Daviesia physodes	<1	1	
		Unknown #5	<1	4	seedlings
		Pericalymma ellipticum	<1	2	seedlings
		Siloxerus filifolius	<1	10	
11	1	*Juncus pallidus*	25	8	
[new rehab area]		*Juncus planifolius*	10	30	
		Juncus ?articulatus	2	1	
		Polypogon tenellus	2	20	
		Haemodorum laxum	2	8	
11	2	*Juncus pallidus*	25	14	
		Hypocalymma angustifolium	1	10	
		Pericalymma ellipticum	<1	1	
		Baumea articulata	1	1	
		Isolepis sp..	2	30	
		Hypolaena exsulca	1	1	
		Weeds	2	10	
11	3	*Juncus pallidus*	25	7	
		Hypocalymma angustifolium	3	8	
		Lepidosperma longitudinale	1	1	
		Polypogon tenellus	<1	10	
		Isolepis sp..	5	50	
		Meeboldina scariosa	5	3	
		Baumea articulata	<1	1	
		Stipa sp.	1	20	
11	4	*Juncus pallidus*	15	12	
		Hypocalymma angustifolium	1	5	
		Isolepis sp..	5	50	
		Meeboldina scariosa	2	1	
		Stipa sp.	<1	10	
		Polypogon tenellus	<1	10	
		Lepidosperma longitudinale	1	1	
		Astartea scoparia	1	1	
		Juncus caespciticius	1	10	
		Weeds	1	10	
11	5	*Juncus pallidus*	25	12	
		Hypocalymma angustifolium	1	6	
		Kunzea glaucescens	1	1	

		Melaleuca preissiana	2	10	
		Pericalymma ellipticum	1	2	
		Polypogon tenellus	<1	10	
		Isolepis sp..	5	30	
		Meeboldina scariosa	1	1	
		Aphelia cyperiodes	1	1	
11	6	*Juncus pallidus*	12	7	
		Lepidosperma longitudinale	2	1	
		Melaleuca preissiana	5	14	
		Hypocalymma angustifolium	1	5	
		Isolepis sp..	5	50	
		Meeboldina scariosa	1	1	
		Astartea scoparia	<1	2	
		Polypogon tenellus	<1	10	
		Weeds	2	10	
	7	*Juncus pallidus*	25	19	
		Melaleuca preissiana	4	30	seedlings
		Hypocalymma angustifolium	<1	2	
		Haemodorum laxum	<1	5	
		Isolepis sp..	5	30	
		Juncus ?articulatus	<1	1	
		Isolepis cyperoides	<1	1	
		Schoenoplectus pungens	<1	5	
		Lepidosperma longitudinale	<1	1	
		Polypogon tenellus	<1	10	
		Meeboldina scariosa	1	1	

Appendix 2. Species X Quadrat Matrix showing Cover (%) Values

Sum of 2008 % cover	QuadCode																							
Species	10-1	10-2	10-3	10-4	10-5	10-6	10-7	1-1	1-10	11-1	11-2	11-3	11-4	11-5	11-6	11-7	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9
?Conostylis sp.																								
?Jacksonia																								
?Melaleuca sp																			0.2			0.2		
Acacia pulchella	0.2	12	25	4	2												0.2					1	3	
Acacia saligna																								
Acacia semitrullata																								
Aotus gracillima		3	10	20	8	1																		12
Aphelia cyperiodes														1										
Astartea scoparia						0.2	1		1				1		0.2			1						
Baumea articulata						3	10		1		1	0.2												
Bossiaea eriocarpa																								
Caladenia ?paludosa																								
Calothamnus lateralis			1	8	30	10	4																	
Calytrix flavescens			0.2																					
Calytrix fraseri		2	1																					
Cassytha glabella																								
Centella asiatica																								
Corymbia calophylla																	1							
Cyperaceae																								
Cytogonidium leptocarpoides																								
Dasypogon bromeliifolius																								
Daviesia physodes		5																						
Drosera glanduligera																								
Drosera macrantha																								
Empodisma gracillimum																					0.2		0.2	0.2
Empodisma gracillimum						0.2																		
Epacridaceae																								
Eucalyptus marginata																	0.2							
Euchilopsis linearis																								
Gompholobium aristatum		1	0.2																					
Gonocarpus paniculatus			0.2																					
Haemodorum laxum										2						0.2								
Hakea sp		1						0.2																
Hardenbergia comptoniana																								
Hibbertia huegelii																								
Hypocalymma angustifolium			2	32	3	6		2			1	3	1	1	1	0.2	1	8	8	6	3	2	6	6
Hypolaena exsulca											1													0.2
Isolepis cyperoides																0.2								
Isolepis sp.											2	5	5	5	5	5								
Jacksonia furcellata																								
Juncus ?articulatus										2						0.2								
Juncus caespiticius													1											
Juncus pallidus						2	20		15	25	25	25	15	25	12	25								3
Juncus planifolius										10														
Juncus sp.																								
Kunzea glaucescens	20	8		1	3			1						1			1		2		2			
Kunzea glaucescens																								
Kunzea recurva																								
Lepidosperma longitudinale				5		15	10		1			1	1		2	0.2								1
Leptocarpus sp																								
Leptocarpus sp.																								
Lomandra sp.																								
Lomandra?																								
Meeboldina scariosa												5	2	1	1	1								
Melaleuca ?thymoides																								
Melaleuca incana subsp. incana																								
Melaleuca lateriflora							4																	
Melaleuca osullivanii																								
Melaleuca preissiana						2								2	5	4							0.2	
Melaleuca rhaphiophylla																								
Melaleuca sp.																								
Melaleuca teretifolia																								
Microtis media					0.2			0.2														0.2		
Patersonia occidentalis																								
Pericalymma ellipticum		0.2	2	5	0.2	0.2	1	0.2			0.2			1				1					1	1
Philotheca spicata																								
Platysace filiformis																								
Platysace sp																								
Poaceae sp																								
Podotheca angustifolia																	1							
Podotheca angustifolium																								
Polypogon tenellus										2		0.2	0.2	0.2	0.2	0.2								
Ptilotus sp																								
Ptilotus? Sp																								
Pultenaea ochreata																								1
Restionaceae																								
Restionaceae sp.						0.2																		
Schoenoplectus pungens																0.2								
Siloxerus filifolius		0.2			0.2																			
Siloxerus filifolius																								
Stipa sp					0.2							1	0.2											
Stirlingia latifolia		0.2																						
unknown #2																								
unknown #4																								
Unknown #5				1																				
Viminaria juncea				12				3										2					1	

Species	4-3	4-4	4-5	4-7	4-8	4-9	5-12	5-14	5-16	5-18	5-20	5-4	5-6	5-8	7-1	7-11	7-13	7-15	7-17	7-19	7-2	7-3	7-5	7-7	7-9	9-1	9-2	9-3	9-4	9-5	9-6	9-7	9-8
?Conostylis sp.																																	
?Jacksonia		0.2																															
Acacia pulchella			0.2	0.2				0.2																	0.2	5	10	10	15	15	6	0.2	0.2
Acacia saligna			0.2				4		15			3																					
Acacia semitrullata																															1		
Aotus gracillima																	0.2	0.2				0.2							0.2		0.2		
Astartea scoparia		2	2	4	27	20									1		2	0.2	2													1	3
Baumea articulata																																	2
Bossiaea eriocarpa																											0.2						
Caladenia ?paludosa					0.2																												
Calothamnus lateralis																													1			3	3
Calytrix fraseri																											1						
Centella asiatica		0.2	0.2																														
Corymbia calophylla											2																						
Cyperaceae																																	
Cytogonidium leptocarpoides							1																										
Dasypogon bromeliifolius																														0.2			
Daviesia physodes													4					0.2		0.2					0.2								
Drosera glanduligera		1	0.2	0.2																													
Drosera macrantha																															1		
Empodisma gracillimum										2		2														0.2	1	0.2	0.2	3	0.2	1	
Empodisma gracillimum																1																	
Epacridaceae																											0.2						
Euchilopsis linearis													1													1	0.2	1	1	2	1	1	
Gompholobium aristatum																	0.2										0.2	0.2	1		1		
Hakea sp																											0.2	0.2					
Hardenbergia comptoniana																																	
Hibbertia huegelii																												0.2					
Hypocalymma angustifolium			0.2	0.2		2	0.2		7	6	2	1	5	9	2	1	2	1	2		1	6	1	1		1	0.2	5	5	2	2	23	
Hypolaena exsulca	2	1																									1	0.2	0.2	2			
Jacksonia furcellata								3	3		2	2	0.2																				
Juncus pallidus	1	1	1																														10
Kunzea glaucescens																										2	1.5	8	1	2	1	1	
Kunzea glaucescens	0.2		2	1	20	25																											
Kunzea recurva	3	3					30	15	6	8	8	9	22	16	5	0.2	3	20	10	15	4	10	8	15	0.2				1				
Lepidosperma longitudinale	10	4	2	2	2	2								0.2	2	30	30	20	15	25	15	13	15	15	5	0.2	0.2	0.2	5	5	2	17	60
Leptocarpus sp																																	
Leptocarpus sp.	5	10	20	10	10	2																											
Lomandra sp.																											0.2				0.2		
Lomandra?																																	
Meeboldina scariosa															1							0.1										1	1
Melaleuca ?thymoides																											0.2			0.2			
Melaleuca incana subsp. inc	20																																
Melaleuca lateriflora		40	40	6	1																												
Melaleuca osullivanii						2	1.5																										
Melaleuca preissiana						3																				2	0.2		0.2			0.2	0.2
Melaleuca rhaphiophylla	12	20													1						1				1								
Melaleuca sp.																																	
Melaleuca teretifolia																																	
Microtis media			0.2				0.2	0.2	0.2																								
Pericalymma ellipticum																				0.2						0.2	1	2	12	2	1	0.2	
Philotheca spicata		0.2		0.2																													
Platysace filiformis																												1	1				
Platysace sp																0.2	0.2		0.2		0.2		0.2	0.2	0.2								
Podotheca angustifolium																0.2									0.2								
Ptilotus sp				0.2	0.2																												
Ptilotus? Sp			0.2																														
Restionaceae sp.																																	
Siloxerus filifolius																				0.2	0.2	0.2		1	0.2	1			0.2				
Siloxerus filifolius				0.2																													
Stipa sp																1						1		1									
unknown #2																																	
unknown #4																																	
Unknown #5																0.2		0.2	0.2	0.2	0.2	0	0.2	0.2	0.2								
Viminaria juncea						10						5							4												0.2		
Grand Total (% Cover)	53.2	82.6	68.4	24.2	60.4	66	36.9	18.4	31.2	16	14	22	32.2	25.2	12	33.8	37.6	41.8	33.4	40.8	21.6	30.5	24.4	33.4	7.4	12.6	17.5	28.2	33.2	33.4	18.8	48.6	79.4

Appendix 3: Species characterising Sector 5 (transect #10) and Sector 6 (transect #9) including those characterising differences between 2007 and 2008 monitoring, and differences between transects 9 and 10.

Examines Year groups
(across all transect groups)
Group 2008
Average similarity: 37.67

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	2.16	8.69	1.00	23.06	23.06
Kunzea glaucescens	1.33	4.84	0.86	12.85	35.91
Lepidosperma longitudinale	1.89	4.60	0.82	12.21	48.12
Hypocalymma angustifolium	1.65	4.55	0.95	12.07	60.19
Pericalymma ellipticum	0.87	3.24	1.23	8.59	68.78
Calothamnus lateralis	1.26	2.61	0.53	6.92	75.69
Euchilopsis linearis	0.46	2.53	0.79	6.72	82.41
Aotus gracillima	0.94	2.21	0.46	5.85	88.26
Empodisma gracillimum	0.40	1.58	0.78	4.19	92.45

Group 2007
Average similarity: 44.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	1.08	9.25	1.46	21.00	21.00
Hypocalymma angustifolium	0.97	7.82	1.42	17.75	38.74
Kunzea glaucescens	0.68	4.80	0.71	10.89	49.63
Pericalymma ellipticum	0.67	4.56	1.00	10.34	59.97
Aotus gracillima	0.52	3.78	0.55	8.57	68.55
Lepidosperma longitudinale	0.62	3.67	0.76	8.33	76.88
Melaleuca preissiana	0.30	2.47	0.96	5.60	82.48
Platysace filiformis	0.28	1.39	0.51	3.15	85.63
Hypolaena exsulca	0.21	1.35	0.55	3.06	88.69
Calothamnus lateralis	0.44	1.13	0.29	2.58	91.26

Groups 2008 & 2007
Average dissimilarity = 63.73

	Group 2008	Group 2007				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Acacia pulchella	2.16	1.08	7.00	1.34	10.98	10.98
Lepidosperma longitudinale	1.89	0.62	6.64	0.94	10.43	21.41
Kunzea glaucescens	1.33	0.68	5.79	0.73	9.08	30.49
Hypocalymma angustifolium	1.65	0.97	5.34	1.11	8.38	38.87
Calothamnus lateralis	1.26	0.44	5.17	0.82	8.12	46.99
Aotus gracillima	0.94	0.52	3.67	0.79	5.75	52.74
Pericalymma ellipticum	0.87	0.67	2.68	1.21	4.21	56.95
Juncus pallidus	0.60	0.00	2.48	0.44	3.88	60.83
Euchilopsis linearis	0.46	0.24	1.93	0.93	3.02	63.86
Baumea articulata	0.42	0.00	1.76	0.45	2.76	66.61
Astartea scoparia	0.28	0.24	1.75	0.81	2.75	69.37
Gompholobium aristatum	0.29	0.17	1.51	0.86	2.37	71.73
Viminaria juncea	0.26	0.17	1.42	0.47	2.23	73.97
Empodisma gracillimum	0.40	0.25	1.39	0.78	2.18	76.15
Melaleuca preissiana	0.31	0.30	1.36	0.65	2.13	78.28
Calytrix fraseri	0.23	0.06	1.27	0.60	2.00	80.28
Platysace filiformis	0.13	0.28	1.16	0.69	1.81	82.09
Hypolaena exsulca	0.22	0.21	1.07	0.68	1.67	83.77
Daviesia physodes	0.15	0.03	0.80	0.31	1.26	85.03
Melaleuca lateriflora	0.13	0.07	0.79	0.35	1.24	86.27
Melaleuca sp.	0.00	0.17	0.77	0.52	1.20	87.47
Siloxerus filifolius	0.16	0.00	0.75	0.50	1.18	88.65
unknown #2	0.00	0.14	0.60	0.49	0.94	89.59
Hakea sp	0.13	0.00	0.57	0.44	0.90	90.49

Examines transect groups(across all Year groups)
Group 10
Average similarity: 30.30

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Aotus gracillima	1.39	6.16	0.84	20.32	20.32
Acacia pulchella	1.25	4.67	0.78	15.42	35.74
Hypocalymma angustifolium	1.24	4.63	0.75	15.28	51.02
Kunzea glaucescens	1.09	4.47	0.54	14.75	65.77
Pericalymma ellipticum	0.76	3.59	0.83	11.85	77.62
Calothamnus lateralis	1.37	3.58	0.60	11.80	89.42

Group 9
Average similarity: 49.46

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Acacia pulchella	2.00	12.61	1.80	25.50	25.50
Hypocalymma angustifolium	1.40	7.28	1.72	14.72	40.22
Lepidosperma longitudinale	1.69	6.48	1.27	13.11	53.33
Kunzea glaucescens	0.95	5.12	1.44	10.35	63.67
Pericalymma ellipticum	0.78	4.06	1.33	8.21	71.89
Euchilopsis linearis	0.61	2.81	0.89	5.68	77.57
Melaleuca preissiana	0.42	2.74	1.19	5.53	83.10
Empodisma gracillimum	0.60	2.46	0.86	4.97	88.07
Hypolaena exsulca	0.42	1.60	0.65	3.23	91.30

Groups 10 & 9
Average dissimilarity = 67.69

	Group 10	Group 9				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Lepidosperma longitudinale	0.84	1.69	6.23	1.08	9.20	9.20
Acacia pulchella	1.25	2.00	6.07	1.35	8.96	18.17
Aotus gracillima	1.39	0.12	5.57	1.35	8.23	26.39
Calothamnus lateralis	1.37	0.39	5.21	0.99	7.70	34.09
Kunzea glaucescens	1.09	0.95	5.12	0.98	7.56	41.66
Hypocalymma angustifolium	1.24	1.40	4.86	1.15	7.17	48.83
Pericalymma ellipticum	0.76	0.78	2.77	1.20	4.10	52.93

Euchilopsis linearis	0.07	0.61	2.65	1.26	3.92	56.84
Empodisma gracillimum	0.03	0.60	2.62	1.03	3.87	60.71
Melaleuca preissiana	0.17	0.42	2.34	1.40	3.46	64.17
Hypolaena exsulca	0.00	0.42	2.14	0.94	3.16	67.34
Platysace filiformis	0.00	0.39	1.98	0.83	2.92	70.26
Astartea scoparia	0.28	0.24	1.86	0.85	2.75	73.01
Juncus pallidus	0.42	0.21	1.84	0.44	2.71	75.73
Viminaria juncea	0.35	0.10	1.50	0.51	2.22	77.95
Gompholobium aristatum	0.21	0.25	1.47	0.85	2.17	80.11
Baumea articulata	0.35	0.09	1.33	0.45	1.96	82.07
Calytrix fraseri	0.17	0.13	1.11	0.65	1.65	83.72
Melaleuca lateriflora	0.21	0.00	0.85	0.40	1.26	84.98
unknown #2	0.00	0.13	0.79	0.46	1.17	86.15
Melaleuca sp.	0.10	0.06	0.79	0.46	1.17	87.32
Daviesia physodes	0.19	0.00	0.77	0.37	1.14	88.46
Hibbertia huegelii	0.00	0.13	0.75	0.41	1.11	89.57
Dasypogon bromeliifolius	0.00	0.12	0.71	0.56	1.04	90.61

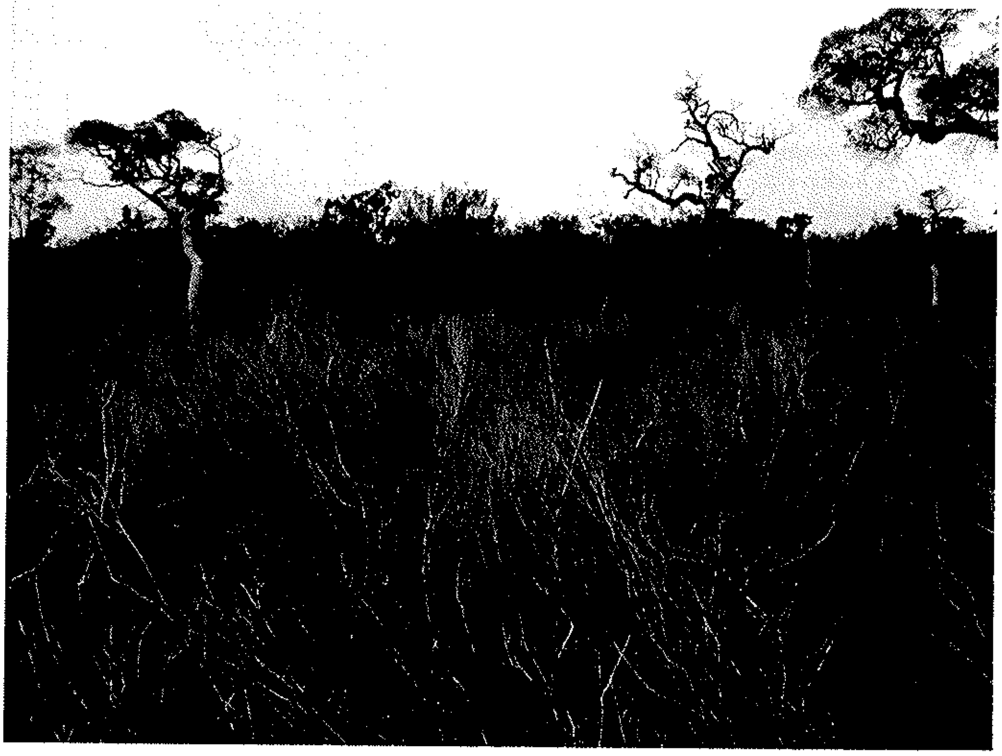
Appendix 4: ANOSIM (Analysis of Similarity) results showing significant differences between transects in terms of species composition.

Global Test
Sample statistic (Global R): 0.704
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
10, 1	0.401	0.2	19448	999	1
10, 4	0.565	0.5	1716	999	4
10, 5	0.836	0.1	6435	999	0
10, 7	0.808	0.1	31824	999	0
10, 9	0.233	3.1	6435	999	30
1, 4	0.733	0.2	8008	999	1
1, 5	0.649	0.1	43758	999	0
1, 7	0.813	0.1	352716	999	0
1, 9	0.447	0.1	43758	999	0
4, 5	0.998	0.1	3003	999	0
4, 7	0.913	0.1	12376	999	0
4, 9	0.692	0.1	3003	999	0
5, 7	0.822	0.1	75582	999	0
5, 9	0.894	0.2	6435	999	1
7, 9	0.847	0.1	75582	999	0

KEMERTON
SIGNIFICANT FLORA AND WETLANDS



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June 2004

CONTENTS

SUMMARY

Bennett Environmental Consulting Pty Ltd was contracted by Martinick Bosch Sell Pty Ltd to undertake a Declared Rare Flora (DRF) and Priority Flora (PF) survey, and mapping these plants and wetlands and to assess the importance of the wetlands at the Kemerton Silica Sand site, Kemerton. Several botanical surveys have been undertaken of the Kemerton area, including Kemerton Silica Sand (Mattiske E.M. and Associates, 1993a-d and Muir Environmental, 1999).

The current survey resulted in the following significant species being recorded.

- *Boronia juncea* subsp. *juncea* a Priority 1 species. This species occurred typically associated with *Astartea scoparia* or with other species where there was water on the surface during the September 2003 survey.
- *Boronia capitata* subsp. *gracilis* a Priority 2 species was only recorded along the powerline track that traverses the northern section from SW to NE.
- *Acacia semitrullata* a Priority 3 species was common in the higher ground associated with *Kunzea glabrescens, Banksia ilicifolia, Banksia attenuata* and/or *Eucalyptus marginata* subsp. *marginata*.
- *Eucalyptus rudis* subsp. *cratyantha* a Priority 3 species was the only subspecies of *Eucalyptus rudis* recorded during the survey.
- *Dillwynia dillwynioides* a Priority 3 species was common in the damp areas where water was on the surface in the September and October surveys but where it was drier in November.
- *Acacia flagelliformis* a Priority 4 species was only recorded in the southern section of the survey area but was common where it did occur.
- *Caladenia speciosa* a Priority 4 species was only recorded from 2 locations.
- *Jacksonia sparsa* a Priority 4 species was very common through the survey area in the higher ground.
- *Evandra pauciflora* is a species restricted to the damplands of the Swan Coastal Plain. It was relatively common in the area occurring on the edge of the wetlands as scattered plants or as the dominant species.
- *Verticordia nitens* is a species at its most southern range extension. It was only located in the south eastern section of the survey area.
- *Banksia menziesii*, recorded by Mattiske Consulting Pty Ltd (2003), is a species at the southern most end of its distribution. One plant was sighted along the fence line at the south west of the property.

The wetlands varied between sumplands, damplands, floodplains and palusplains depending on the soil, shape and standing water. They are within the Jandakot consanguineous wetland suite (Semeniuk, 1998). As the land had been grazed previously the vegetation condition was recorded as very good (vegetation condition 3) for most of the wetlands, some as good (vegetation condition 4) but none were degraded (vegetation condition 5) or completely degraded (vegetation condition 6). Each of the wetlands was a mosaic of vegetation units and, apart from areas of *Melaleuca rhaphiophylla* or *Melaleuca viminea* in standing water during the September and October surveys, was impossible to map in fine detail using an aerial photograph. The scale of the aerial photograph was the limiting factor. Vegetation units present at each wetland were described.

The wetland suites, a combination of one or more of the wetlands, were assessed using the questionnaire in Environmental Protection Authority (1993). This resulted in all being classified as Conservation (Environmental Protection Authority, 1993 and Water and Rivers Commission, 2001). This indicates that the wetlands at the site are of conservation importance although there is an area in wetland suite WC3 which already has infrastructures, including a drain at the wetland. Wetland Suite WC3 also includes EPP wetland 4.

The Environmental Protection Authority (2002) provides selection criteria for the identification of regionally significant natural areas on the southern Swan Coastal Plain. Kemerton Silica Sand met all these selection criteria with the exception that the land is privately owned. There is:

- Less than 30% of the pre-clearing extent of the Bassendean Complex – Central and South (27% remains);
- The area is in excess of 20ha;
- The vegetation is vegetation condition 3, very good.;
- Both uplands and wetlands occur;
- The area has importance for a linkage from the Spearwood system to the west, through the Bassendean Complex – Central and South and the Guildford system to the east.

Using the criteria identified by the Environmental Protection Authority (2002) for assessing the regional significance of an area within the Bunbury Greater Region, Kemerton Silica Sand is considered to be regionally significant. This is provided in the planning scheme of the Environmental Protection Authority (2003) in their consideration of the Greater Bunbury Region Scheme. This plan had not been resolved at the time of this report. If approval is received to extend the mining area care will need to be exercised to ensure that the remnant and conservation classified wetlands are not compromised.

1. INTRODUCTION

Bennett Environmental Consulting Pty Ltd was contracted by Martinick Bosch Sell Pty Ltd to undertake an assessment of the wetlands and significant flora at the Kemerton Silica Sand site. This included to:

- undertake a survey to located Declared Rare Flora (DRF) and Priority Flora (PF) survey;
- map Declared Rare Flora and Priority Flora located;
- assess vegetation units of the wetlands;
- record the vegetation condition of the wetlands; and
- assess the wetlands using the questionnaire in Department of Environmental Protection (1993).

There have been several vegetation surveys undertaken of the site and the surrounding area over the last 10 years with most of the data being summarised in Mattiske Consulting Pty Ltd (2003). In this publication it was recommended that a search be undertaken to extend the known distribution of recorded DRF and PF within the site. Muir Environmental (1999) undertook a vegetation survey of the Kemerton Industrial Estate, which includes the Kemerton Silica Sand site in a more extensive area.

The Kemerton Silica Sand project area contains areas of the Bassendean Complex (Central and South), Guildford Complex and the interface between them with the Karrakatta Complex abutting to the west (Keighery, 1998). Within the Greater Bunbury Region, 39% of the Bassendean Complex Central and South remain vegetated and less than 4% of the Guildford Complex (Environmental Protection Authority, 2002). Only 1% of the Bassendean Complex Central and South remains in secure tenure in the Greater Bunbury Region. Within the area surveyed during this study there was only a small area of Guildford Complex included and that occurred in the section to the north of the proposed conservation area.

A large percentage of the project area consists of wetlands and is included in the Jandakot consanguineous wetland suite (Semeniuk, 1998). Consanguineous wetlands are genetically related types based on wetland type, wetland geometry, stratigraphy, inferred origin and water characteristics. The primary wetlands identified for the Jandakot consanguineous wetland suite are damplands and sumplands typically occurring in peat or peaty sand or humic sand overlying quartz sand where the groundwater surfaces is at or near the surface in depressions to develop water table basins.

2. METHODS

Prior to undertaking the field work a list of Declared Rare Flora (DRF) and Priority Flora (PF) was obtained from the Department of Conservation and Land Management by Martinick Bosch Sell Pty Ltd. In addition Mattiske Consulting Pty Ltd (2003) was consulted for the list of species previously recorded from the location. All staff involved with the field work then checked and made notes on these species against the specimens housed at the Western Australian Herbarium to ensure their recognition in the field.

The field work was undertaken in three stages to ensure that the potential DRF and PF within the area were located. The first field work was undertaken between 22nd and 26th September, the second between 15th and 17th October and the third between 3rd and 5th November 2003. The project consisted of two sections, the first a search for DRF and PF, and the second the mapping and consideration of the importance of the wetlands at the site.

A team of three qualified environmentalists walked transects through the area at 100m intervals during the September survey. It had been intended to walk transects at 50m intervals but the bushland was very thick making progress very slow. The location of the transects are indicated in Appendix A. DRF and PF were again searched for at the October and November surveys when additional notes were made on the wetlands.

A collection of each species of DRF and PF was made for lodging at the Western Australian Herbarium. When these species were located a GPS reading in WGS84 datum was recorded together with a brief note about the associated vegetation. Where possible a photograph of each species was made but conditions when the field work was undertaken were not conducive for photography.

As the transects were walked, the different vegetation units traversed through the wetlands were recorded. The dominant species of each stratum within the different vegetation units was recorded, together with the presence of standing water. As the field work was undertaken each wetland or section of wetland was allocated a letter and the different vegetation units present within this recorded. As variations were small and often impossible to delineate on the aerial photographs the wetland as a whole is described. Areas of *Melaleuca rhaphiophylla/Melaleuca viminea* were often obvious and could be mapped. Where appropriate the mapping provided by Mattiske Consulting Pty Ltd (2003) was incorporated.

To ensure all wetlands had been thoroughly surveyed an afternoon was spent specifically completing all those not covered as a result of the transects. This included those to the east of the SW-NE powerline track and those to the east of the limestone track not covered by the transects.

3 RESULTS

3.1 Significant Flora

3.1.1 Background Information

The search of the Department of Conservation and Land Management records of occurrence of declared rare and priority species conducted in May 2003 resulted in the following species likely to be present.

- Four Declared Rare Flora species (*Caladenia huegelii, Diuris purdiei, Drakaea elastica* and *Drakaea micrantha*).
- No Priority 1 species.
- Three Priority 2 species (*Boronia capitata* subsp. *capitata*⁺, *Haloragis aculeolata* and *Oligochaetochilus* sp. Yalgorup (G Brockman GBB463).
- Ten Priority 3 species (*Acacia semitrullata*⁺, *Chamaescilla gibsonii, Haloragis tenuifolia, Hemigenia microphylla, Hibbertia spicata* subsp. *leptotheca, Lasiopetalum membranaceum, Myriophyllum echinatum, Rhodanthe pyrethrum, Schoenus* sp. *Waroona* (GJ Keighery 12235) (pn)⁺ and *Verticordia attenuata).*
- Five Priority 4 species (*Anthotium junciforme, Caladenia speciosa*⁺, *Conostylis pauciflora* subsp. *pauciflora, Jacksonia sparsa* and *Pultenaea skinneri).*

NOTE: ⁺ Indicated have or may previously have been recorded from the Kemerton Silica Sand project area in previous surveys.

In surveys undertaken by Mattiske Consulting Pty Ltd (1993a-d) the additional species were recorded:

- One Priority 1 species (*Boronia juncea* subsp. *juncea*).
- One Priority 2 species (*Boronia capitata* subsp. *gracilis).*
- One Priority 3 species (*Goodenia filiformis*).
- One Priority 4 species (*Acacia flagelliformis*).

B. Keighery (1998) also suggested that *Hydatella dioica* (DRF), *Centrolepis caespitosa* (DRF), *Schoenus* sp. Waroona (GJ Keighery 12235) (pn), *Drosera occidentalis* subsp. *occidentalis* and *Schoenus capillifolius* (P2) are likely to occur in the project area. She also listed the following taxa as uncommon and restricted on the Swan Coastal Plain:

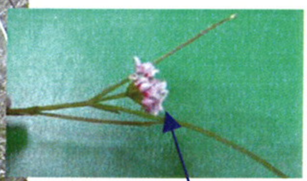
- A form of *Melaleuca systena* growing to two metres;
- *Melaleuca* sp. (*brachyphylla* – B.Keighery) an uncommon species on the Plain;
- *Hakea trifurcata* – a small flowered form;
- *Hibbertia perfoliata* – an uncommon and poorly collected species on the Plain (Muir, 1999).

In addition B. Keighery (1998) noted *Verticordia nitens* and *Banksia menziesii* are at the southern limits of their range and *Evandra pauciflora* as a distinctive sedge that inhabits damplands on the Swan Coastal Plain. This resulted in a relatively extensive list of significant species that could occur in the area.

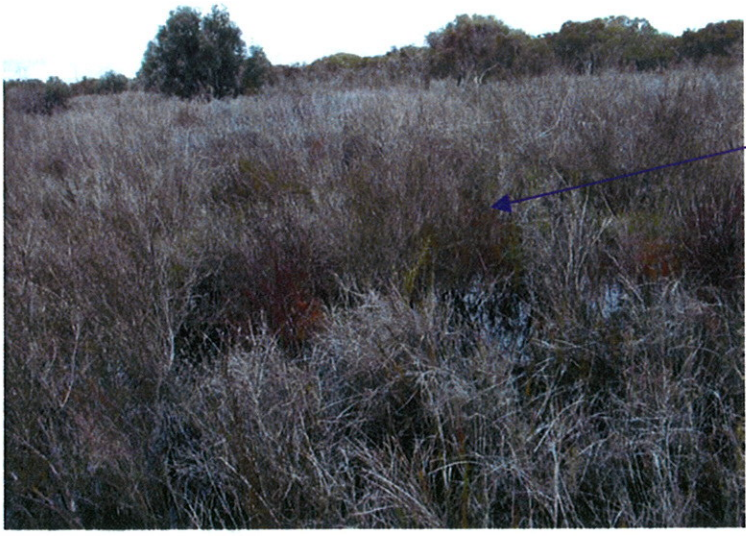
3.1.2 Field Results

Ten of the significant species listed for the area were recorded during the survey. The occurrence of these is mapped and the number recorded is provided in Appendix B.

Boronia juncea subsp. *juncea* P1 was common through a lot of the wetlands, but only where there was standing water present during the September survey. Although not in flower it was readily recognised by the bright red stems, its height up to 1m and branching method. Some plants had commenced to flower when the November survey was undertaken.



Shrub and flower of *Boronia juncea* subsp. *juncea*



Shrubs of *Boronia juncea* subsp. *juncea* readily identified by their red colour. Photograph taken in September. Standing water visible.

Boronia capitata subsp. *gracilis* (P2) was recorded from along the SW/NE power line track in the northern area of the lease. There were hundreds of plants in this area, which had recently been disturbed. The site where Mattiske Consulting Pty Ltd (2003) had recorded the species was searched thoroughly but no plants were recorded. It is possible that when the original Mattiske Consulting survey was undertaken that the area had been recently disturbed, and that if the area is disturbed again the species will reappear.

Boronia capitata subsp. *gracilis*

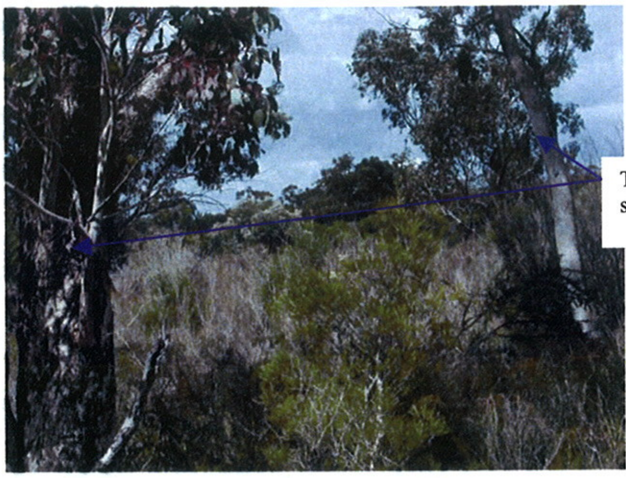
Acacia semitrullata (P3) was very common through the damp and slightly higher ground. It occurred as scattered plants throughout the location. It was so common that its distribution is illustrated broadly on the map. It was so abundant that all sites were not recorded with a GPS reading.

Acacia semitrullata

Dillwynia dillwynioides (P3) blended in with the surrounding vegetation until it was in full flower. In the October and November survey there were many plants of this species recorded in areas that were currently or until recently were in standing water. The bright orange flowers contrasted markedly with the surrounding vegetation. When in bud or flower this species can be positively identified by the dense long hairs on the calyx.

Dillwynia dillwynioides shrub in flower

Eucalyptus rudis subsp. *cratyantha* (P3) was the only *E. rudis* recorded from the location. It is stated in 'Flora of the South West Bunbury – Augusta – Denmark' (Wheeler *et al*., 2003) that only this subspecies occurs within the area covered by this publication. Often this species occurred as individual trees but there were a few locations were it was the dominant tree in the upper storey as was the case where it was recorded in the northern section to the east of the limestone track. This subspecies has larger buds and fruits than the typical subspecies.



Trees of *Eucalyptus rudis* subsp. *cratyantha*

Acacia flagelliformis (P4) was reasonably common in the southern section of the lease, only being recorded in the swamp to the south of the power line track on both the east and west sides of the access road. It is a rush-like shrub that is readily recorded when in flower but when in fruit can often be overlooked when a general survey is undertaken. Where this species was recorded generally there were many plants present.

Acacia flagelliformis

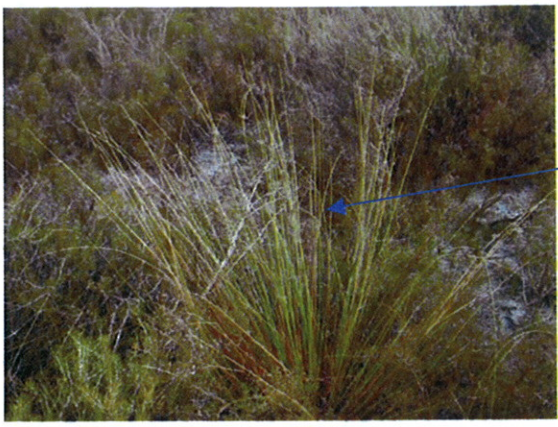
Caladenia speciosa (P4) was recorded from 3 sites. This is another species which is readily overlooked if not in flower as it has the characteristic hairy leaf of most 'Spider orchids'. NO photograph was taken of this species.

Jacksonia sparsa (P4) like *Acacia semitrullata* was widespread through the slightly higher ground. It was common in the *Kunzea glabrescens* thickets as well as in the Jarrah and Banksia woodlands. The general area of distribution of this species is indicated on the map as being so common all locations were not recorded with a GPS reading.

Banksia menziesii (southern extension) one plant was observed just off the area surveyed. This was to the east of the fenceline, south of the power line track. No other trees of this species were observed during the survey.

Verticordia nitens (southern extension) was only recorded to the east of the access road and to the south of where the mining is currently taking place. Where it was recorded there were generally several plants present. This species is readily recognised by the characteristic inflorescence even when not in flower. C. Karelse (pers. comm.) stated that a few plants were observed in flower in December 2003 along the edge of the west side of this road. The limestone used as a base for the access road may influence its occurrence in this location.

Evandra pauciflora (sedge of damplands of the Swan Coastal Plain) was recorded from many of the wetlands as indicated in Appendix C. At some locations it was the dominant species at others there were scattered plants through the wetland. At the time of the survey it was readily identified as the inflorescence were held above the height of the surrounding bushland.



Evandra pauciflora

3.1.3 Comments on Priority Flora not located during the survey

Careful searching of the wetlands was undertaken at the two later surveys to look for those species that occur on the wetland margins. These included the following annual and ephemeral species:

- *Diuris purdiei, Centrolepis caespitosa, Hydatella dioica* (DRF);
- *Haloragis aculeolata, Schoenus capillifolius* (P2);
- *Chamaescilla gibsonii, Drosera occidentalis* subsp. *occidentalis, Haloragis tenuifolia, Myriophyllum echinatum, Rhodanthe pyrethrum, Schoenus* sp. Waroona (GJ Keighery 12235) (pn) (P3)
- *Anthotium junciforme* (P4)

Anthotium junciforme has previously been recorded from the project area. This is a summer flowering species but the leaves should have been visible at the time of the survey. No plants of this species were recorded although plants of *Stylidium dichotomum* were collected to check their identity.

Centrolepis caespitosa has recurved leaves as does *Centrolepis glabra* but *C. caespitosa* has the inflorescence hidden in the leaves whereas the inflorescence of *C. glabra* is exserted and obvious. *C. .glabra* was recorded from the location but not *C. caespitosa.*

3.1.4 Checks on previous species

It was suggested by Mattiske Consulting Pty Ltd (2003) that the record of *Conostylis micrantha*, a species occurring north of Perth should be checked. This species is restricted to the Dongara - Mingenew area (Western Australian Herbarium, 2003) so it is likely that the plant collected at Kemerton was misidentified. If the plants were only collected in a vegetative form they could have been *Conostylis juncea* recorded from the area by Mattiske Consulting Pty Ltd (2003).

Goodenia filiformis collected during the Mattiske surveys (Mattiske, 2003) has recently been renamed as *Goodenia pulchella* subsp. Coastal Plain, and is not a priority species (L. Sage, pers. comm.). *Goodenia filiformis* is restricted to the Albany area and is a priority flora (L. Sage, pers. comm).

Other species that include subspecies recorded as priority flora were also noted by Mattiske Consulting Pty Ltd (2003) to be checked. These were:

- *Adenanthos cygnorum* subsp. *chamaephyton* – at Kemerton they were *Adenanthos cygnorum* subsp. *cygnorum*;
- *Eucalyptus rudis* subsp. *cratyantha* – all plants at Kemerton were of this subspecies; *and*
- *Pimelea ciliata* subsp. *longituba* – at Kemerton were *Pimelea ciliata* subsp. *ciliata*.

Keighery (1998) also recorded *Cyathochaeta stipoides* in the wetland adjacent to the northern margin of the dredge pond, which is to the east of the current search area. None of these plants were located during the current search. Most of the research undertaken by Keighery at Kemerton has been on the eastern side of the entrance road in the Gwalia Nature Reserve, which contains an area of Muchea limestone. This area supports species different to those in the remainder of the lease area. Species considered characteristic of the Muchea limestone include *Eucalyptus decipiens, Pimelea rosea, Austrostipa flavescens, Gahnia trifida, Verticordia nitens* and *Logania vaginalis*. *Gahnia trifida* was recorded in one of the vegetation units at the northern area of the lease to the east of the limestone track and *Verticordia nitens* has been discussed previously.

3.2 Wetlands

3.2.1 Background Information

Most of the site surveyed consisted of areas defined as wetlands. Semenuik (1987) states that a consensus of Western Australian researchers define wetlands as:

> 'Areas of seasonally, intermittently or permanently waterlogged soils or inundated land, whether natural or otherwise, fresh or saline, eg waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries.'

Using the classification of Semeniuk (1987) the wetlands surveyed at the Kemerton area would be classified as consisting of:

- Sumpland – seasonally inundated basin
- Dampland – seasonally waterlogged basin
- Floodplain – seasonally inundated flat and
- Palusplain – seasonally waterlogged flat.

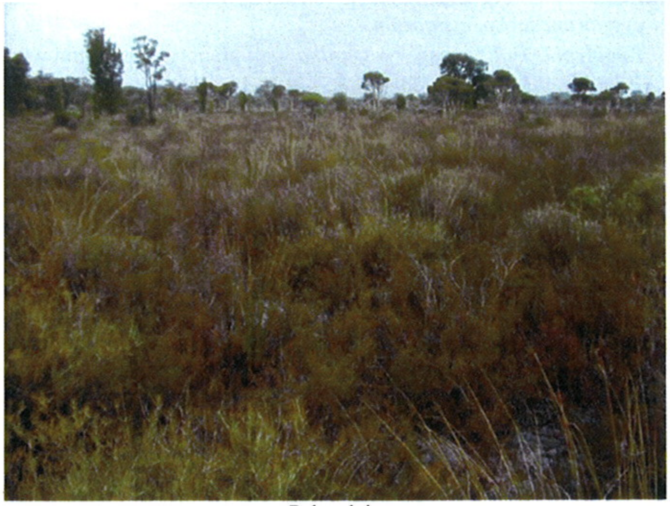
From the data provided in Semeniuk (1998) the study area would be included in the Jandakot consanguineous wetland suite where the characteristic wetlands are damplands and sumplands. The Guildford Complex occurs in the Pinjarra Plain, which is characterised by the consanguineous Keysbrook wetland suite. In this suite the primary wetlands are palusplains, floodplains and creeks typically occurring in clay overlying lateritic clay and sand.

A marked variation was noted whilst undertaking the field work between the wetlands in the southern section of the area surveyed and those in the north and again between the northern ones from west to east ie Jandakot and Keysbrook wetland suites. The wetlands in the southern section occurred in sandy soil as did most of those in the north west of the study site, but those in the north east were in clay soils.

3.2.2 Wetland Types

The different wetlands identified at the site are mapped in Appendix C, Map 1.

The wetlands in the southern section of the area were examples of palusplains as they were mostly seasonally waterlogged flats. Sections of these wetlands were deeper and held the water for a longer period than the remainder of the wetland. The species and therefore the vegetation units varied with changes in water retention. For example where the ground was only damp *Pericalymma ellipticum* and *Hypocalymma angustifolium* dominated, but where the water was retained for a longer period *Astartea* scoparia became dominant. These variations were still considered to be a palusplain.



Palusplain

In a few of these palusplains there were damplands where *Melaleuca rhaphiophylla* became dominant. These areas retained water on the surface for a much longer period than the remaining areas of the palusplain and would be expected to have the water table at a higher level throughout the dry period. Where these damplands were extensive they were mapped as individual groups but occasionally they were relatively small and could not be mapped at the scale provided.

Dampland

There were a few sumplands in the central and middle sections of the area. These sumplands were obvious as they were approached due to the obvious nature of the depression. Typically these consisted of a fringe of *Astartea scoparia* Shrubland around the perimeter, with a ring of Tall Shrubland of *Melaleuca viminea* extending into the centre with *Melaleuca rhaphiophylla*. The water was retained for longer than the other wetlands in the area and many were still underwater when the survey was undertaken in November. *Baumea articulata* was a common sedge in these wetter areas. When these sumplands dried they left a floor of litter where the water had been which inhibits the growth of annual species.

Sumplands included those listed as Environmental Protection Policy (EPP) wetlands. EPP wetlands are subject to permanent or seasonal inundation or waterlogging, whether by water that is fresh, brackish, or saline, or flowing or static but does not include estuaries, rivers or their tributaries.

Sumpland

Floodplains were identified in the north eastern section to the north of the conservation area. The floodplains had more clay in the soil and extensive herblands not recorded in the other wetland types. The dominant vegetation varied from Woodlands of *Melaleuca rhaphiophylla* and/or *Melaleuca viminea* to Dense Shrublands of *Melaleuca teretifolia*. These vegetation units are mapped in Mattiske Consulting Pty Ltd (2003).

Floodplain

3.2.3 Vegetation of Wetlands

The wetland boundaries could be readily mapped from aerial photographs. However sections of each wetland were often 'separated' by thickets dominated by *Kunzea glabresens* and *Banksia ilicifolia*. Although not classified as wetlands (Semeniuk, 1987) they are an integral part of the health and maintenance of the wetlands and as such shall be included in this discussion as units associated with the wetlands. Very few areas of Jarrah (*Eucalyptus marginata*) as mapped by Mattiske Consulting Pty Ltd (2003) were observed during the survey, most of the higher ground consisting of *Kunzea glabresens* usually associated with *Banksia ilicifolia*.

Wetlands are not simple units and the vegetation cannot be described as one individual unit. This was particularly apparent, as the areas identified on an aerial photograph as representing a wetland were not a simple vegetation unit but a mosaic of units. Mattiske Consulting Pty Ltd (2003) also noted this when they mapped the vegetation of the site. With this current study it was found impossible to map the individual vegetation units within the wetland so the different wetlands marked on the aerial photographs were each allocated an identifier and the different vegetation units present described. This current survey was not a detailed vegetation survey or a listing of all species present in each unit as Mattiske Consulting Pty Ltd has undertaken this, but was to identify and determine the environmental significance of each wetland and the area as a whole.

A description of the vegetation recorded at each of the wetlands is described below using the vegetation layers as given in Table 1. The location of each is mapped in Appendix C, Map 1.

Table 1. Vegetation layers. Adapted from: Bush Forever (Department of Environmental Protection, 2000)

Life Form/ Height Class	Canopy Cover			
	100-70%	70-30%	30-10%	10-2%
Trees over 30m	Tall Closed Forest	Tall Open Forest	Tall Woodland	Tall Open Woodland
Trees 10-30m	Closed Forest	Open Forest	Woodland	Open Woodland
Trees under 10m	Low Closed Forest	Low Open Forest	Low Woodland	Low Open Woodland
Tree mallee(8m tall)	Closed Tree Mallee	Tree Mallee	Open Tree Mallee	Very Open Tree Mallee
Shrub mallee(under 8m tall)	Closed Shrub Mallee	Shrub Mallee	Open Shrub Mallee	Very Open Shrub Mallee
Shrubs over 2m	Closed Tall Scrub	Tall Open Scrub	Tall Shrubland	Tall Open Shrubland
Shrubs 1-2m	Closed Heath	Open Heath	Shrubland	Open Shrubland
Shrubs under 1m	Closed Low Heath	Open Low Heath	Low Shrubland	Low Open Shrubland
Grasses	Closed Grassland	Grassland	Open Grassland	Very Open Grassland
Herbs	Closed Herbland	Herbland	Open Herbland	Very Open Herbland
Sedges	Closed Sedgeland	Sedgeland	Open Sedgeland	Very Open Sedgeland

WETLAND A

Palusplain

- The centre of this wetland is Closed Heath dominated by *Astartea scoparia* and *Pericalymma ellipticum* over bare ground.
- There is a zone of Low Open Forest of *Banksia littoralis* over Open Heath dominated by *Astartea* scoparia surrounding this Heath.
- To the east there is Low Woodland of *Melaleuca preissiana* over a Sedgeland of *Lepidosperma longitudinale*.

Significant Flora

None recorded

WETLAND B

Palusplain

- The centre of this wetland consists of Closed Heath of mixed species dominated by *Hakea varia, Astartea scoparia, Calothamnus lateralis* and *Melaleuca lateritia* over a Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata* and a Very Open Herbland of *Villarsia albiflora*. The area when surveyed in September was very moist but there was no standing water. *Boronia juncea* subsp. *juncea* was common in this wetland. The edge of this unit heading to the north consisted mainly of dead shrubs. The soil was very dry compared to the surrounding area but there was no indication as to the cause. The same vegetation unit to the south did not record these deaths.
- Where there was standing water there was Open Heath of *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale*.
- Scattered occurrences of Closed Tall Scrub of *Melaleuca viminea* occurred in the wetland sometimes associated with Low Woodland of *Melaleuca rhaphiophylla* over a Sedgeland of *Lepidosperma longitudinale*.
- Most of the surrounding wetland was Low Open Woodland of *Melaleuca preissiana* and *Kunzea glabrescens* over Closed Low Heath of mixed species dominated by *Adenanthos obovatus, Adenanthos meisneri, Hypocalymma angustifolium* and *Pultenaea ochreata*.
- Areas of Open to Dense Herbland dominated by *Dasypogon bromeliifolius*.

Higher Ground

- The wetland was surrounded by Tall Open Scrub of *Kunzea glabrescens* over a Shrubland dominated by *Hypocalymma angustifolium*.

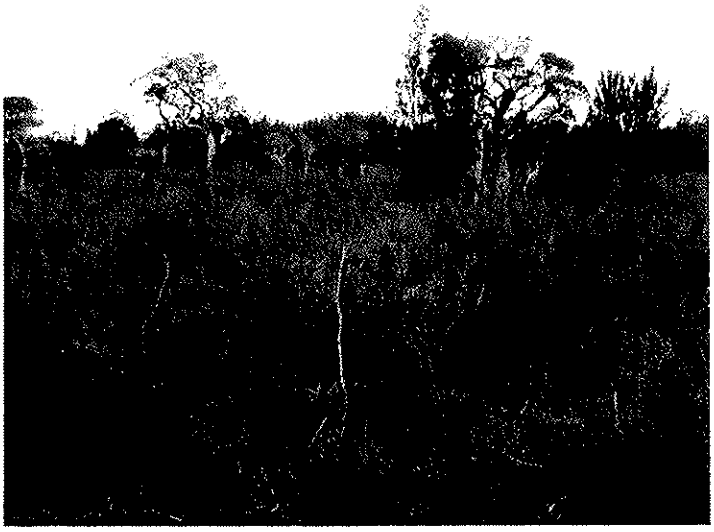
Significant Flora

None recorded

WETLAND C

Palusplain

- Most of the surrounding wetland was Low Open Woodland of *Melaleuca preissiana* and *Kunzea glabrescens* over Closed Low Heath of mixed species dominated by *Pericalymma ellipticum, Astartea scoparia, Calothamnus lateralis* over Open Sedgeland of *Meeboldina coangustata* and *Meeboldina tephrina* or bare ground. Most of the *Melaleuca preissiana* were 3m tall but there were occasional areas where they were up to 12m tall. Where Astartea became abundant there was shallow standing water but the remainder of the area was damp. In some areas there were several plants of **Hypochaeris glabra*. (Photograph below.)



- Where *Melaleuca preissiana* was 12m tall the understorey was as in the above description but there were additional *Astartea scoparia.*

Sumpland

- Where there was standing water it was Open Forest of *Melaleuca rhaphiophylla* and *Eucalyptus rudis* subsp. *cratyantha* over a Sedgeland of *Baumea articulata.* In addition there were several clumps of *Eucalyptus rudis* subsp. *cratyantha* scattered through this wetland.

Higher Ground

- Higher ground was Tall Open Scrub of *Kunzea glabrescens* and *Banksia ilicifolia* over Low Shrubland of *Hypocalymma angustifolium* and/or *Xanthorrhoea preissii* with several *Jacksonia sparsa* and *Acacia semitrullata* over a Very Open Herbland/Sedgeland of *Dasypogon bromeliifolius* and *Hypolaena exsulca* or bare ground. Weeds in this vegetation unit included **Ursinia anthemoides.*
- The higher ground (not considered part of the wetland complex) was Low Open Woodland of *Banksia attenuata* over Tall Open Scrub of *Kunzea glabrescens* over a Shrubland dominated by *Calytrix fraseri* over bare ground.

Significant Flora

Eucalyptus rudis subsp. *cratyantha*

WETLAND D

This was an extensive and varied wetland that was divided into 2 sections, D1 the southern section and D2 the northern section. In this wetland many plants of *Boronia juncea* subsp. *juncea* were recorded growing in standing water in association with *Astartea scoparia.*

D1

Palusplain

- Closed Low Heath dominated by *Pericalymma ellipticum* with *Adenanthos obovatus, Calothamnus lateralis, Hypocalymma angustifolium, Adenanthos meisneri* and *Euchilops linearis* over a Very Open Sedgeland of *Evandra pauciflora* and *Hypolaena exsulca.* There was no standing water.

- Closed Heath of *Astartea scoparia* and *Calothamnus lateralis* with emergent *Banksia littoralis* and *Melaleuca rhaphiophylla* over Low Open Shrubland dominated by *Hibbertia stellaris* over a Sedgeland of *Meeboldina coangustata, Meeboldina scariosa* and *Lepidosperma longitudinale* and a diverse herb layer.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum*. The ground was damp.
- Closed Heath of *Calothamnus lateralis* and *Astartea scoparia* over a Sedgeland of *Meeboldina coangustatus* in standing water. It was in this vegetation community the *Dillwynia dillwynioides* was recorded.
- Low Open Woodland of *Eucalyptus rudis* subsp. *cratyantha* and *Melaleuca preissiana* over Low Open Shrubland dominated by *Hypocalymma angustifolium* and Open Sedgeland of *Hypocalymma exsulca* with 10-30% bare ground.
- Open Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp soil.
- Low Woodland of *Melaleuca viminea* and *Melaleuca preissiana* over Open Heath of *Astartea scoparia, Calothamnus lateralis, Melaleuca lateritia* and *Melaleuca teretifolia* over a Sedgeland dominated by *Lepidosperma longitudinale* with *Meeboldina coangustata* and *Meeboldina tephrina* in wet ground. There was a lot of dead *Melaleuca lateritia* in some sections.

Higher Ground

- Low Open Woodland of *Melaleuca preissiana* over Tall Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Adenanthos meisneri, Euchilops linearis, Adenanthos obovatus* and Open Herbland of *Dasypogon bromeliifolius*. The ground was damp in September. In some sections of this unit there were scattered trees of *Nuytsia floribunda*, shrubs of *Xanthorrhoea preissii* and clumps of *Evandra pauciflora*.
- Tall Open Shrubland of *Kunzea glabrescens* and *Nuytsia floribunda* over Open Low Heath of *Hypocalymma angustifolium, Adenanthos meisneri* and *Xanthorrhoea preissii* over Open Sedgeland of *Anarthria laevis* and *Evandra pauciflora*. Soil moist.
- Tall Open Shrubland of *Kunzea glabrescens* and *Melaleuca preissiana* over Open Low Heath of *Hypocalymma angustifolium. Adenanthos meisneri, Euchilops linearis* and *Dasypogon bromeliifolius*. Damp ground.

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora

D2

Palusplain

- Tall Shrubland of *Kunzea glabrescens* with emergent *Banksia ilicifolia* and *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* with occasional *Pericalymma ellipticum* in damp ground.
- Closed Low Heath of *Pericalymma ellipticum* with scattered *Hypocalymma angustifolium* and *Euchilops linearis* with emergent *Kunzea glabrescens* and *Melaleuca preissiana*, in damp ground.
- Closed Heath of *Pericalymma ellipticum* and *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale* in damp ground.
- Closed Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* with scattered emergent *Melaleuca preissiana, Xanthorrhoea preissii* and occasional *Evandra pauciflora* in damp ground. (Photograph below.)

- Low Open Woodland of *Melaleuca preissiana* over a Shrubland of *Xanthorrhoea preissii* over Open Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum* and Open Sedgeland of *Hypolaena exsulca.* In damp nearly dry ground.
- There was a small area of Sedgeland of *Anarthria occidentalis* with emergent *Xanthorrhoea preissii* and *Melaleuca preissiana* in amongst the vegetation unit described above in damper ground.

Higher Ground

- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Pericalymma ellipticum* and scattered *Adenanthos obovatus* over bare ground in damp soil.
- Low Woodland of *Banksia ilicifolia* and *Melaleuca preissiana* over Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp soil.
- Low Open Woodland of *Banksia ilicifolia* over Tall Open Scrub of *Kunzea glabrescens* over Open Herbland of *Dasypogon bromeliifolius* and bare ground.
- Tall Open Scrub of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium* and *Adenanthos meisneri* over Open Herbland of *Dasypogon bromeliifolius* in damp ground.
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium, Adenanthos obovatus* and over Open Sedgeland of *Hypolaena exsulca* in dry soil.
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium, Platytheca verticillata, Euchilops linearis* and a Dense Sedgeland of *Hypolaena exsulca* in dry soil.

Significant Flora

Acacia semitrullata
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora
Jacksonia sparsa

WETLAND E

Palusplain

- Low Open Woodland of *Melaleuca preissiana* and Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium, Pericalymma ellipticum, Jacksonia sparsa* and *Adenanthos meisneri* in damp ground.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum* in damp ground.
- Closed Heath of *Astartea scoparia* over a Sedgeland of *Meeboldina coangustata* in wet soil.
- Slightly higher ground Closed Heath of *Astartea scoparia* and *Pericalymma ellipticum* with occasional emergent *Melaleuca preissiana* in wet soil. (Photograph below)

Dampland

- Low Open Forest of *Melaleuca rhaphiophylla* over Tall Open Scrub of *Astartea scoparia* over Open Sedgeland of *Baumea articulata* in 1m standing water. Plants of *Boronia juncea* subsp. *juncea* recorded on the edge of the deep water.

Higher Ground

- Closed Tall Scrub of *Kunzea glabrescens* over a Shrubland of *Xanthorrhoea preissii* over Open Sedgeland/Open Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius* in dry ground.

Significant Flora

Boronia juncea subsp. *juncea*
Evandra pauciflora
Jacksonia sparsa

BETWEEN D AND E

High Ground

- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* with scattered *Adenanthos obovatus* and *Euchilops linearis*.
- Large areas of Closed Sedgeland/Closed Low Heath of *Anarthria laevis* with *Hypocalymma angustifolium*.

Significant Flora
Dillwynia dillwynioides

NOTE: Wetlands D and E blend into one another .

WETLAND F

This wetland is a large basin surrounded by higher area.

Palusplain

- Sedgeland of *Evandra pauciflora* in damp ground.
- Tall Shrubland of *Melaleuca viminalis* over Open Heath of *Melaleuca teretifolia* and *Melaleuca polygaloides* in standing water. *Boronia juncea* subsp. *juncea* recorded from this unit.
- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* on the edge of the wetland where it abuts the higher ground.
- Closed Low Heath of *Pericalymma ellipticum* with *Calothamnus lateralis* over Very Open Sedgeland of *Lepidosperma longitudinale* long with very scattered *Melaleuca preissiana.*
- Closed Heath of *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale.* Many of the Astartea shrubs were dead.
- Closed Heath of *Astartea scoparia* over Open Low Heath of *Pericalymma ellipticum, Hibbertia stellaris, Calothamnus lateralis* over open dry ground.

Higher Ground

- Low Woodland of *Banksia ilicifolia* over Closed Low Heath of *Hypocalymma angustifolium* in dry soil.
- Low Open Woodland of *Melaleuca preissiana* and *Banksia ilicifolia* over Open Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp ground. *Hypocalymma angustifolium* becomes dominant on the drier margins.

Significant flora recorded
Acacia flagelliformis
Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND G

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Pericalymma ellipticum* and *Astartea scoparia* over Open Sedgeland of *Meeboldina tephrina* and *Meeboldina coangustata* over open damp ground.

Higher Ground

- Closed Tall Scrub of *Kunzea glabrescens* over bare ground surrounds the wetland.

Significant Flora
None located

WETLAND H

Dampland

- Low Open Forest of *Melaleuca rhaphiophylla* over a Sedgeland of *Baumea articulata* and *Lepidosperma longitudinale* in standing water.

Palusplain

- Closed Heath of *Astartea scoparia* over bare ground.
- Tall Open Scrub of *Kunzea glabrescens* with emergent *Melaleuca preissiana* over Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum.*
- Closed Heath of *Astartea scoparia* over Open Sedgeland of *Lepidosperma longitudinale* in very damp soil.

Higher Ground

- Closed Low Heath of *Hypocalymma angustifolium, Adenanthos obovatus* and *Pultenaea ochreata* with scattered emergent *Melaleuca preissiana* and *Kunzea glabrescens* in dry soil.

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Jacksonia sparsa

WETLAND K

This is the wetland in the northern area of the lease where the soil was clay compared to the sand or sandy loam of the other wetlands.

Floodplain

- Tall Open Scrub of *Melaleuca viminea* over Open Herbland/Grassland in clay. (Photograph below.)

- Tall Open Scrub/Tall Open Forest of *Kunzea glabrescens, Melaleuca cuticularis, Melaleuca incana, Melaleuca preissiana* and *Agonis flexuosa* with scattered emergent *Corymbia calophylla* over Open Low Heath of *Hypocalymma angustifolium, Melaleuca pauciflora* and *Astartea scoparia* over a Sedgeland of *Chaetanthus leptocarpoides* and *Gahnia trifida.* Scattered *Eucalyptus rudis* subsp. *cratyantha* occurred through this vegetation unit. (Photograph below.)

- Tall Open Scrub of *Melaleuca viminea* over Closed Sedgeland of *Lepidosperma longitudinale* on the outer edge of the above.

Edge of dampland
- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* in dry sand. Scattered *Melaleuca preissiana* occur further into wetland.
- Closed Heath of *Astartea scoparia* with emergent *Melaleuca preissiana* over Open Sedgeland of *Lepidosperma longitudinale* in moist soil.
- Closed Tall Scrub of *Melaleuca viminea* over a Sedgeland of *Lepidosperma longitudinale* in damp soil.

Higher ground
- Low Open Woodland of *Melaleuca preissiana* with scattered *Nuytsia floribunda* over Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* in damp ground.

Significant Flora
None recorded

WETLAND I

Palusplain
- Closed Low Heath dominanted by *Hypocalymma angustifolium* and *Pericalymma ellipticum* with emergent *Melaleuca preissiana.*

Higher ground
- Low Open Woodland of *Melaleuca preissiana* over Tall Open Shrubland of *Kunzea glabrescens* and scattered *Banksia ilicifolia* over Closed Low Heath of *Hypocalymma angustifolium.* A few *Banksia ilicifolia* are dead. This could be due to dieback as banksias are notoriously affected by this pathogen.
- Closed Tall Scrub of *Kunzea glabrescens* with emergent *Banksia ilicifolia* and *Eucalyptus marginata* subsp. *marginat*a over Open Heath/Sedgeland of *Xanthorrhoea brunonis, Dasypogon bromeliifolius* and *Hypolaena exsulca.* Few of the *Banksia ilicifolia* are dead, could be due to dieback.
- Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum* with emergent and scattered *Melaleuca preissiana.*

WETLAND J

This wetland is a sumpland with non-permanent standing water and surrounded by a palusplain.

Sumpland
- Low Closed Forest of *Melaleuca rhaphiophylla* and *Melaleuca viminea* cover over Open Sedgeland of *Baumea articulata* in standing water. This was the vegetation unit in the centre of the sumpland.
- Low Closed Forest of *Melaleuca preissiana* and *Melaleuca viminea* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata.* This vegetation unit surrounded the one above.
- Closed Tall Scrub of *Melaleuca viminea* surrounded by Low Closed Forest *of Melaleuca preissiana* with Closed Sedgeland of *Lepidosperma longitudinale.* Soil wet with standing water.
- Closed Heath of *Astartea scoparia* with scattered emergent *Melaleuca preissiana* over a Very Open Sedgeland of *Lepidosperma longitudinale* in very damp soil.

- Low Woodland of *Eucalyptus rudis* over Open Shrubland of *Xanthorrhoea preissii* and *Acacia saligna* over Sedgeland of *Lepidosperma longitudinale* over a Herbland of mixed species. (Photograph below.)

- Low Woodland of *Melaleuca rhaphiophylla* over Sedgeland of *Lepidosperma longitudinale* and a Herbland of *Chamaescilla corymbosa, Hypoxis occidentalis, Tribonanthes longipetala, Utricularia multifida* in moist soil. (Photograph below.)

- Tall Open Scrub of *Melaleuca teretifolia* over a Herbland. (Photograph below.)

Higher Ground

- Tall Open Shrubland of *Kunzea glabrescens* with emergent and scattered *Eucalyptus marginata* subsp. *marginata* and *Banksia ilicifolia* over a Shrubland of *Hypocalymma angustifolium* and *Xanthorrhoea brunonis* and a Sedgeland/Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius.* Where this vegetation unit was recorded along an old cleared grid line it was degraded due to many weeds. (Photograph below.)

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Eucalyptus rudis subsp. *cratyantha*
Evandra pauciflora
Boronia capitata subsp. *gracilis* (recorded by Mattiske Consulting Pty Ltd, 2003)

WETLAND L

Palusplain

- Low Woodland of *Melaleuca preissiana* and Tall Shrubland of *Kunzea glabrescens* over Tall Shrubland of *Astartea scoparia* and *Hypocalymma angustifolium* over a Herbland of weeds. A few pines were scattered through. Very dry.
- Tall Shrubland of *Kunzea glabrescens* and *Banksia ilicifolia* over Open Low Heath of *Hypocalymma angustifolium.*

Significant Flora

Dillwynia dillwynioides

WETLAND M – EPP Wetland 8

Sumpland

- Low Open Forest of *Melaleuca rhaphiophylla* and *Melaleuca viminea* over a Sedgeland of *Lepidosperma longitudinale* with open water.
- Closed Low Scrub of *Astartea scoparia* with scattered *Oxylobium lineare* over Sedgeland of *Lepidosperma longitudinale*. Water covering ground. (Photograph below.)

View as enter the wetland from the south

Higher Ground

- Low Woodland of *Melaleuca preissiana* and Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium.*

Significant Flora

Dillwynia dillwynioides

WETLAND N

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Astartea scoparia* and *Calothamnus lateralis* in wet ground.
- Closed Low Heath of mixed species dominated by *Pericalymma ellipticum*, *Hypocalymma angustifolium* and *Euchilops linearis* over a Sedgeland of *Hypolaena exsulca* and *Evandra pauciflora* in damp soil.
- Open Heath of *Astartea scoparia* over Open Low Heath of *Pericalymma ellipticum* and *Calothamnus lateralis* over Open Sedgeland of *Meeboldina coangustata* water on the surface.
- Low Woodland of *Melaleuca rhaphiophylla* over Tall Shrubland of *Melaleuca teretifolia* with water on the surface. This was only a small area within the wetland.

Higher Ground

- Tall Shrubland of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp ground on the edge of the wetland. Scattered *Eucalyptus marginata* subsp. *marginata* recorded from this vegetation unit.
- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath of *Hypocalymma angustifolium* in damp ground on the edge of the wetland. Scattered *Kunzea glabrescens* was recorded in this vegetation unit.

Significant Flora

Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND P

Dampland

- Low Woodland of *Melaleuca rhaphiophylla* and *Melaleuca viminea* over a Sedgeland dominated by *Lepidosperma longitudinale* over standing water. Many plants were whipstick but there were some larger trees as shown in photograph below.

- Open Heath of *Melaleuca lateritia* over a Sedgeland of *Lepidosperma longitudinale* in very damp to open water. Many *Boronia juncea* subsp. *juncea* were recorded from this vegetation unit.
- Tall Open Scrub of *Melaleuca polygaloides, Melaleuca pauciflora, Astartea scoparia, Melaleuca rhaphiophylla, Hakea sulcata* over a Sedgeland of *Lepidosperma longitudinale*, over open water.
- Low Open Woodland of *Melaleuca preissiana* over Closed Heath of *Hakea sulcata, Pericalymma ellipticum* and *Calothamnus lateralis* over a Sedgeland of *Meeboldina coangustata* in very wet soil.
- Low Open Woodland of *Banksia littoralis* and *Melaleuca preissiana* over Closed Sedgeland of *Lepidosperma longitudinale* in standing water in September, which was drying by November.

Palusplain

- Closed Heath of *Astartea scoparia* over a Sedgeland of *Meeboldina coangustata.* (Photograph below.)

- Closed Heath of *Astartea scoparia* over Closed Low Heath of *Pericalymma ellipticum* with scattered plants of *Hakea sulcata*. (Photograph below.)

- Low Open Woodland of *Melaleuca preissii* over Closed Low Heath of *Xanthorrhoea preissii, Pericalymma ellipticum, Adenanthos obovatus* and *Hypocalymma angustifolium* with scattered plants of *Evandra pauciflora*. (Photograph below.)

- Low Woodland of *Melaleuca preissiana* over Closed Sedgeland of *Hypolaena exsulca* in damp soil.
- Shrubland of *Astartea scoparia* over Closed Low Heath of *Pericalymma ellipticum* over Sedgeland of *Meeboldina coangustata* and *Lepidosperma longitudinale* in damp soil. Scattered *Hakea varia* and *Hakea sulcata* occur in this unit as well as the occasional *Melaleuca preissiana.*
- Closed Low Heath of *Astartea scoparia, Pericalymma ellipticum* and *Hibbertia stellaris* over bare ground.
- Closed Tall Scrub of *Hakea varia, Astartea scoparia, Melaleuca polygaloides* and *Oxylobium lineare* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina tephrina.* Area damp.

Higher Ground

- Low Open Woodland of *Banksia ilicifolia* over Tall Open Shrubland of *Kunzea glabrescens* over Closed Herbland of *Dasypogon bromeliifolius.*
- Tall Open Scrub of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* in damp ground.
- Tall Open Shrubland of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* or *Pericalymma ellipticum* in dry soil. Several plants of *Pericalymma ellipticum* are stressed or dead. (Photograph below.)

- Tall Open Scrub of *Kunzea glabrescens* with emergent trees of *Melaleuca preissiana* over Low Open Shrubland of *Hypocalymma angustifolium* and *Xanthorrhoea preissii* over Open Herbland/Sedgeland of *Hypolaena exsulca* and *Dasypogon bromeliifolius*. (Photograph below.)

Lots of weeds along this track, mainly **Hypochaeris glabra*

- Tall Open Scrub of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium, Xanthorrhoea brunonis* and *Adenanthos meisneri* and a Sedgeland of *Hypolaena exsulca* and bare ground in dry soil.
- Low Woodland of *Melaleuca preissiana* over a Shrubland of *Xanthorrhoea brunonis, Hypocalymma angustifolium, Pericalymma ellipticum* and *Adenanthos obovatus* over a Sedgeland/Herbland of *Hypolaena exsulca* and *Dasypogon bromeliifolius* in dry ground. (Photograph below.)

- Low Open Woodland of *Melaleuca preissiana* over Closed Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium.*

Significant Flora

Acacia semitrullata
Boronia juncea subsp. *juncea*
Dillwynia dillwynioides
Evandra pauciflora

WETLAND Q

This is EPP wetland 4

Sumpland

- Low Closed Forest of *Melaleuca viminea* and *Melaleuca rhaphiophylla* in and surrounding standing water. (Photograph below.)

Palusplain

- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath of *Hakea varia, Astartea scoparia, Melaleuca pauciflora* and *Pericalymma ellipticum.*
- Closed Low Heath of *Pericalymma ellipticum, Xanthorrhoea preissii, Xanthorrhoea brunonis* and *Hypocalymma angustifolium* with scattered *Evandra pauciflora.* Behind and south of EEP4.

Significant Flora

Evandra pauciflora

WETLAND R

Palusplain

- Low Woodland of *Eucalyptus rudis* subsp. *cratyantha* with occasional *Banksia littoralis* and *Melaleuca preissiana* over Closed Tall Scrub of *Astartea scoparia* over a Sedgeland of *Lepidosperma longitudinale*.
- Low Woodland of *Melaleuca preissiana* behind.

Significant Flora

None recorded

WETLAND S

Sumpland

- *Melaleuca rhaphiophylla* 8m tall over *Lepidosperma longitudinale* wet below. (Photograph below.)

Palusplain

- Closed Tall Scrub of *Astartea scoparia, Calothamnus lateralis* over Closed Sedgeland of *Lepidosperma longitudinale* and *Meeboldina coangustata* over bare, damp ground.

Significant Flora

Jacksonia sparsa

WETLAND T

Palusplain

- Low Open Woodland of *Melaleuca preissiana* and *Banksia ilicifolia* over Open Low Heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium.*

Higher Ground

- Palusplain surrounded by *Banksia ilicifolia, Banksia attenuata* and *Eucalyptus marginata* Woodland.
- Closed Tall Scrub of *Kunzea glabrescens* over Open Sedgeland of *Schoenus efoliatus* and bare, dry ground. There were a few scattered trees of *Melaleuca preissiana.*
- Tall Open Scrub of *Kunzea glabrescens* over Closed Low Heath of *Hypocalymma angustifolium* and *Pericalymma ellipticum.*

Significant Flora

Acacia flagelliformis
Acacia semitrullata
Evandra pauciflora

WETLAND U

Palusplain

- Tall Shrubland of *Kunzea glabrescens* over Open Low Heath of *Hypocalymma angustifolium* and scattered *Pericalymma ellipticum.*
- Low Open Woodland of *Melaleuca preissiana* over Open Low Heath *Pericalymma ellipticum* with scattered *Calothamnus lateralis* over Sedgeland dominated by *Meeboldina coangustata.*

- Closed Tall Scrub of *Astartea scoparia* over Closed Sedgeland of *Lepidosperma longitudinale* with open water. *Dillwynia dillwynioides* located in this vegetation unit.

Higher Ground

- Low Woodland of *Banksia attenuata* and *Banksia ilicifolia* over a Shrubland dominated by *Melaleuca thymoides* and *Verticordia nitens* on the higher ground above and to the east of the wetland.
- Tall Open Scrub of *Kunzea glabrescens* over bare ground and weeds.
- Tall Shrubland of *Kunzea glabrescens* over Open Heath of *Hypocalymma angustifolium* and *Xanthorrhoea preissii*.

Significant Flora

Acacia semitrullata
Caladenia speciosa
Dillwynia dillwynioides
Verticordia nitens

3.2.4 Condition of Wetlands

Very few weeds were recorded within the wetlands with marginally more present observed on the higher ground. Most of the weeds, where they were recorded, were along tracks, especially the limestone track from north to south, the perimeter where it adjoins farming properties and especially the north eastern section. The north eastern section had degraded areas scattered through parts in good or better condition (See Table 2). In addition to the presence of weeds, there was observed to be damage caused by feral pigs.

Table 2. Explanation of Vegetation Condition Rating (Department of Environmental Protection, 2000)

Rating	Description	Explanation
1	Pristine	Pristine or nearly so, no obvious signs of disturbance.
2	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
3	Very Good	Vegetation structure altered, obvious signs of disturbance.
4	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it.
5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.
6	Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species.

Although most of the wetlands had very few or no weeds present, the area was previously grazed and selectively logged, so consequently it can only be rated as 3, very good as the vegetation structure has been altered although it is recovering very well. The transects through the bushland are becoming less obvious, but the tree stratum is still recovering and is much lower than that of the surrounding bushland. A track through scrubland re-opened in April 2003 has the shrubs and sedges commencing to rehabilitate from lignotubers and rhizomes, but it will be some years before the plants are of the same height as the surrounding bushland.

The areas where the vegetation were in good even bordering on degraded condition, include the area of the current stockpile and EPP Lake 4 and the original open drain connecting the soil sorting area with the stockpile area. Here the vegetation was more open and of lower size but the areas to the west, north and east of the drain were in better condition.

The higher ground to the south of Wetland F also included many weeds. This wetland also had many of the *Astartea scoparia* plants dead or dying which could be an affect from the previous dry years, but it would be expected if so that other species would also be showing these deaths. The high ground abuts the Blue gum plantation to the south which may be having an effect on the water level in the area as *Astartea scoparia* prefers soggy ground where as the other species recorded from this wetland tolerate a higher degree of drying.

Some weeds of concern along the north-west track included **Gomphocarpus fruticosus*, Swan plant, a declared plant pursuant to section 37 of the Agriculture and Related Resources Protection Act, 1976 (Department of Agriculture, 2003). This weed is classified as

- P1; Whole of the State. P1 Requirements - Prohibits movement. The movement of plants or their seeds is prohibited within the State. This prohibits the movement of contaminated machinery and produce including livestock and fodder.
- P4; Those portions of the State constituted as the Esperance, Katanning, Manjimup, Albany, Narrogin, Cunderdin, Northam, Busselton, Harvey and Lakes regions under Section 13 of the Act.

Another weed which appeared to be spreading and which should be controlled was **Centaurea melitensis*, Maltese cockspur. Both **Centaurea melitensis* and **Gomphocarpus fruticosus* have light seeds with hairy attachments that aid in their dispersal. These plants need to be removed before flowering and any seedlings should be hand pulled or sprayed with a herbicide.

3.2.5 Comparison with Wetland mapping of Mattiske Consulting Pty Ltd

In Mattiske Consulting Pty Ltd (2003), Figure 2 indicates the plant communities identified during several surveys (Mattiske E.M. and Associates, 1993a-d). These were communities that included Muchea limestone species *Eucalyptus decipiens, Melaleuca systena*, as one group and *Verticordia nitens* as a second group. In the vegetation mapping Figure 3 these areas were mapped as *Eucalyptus marginata – Banksia attenuata* associated communities. A comparison with the high ground mapping of Mattiske Consulting Pty Ltd (2003) is impossible as there are differences in the significance of the communities depending upon which of the maps are used. The Muchea limestone communities are restricted, but most of those areas occur to the east of the current survey area, where as the high ground of the area surveyed consisted of *Kunzea glabrescens* and *Banksia ilicifolia* with scattered to dense *Banksia attenuata* and some *Eucalyptus marginata* subsp. *marginata*. There were some small areas where *Eucalyptus marginata* was dominant, but it was not as common as indicated in Figure 3. In addition *Verticordia nitens* was not recorded to the west of the main access track or limestone track. It was not the brief of this contract to map the vegetation only to describe the different vegetation units of the wetlands.

This survey has shown the wetlands are basically mosaics of small vegetation units as described in Section 3.2.2 of this report.

3.2.6 Wetland Classification

A requirement of this survey was that the wetlands were to be evaluated using the questionnaire contained in Department of Environmental Protection (1993). A level of significance and therefore the appropriate management category are assigned based on the above evaluation. Completed questionnaire sheets for each wetland are provided in Appendix D. After these assessments are completed, the management category was assessed using information provided in 'A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area – EPA Bulletin 686' (Department of Environmental Protection, 1993). Using this questionnaire it proved difficult for palusplains in very good condition to record a high score as they lack permanent water and are not a refuge for birds.

Table 3. Categories assigned to wetlands

Category (Department of Environmental Protection, 1993).	**Management Category** (Water and Rivers Commission, 2001)	**General Description**	**Management Objectives**
H – High conservation	C - Conservation	Wetland support high level of ecological attributes and functions.	Highest priority. These are the most valuable wetlands. No development.
C - Conservation			
O – Conservation and recreation	R - Resource enhancement	Wetlands, which may have been partially modified but still support substantial ecological attributes and functions.	Priority wetland. Ultimate objective is for management, restoration and protection to improve conservation category. Protection recommended.
R – Resource enhancement			
M – Multiple Use	M - Multiple use	Wetlands with few important ecological attributes and functions remaining.	Use, development and management should be considered in the context of ecologically sustainable development.

Assessing the wetlands within the study area resulted in the following scores that are then interpreted using the Environmental Protection Authority (1993) questionnaire and then placed into the Management Categories of Water and Rivers Commission (2001). The assessment is divided into 2 sections, the natural and human attributes of the wetland. If Declared Rare Flora are recorded, the wetland is automatically considered to be category H, high conservation.

This classification does not take into account the higher ground, which at Kemerton is an extension of the wetlands. Several of the individual wetlands discussed in Section 3.2.4 should be combined into one wetland complex (WC). These are listed below and mapped in Appendix C, Map 2.

- Wetland F is a distinctive wetland. The dune to the north is much higher, a ridge, above the wetland. (WC1)
- Wetlands D1, D2, E, I, K, P with the intervening higher ground of *Kunzea glabrescens* and *Banksia ilicifolia* make up one large wetland complex. (WC2)
- Due to the drain to the north of the stockpile area there is a changed wetland section bounded by the drain, stockpile area and office/loading area. This consists of wetland Q, an EPP wetland, and a section of wetland B. (WC3)
- Wetlands R, A and C make up a complex. (WC4)
- Wetlands J, H, S and remainder of B. This complex includes sumplands as well as palusplains. (WC5)
- Wetland K is unique in this area as it was the only area where clay soils and floodplain were recorded. Although this area is to the north of the proposed conservation area it is recommended that it be included in the conservation area. Wetland G on the western side is also a part of this wetland complex. (WC6)
- Wetland U is a small portion of a larger wetland south of the current approved conservation area west of the Muchea limestone area. (WC7)
- Wetland M and N together with other wetlands not surveyed to the east of the project area. (WC8)
- Wetland L is a small wetland surrounded by a pine plantation so is for this report considered as a separate wetland. (WC9)
- Wetland T is a section of a much larger wetland extending beyond this survey to the east but will for this report be considered as a separate wetland. (WC10)

Table 4. Wetland Assessments using Environmental Protection Authority (1993)

Wetland	Attributes Score		Category (EPA)	Management Category
	Natural	Human		
WC1	41	7	C - Conservation	C - Conservation
WC2	49	7	C - Conservation	C - Conservation
WC3	41	6	C - Conservation	C - Conservation
WC4	38	6	C - Conservation	C - Conservation
WC5	44	8	C - Conservation	C - Conservation
WC6	46	7	C - Conservation	C - Conservation
WC7	38	5	C - Conservation	C - Conservation
WC8	44	7	C - Conservation	C - Conservation
WC9	40	5	C - Conservation	C - Conservation
WC10	35	5	R - Resource enhancement	R – Resource enhancement

Considering all the above most of the wetlands complexes within the area surveyed, can be considered to be of Conservation category. This was also identified in 'Greater Bunbury Region Scheme – EPA Bulletin 1108' (Environmental Protection Authority, 2003).

4. DISCUSSION

Several botanical surveys have been undertaken of the Kemerton area, including Kemerton Silica Sand. However a detailed search specifically for Declared Rare and Priority Flora and assessment of the wetlands had not been undertaken previously. This current survey resulted in the following significant species being recorded.

- *Boronia juncea* subsp. *juncea* a Priority 1 species. This species occurred typically associated with *Astartea scoparia* or with other species where there was water on the surface during the September 2003 survey.
- *Boronia capitata* subsp. *gracilis* a Priority 2 species was only recorded along the powerline track that traverses the northern section from SW to NE. Previously this species had been recorded from an area to the east of this location but although a search was undertaken it was not relocated.
- *Acacia semitrullata* a Priority 3 species was common in the higher ground associated with *Kunzea glabrescens*, *Banksia ilicifolia*, *Banksia attenuata* and/or *Eucalyptus marginata* subsp. *marginata*.
- *Eucalyptus rudis* subsp. *cratyantha* a Priority 3 species was the only subspecies of *Eucalyptus rudis* recorded during the survey. It occurred as individual trees but more commonly as a clump of a few to stands of several trees with a dense canopy.
- *Dillwynia dillwynioides* a Priority 3 species was common in the damp areas where water was on the surface in the September and October surveys but where it was drier in November.
- *Acacia flagelliformis* a Priority 4 species was only recorded in the southern section of the survey area but was common where it did occur. This species occurs in the drier soils on the edge of the wetland proper and is readily overlooked when not in flower.
- *Caladenia speciosa* a Priority 4 species was only recorded from 2 locations. Unless in flower this species is readily overlooked as the leaves are hairy, typical of many of the 'spider orchids'.
- *Jacksonia sparsa* a Priority 4 species was very common through the survey area in the higher ground. It is a spindly shrub up to 1.5m tall.
- *Evandra pauciflora* is a species restricted to the damplands of the Swan Coastal Plain. It was relatively common in the area occurring on the edge of the wetlands as scattered plants or as the dominant species.
- *Verticordia nitens* is a species at its most southern range extension. It was only located in the south eastern section of the survey area.

- *Banksia menziesii*, recorded by Mattiske Consulting Pty Ltd (2003), is a species at the southern most end of its distribution. One plant was sighted along the fence line at the south west of the property.

The wetlands present at the site were assessed by recording the different vegetation units present in each wetland. The wetlands varied between sumplands, damplands, floodplains and palusplains depending on the soil, shape and standing water. As the land had been grazed previously the vegetation condition was recorded as very good for most of the wetlands, some as good but none were degraded or completely degraded. Each of the wetlands was a complex of vegetation units and, apart from areas of *Melaleuca rhaphiophylla* or *Melaleuca viminea* in standing water during the September and October surveys, was impossible to detail map from an aerial photograph. Each wetland was therefore allocated a letter and the vegetation units present in each described.

The wetland suites, a combination of one or more of the wetlands, were assessed using the questionnaire in 'A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area – EPA Bulletin 686' (Environmental Protection Authority, 1993). This resulted in all being classified as Conservation (Environmental Protection Authority, 1993 and Water and Rivers Commission, 2001). This indicates that the wetlands at the site are of conservation importance although there is an area in wetland suite WC3 which already has infrastructures, including a drain at the wetland. Wetland Suite WC3 also includes EPP wetland 4.

The Environmental Protection Authority (2002) provides selection criteria for the identification of regionally significant natural areas on the southern Swan Coastal Plain. Below the different selection criteria are listed and related to the area of Kemerton Silica Sand:

- Retain at least 30% of the pre-clearing extent of the ecological communities – Bassendean Complex – Central and South, 27% remains;
- Size and shape – a large area is preferable to a small one the lower size limit being 20ha – area is in excess of 20ha;
- Vegetation condition – the vegetation is recorded as vegetation condition 3, very good, due to the area having been grazed previously;
- Uplands and wetlands – natural areas supporting both ecological community groups support the highest diversity, apparent at Kemerton Silica Sand;
- Relationship to other areas – importance for linkage corridors is given the highest priority, forms an important link with the Spearwood system to the west and the Guildford system to the east;
- Ownership – publically preferred lands are preferred to privately owned land – Kemerton Silica Sand is privately owned.

Careful consideration will therefore need to be given to any proposed development and a management plan prepared to ensure that the remnant and conservation wetlands are not compromised with any proposed development. Areas for development will need to be considered in conjunction with the fauna survey and any water research undertaken for the site.

5. SURVEY TEAM

Three qualified botanists undertook the survey, Dr Eleanor Bennett of Bennett Environmental Consulting Pty Ltd., Ms Cate Tauss of Catherine Tauss Botanist and Ms Kirsty Stratford and Ms Kate George of Martinick Bosch Sell Pty Ltd. Dr Bennett identified the plants and wrote the report.

6. ACKNOWLEDGEMENTS

Mr Paul Wilson is thanked for his comments on the *Boronia* species, Mr Leigh Sage for information on *Goodenia filifolia* and Mr Andrew Brown for confirming the identification of the orchid species.

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APPENDIX A

Location of transects

MBS Environmental
KEMERTON SILICA SAND

LOCATION OF TRANSECTS

BENNETT ENVIRONMENTAL CONSULTING

Figure 4

Drawn: EB Date: 06/04

PINPOINT CARTOGRAPHICS (08) 9277 7763

bec-09-f04.dgn

Sun 20 Jun

APPENDIX B

Location of Declared Rare and Priority Flora

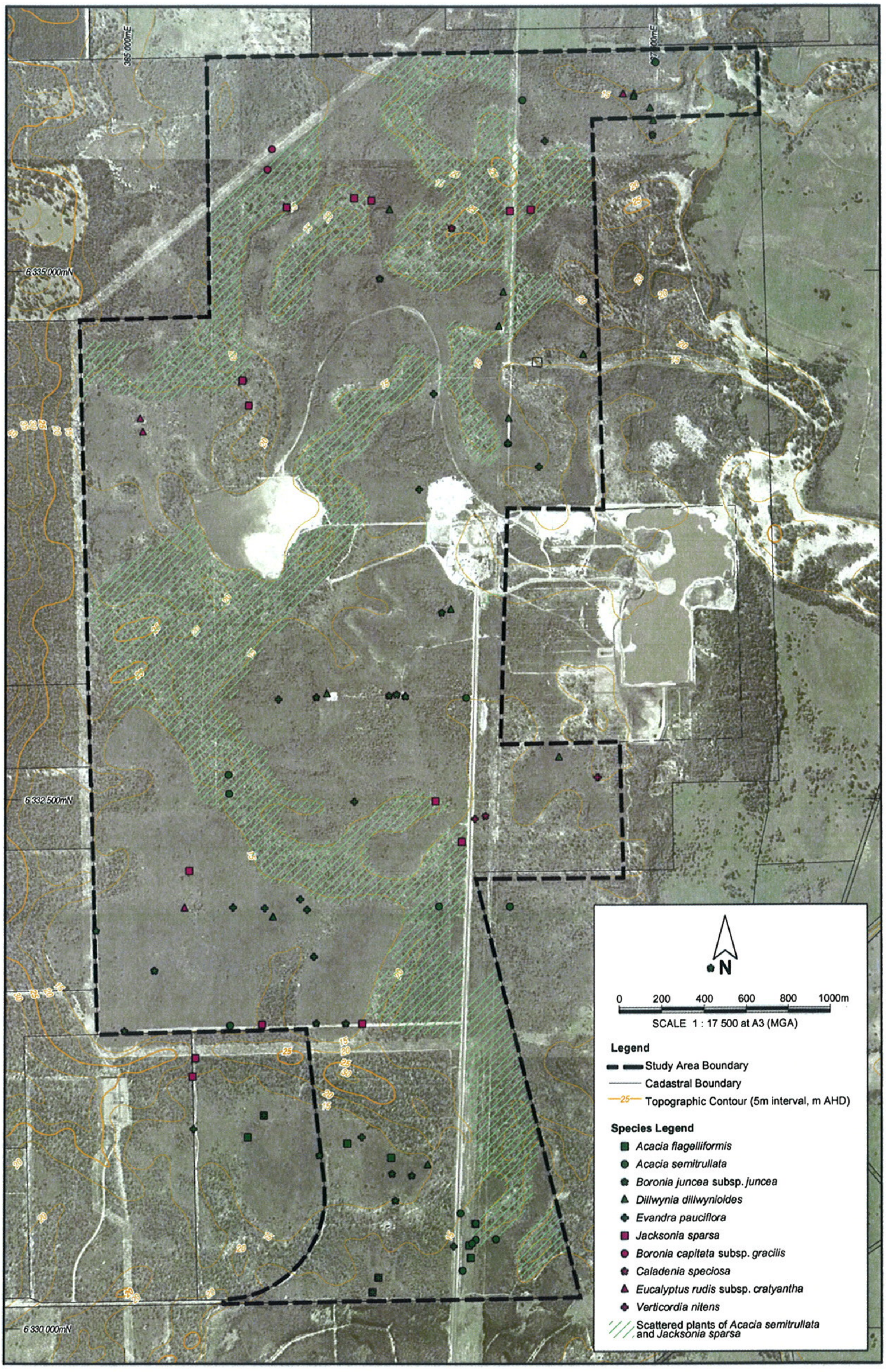
1: Field information
2: Map of locations

SPECIES	NO. PLANTS	NORTHING	EASTING	FIELD NOTES - VEGETATION
Acacia flagelliformis	9+			
Acacia flagelliformis	Ca 50	6330877	386053	*Pericalymma ellipticum* shrubland
Acacia flagelliformis	2	6330175	386172	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Acacia flagelliformis	6+	6330243	386200	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Acacia flagelliformis	1	6330337	386635	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	4	6330395	386627	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	5	6330498	386657	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia flagelliformis	2	6330810	386257	*Pericalymma ellipticum, Hypocalymma angustifolium*
Acacia flagelliformis	100	6330907	385581	*Pericalymma ellipticum* wetland
Acacia flagelliformis	100+	6331009	385658	Edge of *Pericalymma ellipticum* wetland
Acacia semitrullata	100++			*Kunzea glabrescens, Banksia ilicifolia* Woodland
Acacia semitrullata	50+			*Kunzea glabrescens* over *Hypocalymma angustifolium*
Acacia semitrullata	2	6330276	386597	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330403	386641	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	1	6330421	386659	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330423	386755	Area burnt - *Kunzea glabrescens, Corymbia calophylla, Melaleuca preissiana*
Acacia semitrullata	2	6330498	386657	*Hypocalymma angustifolium, Kunzea glabrescens*
Acacia semitrullata	8	6330546	386586	Regrowth *Kunzea glabrescens*
Acacia semitrullata	common	6331193	385316	*Eucalyptus marginata, Banksia attenuata* woodland
Acacia semitrullata	3	6331280	385331	*Eucalyptus marginata, Banksia attenuata* woodland
Acacia semitrullata	3	6331433	385496	Wetland edge
Acacia semitrullata	scattered	6331996	386819	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Acacia semitrullata	5	6331997	386482	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Acacia semitrullata	5	6332528	385490	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata* over *Dasypogon bromeliifolius*
Acacia semitrullata	scattered thro	6332618	385486	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata* over *Dasypogon bromeliifolius*
Acacia semitrullata	3	6332982	386610	*Melaleuca preissiana, Hypocalymma angustifolium*
Acacia semitrullata	10	6334365	385580	*Eucalyptus marginata, Banksia attenuata, Kunzea glabrescens*
Acacia semitrullata	2	6334483	385550	*Eucalyptus marginata, Kunzea glabrescens*, few *Banksia ilicifolia*
Acacia semitrullata	5	6334483	385555	*Eucalyptus marginata, Kunzea glabrescens*
Acacia semitrullata	20	6335304	385761	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata*
Acacia semitrullata	20	6335349	386078	*Kunzea glabrescens, Banksia attenuata* over *Calytrix fraseri*
Acacia semitrullata	1	6335813	386878	*Kunzea glabrescens* over *Hypocalymma angustifolium*
Acacia semitrullata	scattered	6335991	387510	*Kunzea glabrescens, Corymbia calophylla*
Acacia semitrullata	20+	High ground D2		
Boronia capitata subsp. *gracilis*	1	6335484	385670	*Kunzea glabrescens* thicket

Boronia capitata subsp. *gracilis*	1000++	6335580	385691	Powerline NE-SW in with *Euchilops linearis* and *Hypocalymma angustifolium*
Boronia juncea subsp. *juncea*	50+	6332991	386245	*Melaleuca rhaphiophylla, Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	50+	6330733	386262	*Astartea scoparia* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	10	6332987	386321	*Pericalymma ellipticum* shrubland
Boronia juncea subsp. *juncea*	50+	6330724	386355	*Astartea scoparia* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	Ca 70	6333384	386494	*Melaleuca rhaphiophylla* over *Lepidosperma longitudinale*
Boronia juncea subsp. *juncea*	20	6335646	387495	*Astartea scoparia* shrubland
Boronia juncea subsp. *juncea*	20+			*Hypocalymma angustifolium, Hypolaena exsulca*
Boronia juncea subsp. *juncea*	20+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath over *Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	4+			*Astartea scoparia, Hakea varia* closed heath
Boronia juncea subsp. *juncea*	scattered			*Astartea scoparia, Pericalymma ellipticum, Meeboldina coangustata, M. tephrina*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* heath with *Melaleuca lateritia*
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* closed heath
Boronia juncea subsp. *juncea*	100+			*Astartea scoparia* heath
Boronia juncea subsp. *juncea*	100+	6330606	386278	*Astartea scoparia, Calothamnus lateralis*, sparse *Melaleuca viminea, M. teretifolia, M. lateritia*, M. pre
Boronia juncea subsp. *juncea*	100+	6330820	385923	
Boronia juncea subsp. *juncea*	100	6331406	384993	Wetland edge
Boronia juncea subsp. *juncea*	10+	6331442	386044	Wetland edge
Boronia juncea subsp. *juncea*	30	6331443	385906	Wetland edge
Boronia juncea subsp. *juncea*	5	6331692	385134	*Astartea scoparia, Pericalymma ellipticum* closed heath
Boronia juncea subsp. *juncea*	ca 50	6331702	387762	*Astartea scoparia, Pericalymma ellipticum* closed heath
Boronia juncea subsp. *juncea*	ca 20	6331880	384858	*Astartea scoparia* thicket
Boronia juncea subsp. *juncea*	100+	6332983	385905	*Pericalymma ellipticum, Astartea scoparia, Meeboldina coangustata* wet area
Boronia juncea subsp. *juncea*	100++	6332997	386280	*Melaleuca lateritia*
Boronia juncea subsp. *juncea*	10	6334185	386809	*Astartea scoparia, Meeboldina coangustata* wetland
Boronia juncea subsp. *juncea*	100+	6334965	386199	*Astartea scoparia, Meeboldina coangustata* wetland
Boronia juncea subsp. *juncea*	Ca 25	Wetland N		
Caladenia speciosa	2	6332423	386703	*Banksia ilicifolia, Banksia attenuata, Eucalyptus marginata, Melaleuca thymoides, Stirlingia latifolia*
Caladenia speciosa	1	6335205	386540	*Kunzea glabrescens, Banksia attenuata* and Jarrah community
Dillwynia dillwynioides	1			*Astartea scoparia, Pericalymma ellipticum* heath
Dillwynia dillwynioides	2			Very low *Pericalymma ellipticum* heath with *Hakea varia* - waterlogged
Dillwynia dillwynioides	50	6332997	385954	Edge of wetland
Dillwynia dillwynioides	Ca 20	6332987	386321	*Pericalymma ellipticum* shrubland
Dillwynia dillwynioides	Ca 40	6330774	386430	*Astartea scoparia* over *Lepidosperma longitudinale*

Dillwynia dillwynioides	Ca 50	6333398	386537	*Melaleuca preissiana* over *Pericalymma ellipticum*
Dillwynia dillwynioides	Ca20	6334737	386766	*Astartea scoparia, Pericalymma ellipticum* wetland
Dillwynia dillwynioides	1	6334899	386787	*Astartea scoparia* thicket
Dillwynia dillwynioides	5	6334301	386812	*Astartea scoparia, Pericalymma ellipticum* wetland
Dillwynia dillwynioides	10	6334603	387164	*Astartea scoparia* thicket
Dillwynia dillwynioides	10+	6335290	386245	
Dillwynia dillwynioides	10 plants	6335827	387405	*Melaleuca cuticularis* thicket
Dillwynia dillwynioides	100+	6331944	385700	*Calothamnus lateralis, Astartea scoparia* wet area
Dillwynia dillwynioides	20	6332699	387050	*Astartea scoparia* over *Lepidosperma longitudinale*
Dillwynia dillwynioides	5	6332998	385948	On edge of dam
Dillwynia dillwynioides	3	6334185	386809	*Astartea scoparia, Meeboldina coangustata* wetland
Dillwynia dillwynioides	3	6335840	387407	*Kunzea glabrescens* shrubland
Dillwynia dillwynioides	Ca 50	6335772	387483	*Astartea scoparia, Melaleuca viminea* shrubland
Dillwynia dillywnioides	20	6335711	387498	*Kunzea glabrescens* thicket
Dillwynia dillywnioides		Wetland D2		
Dillwynia dillywnioides		Between wetlands D and E		
Dillwynia dillwynioides	100++	Wetland P		
Dillwynia dillwynioides	50+	Wetland U		
Eucalyptus rudis subsp. *cratyantha*	100+			*Melaleuca preissiana, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	10	6331986	385278	*Eucalyptus rudis, Banksia ilicifolia, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	11	6334236	385076	Wetland fringe
Eucalyptus rudis subsp. *cratyantha*	6	6334300	385063	*Eucalyptus rudis, Melaleuca preissiana, Hypocalymma angustifolium*
Eucalyptus rudis subsp. *cratyantha*	15	6335839	387355	*Eucalyptus rudis, Melaleuca rhaphiophylla*
Evandra pauciflora	ca 20			*Hypocalymma angustifolium, Hypolaena exsulca*
Evandra pauciflora	50+			*Hypocalymma angustifolium, Pericalymma ellipticum* heath
Evandra pauciflora	Ca 20	6330907	386119	*Pericalymma ellipticum* shrubland
Evandra pauciflora	50+	6330390	386555	Edge of road
Evandra pauciflora	Many	6330175	386172	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Evandra pauciflora	many	6330243	386200	*Pericalymma ellipticum, Hypocalymma angustifolium, Evandra pauciflora*
Evandra pauciflora	2	6330944	385322	Edge of *Pericalymma ellipticum* wetland
Evandra pauciflora	100+++	6331009	385658	Edge of *Pericalymma ellipticum* wetland
Evandra pauciflora	2	6331759	385895	*Pericalymma ellipticum* wetland
Evandra pauciflora	50+	6331981	385861	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	100+	6331988	385660	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	100+	6331991	385509	*Hypocalymma angustifolium, Adenanthos meisneri, Kunzea glabrescens*
Evandra pauciflora	ca 50	6332030	385829	Wetland edge

Evandra pauciflora	50+	6332974	385725	*Pericalymma ellipticum, Xanthorrhoea brunonis* wetland
Evandra pauciflora	>>1000	6332491	386082	Wetland edge
Evandra pauciflora	50+	6333967	386385	*Pericalymma ellipticum, Hypocalymma angustifolium*
Evandra pauciflora	100+	6334074	386955	
Evandra pauciflora	50+	6334185	386809	*Astartea* scoparia, *Meeboldina coangustata* wetland
Evandra pauciflora	20	6334420	386454	*Hypocalymma angustifolium, Pericalymma ellipticum*
Evandra pauciflora	2	6335618	386983	*Kunzea glabrescens* over *Hypocalymma angustifolium*
Evandra pauciflora	100+	Wetland F		
Evandra pauciflora	100+	Wetland D2		
Evandra pauciflora	100+	Wetland P		
Jacksonia sparsa	common	6331193	385316	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	ca 50	6331280	385331	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	common	6331438	385648	*Eucalyptus marginata, Banksia attenuata* woodland
Jacksonia sparsa	5	6331443	386120	*Banksia ilicifolia* wetland interzone
Jacksonia sparsa	common	6332165	385300	*Banksia ilicifolia* and *Kunzea glabrescens* Shrubland
Jacksonia sparsa	100++	6332303	386590	*Banksia attenuata, Eucalyptus marginata* Woodland
Jacksonia sparsa	20	6332494	386465	*Kunzea glabrescens* thicket
Jacksonia sparsa	common	6334365	385580	*Eucalyptus marginata, Banksia attenuata, Kunzea glabrescens*
Jacksonia sparsa	10	6334483	385550	*Eucalyptus marginata, Kunzea glabrescens*, few *Banksia ilicifolia*
Jacksonia sparsa	common	6335287	386819	Regrowth *Kunzea glabrescens*
Jacksonia sparsa	common	6335293	386917	Regrowth *Kunzea glabrescens*
Jacksonia sparsa	100++	6335304	385761	*Kunzea glabrescens, Banksia ilicifolia, Eucalyptus marginata*
Jacksonia sparsa	common	6335338	386159	*Kunzea glabrescens* thicket
Jacksonia sparsa	many	6335349	386078	*Kunzea glabrescens, Banksia attenuata* over *Calytrix fraseri*
Jacksonia sparsa	many	Wetland D2		
Jacksonia sparsa	many	Wetland S		
Jacksonia sparsa	many	Wetland U		
Verticordia nitens	20+	6332410	386652	*Eucalyptus marginata, Banksia ilicifolia, Melaleuca thymoides, Calytrix fraseri*
Verticordia nitens	100+	6332606	387230	*Banksia ilicifolia, Banksia attenuata, Eucalyptus marginata, Melaleuca thymoides*
Verticordia nitens	100++	6332606	387235	*Banksia ilicifolia, Banksia attenuata* over *Melaleuca thymoides*



MBS Environmental
KEMERTON SILICA SAND

LOCATIONS OF PRIORITY SPECIES

BENNETT ENVIRONMENTAL CONSULTING

Drawn: EB

Figure 2

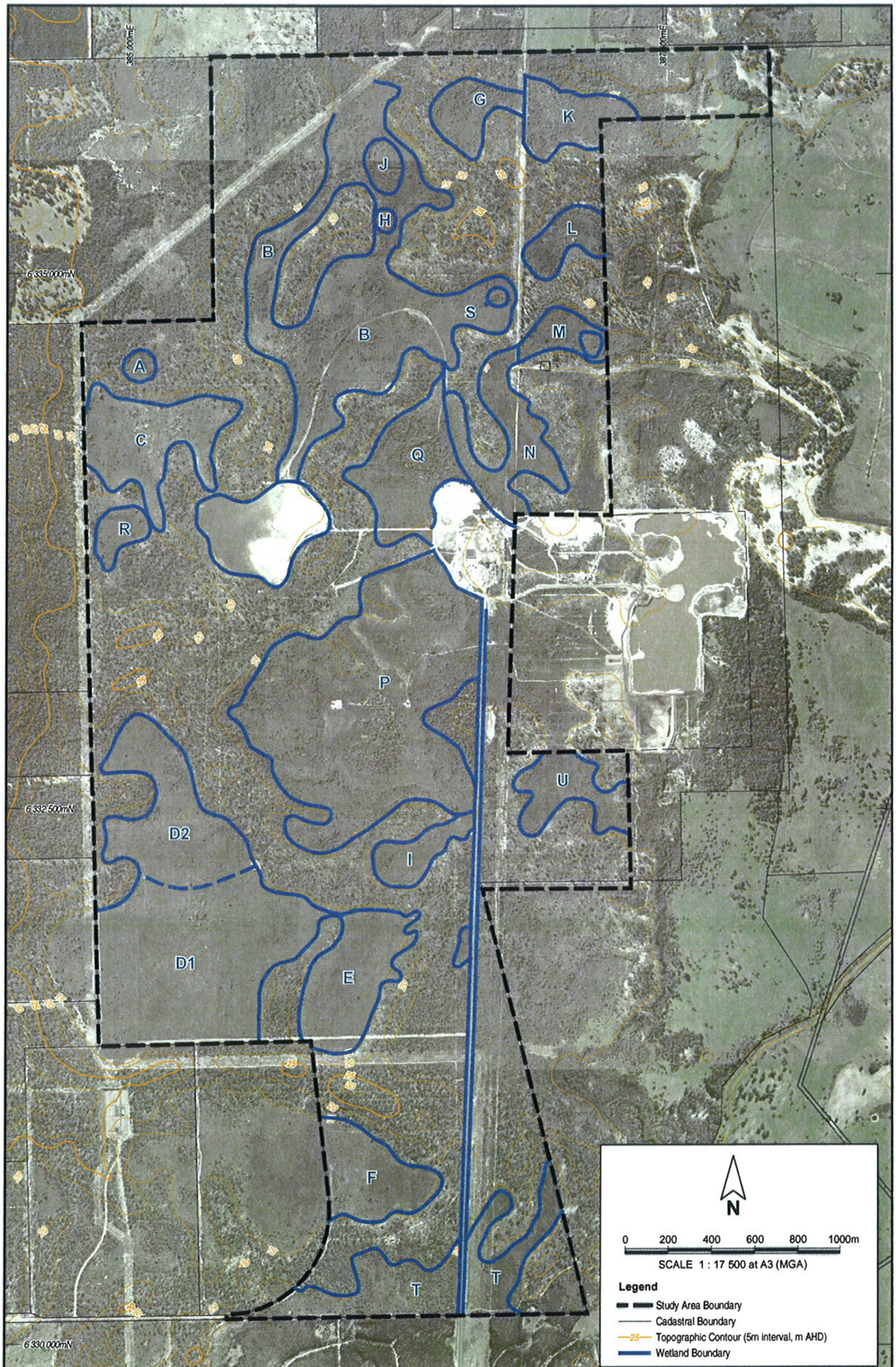
Date: 02/04

APPENDIX C

Wetland Locations

Map 1: Wetland locations
Map 2: Wetland complexes

PINPOINT CARTOGRAPHICS (08) 9277 7763 bec-09-f01.dgn Sun 20 Jun



MBS Environmental
KEMERTON SILICA SAND

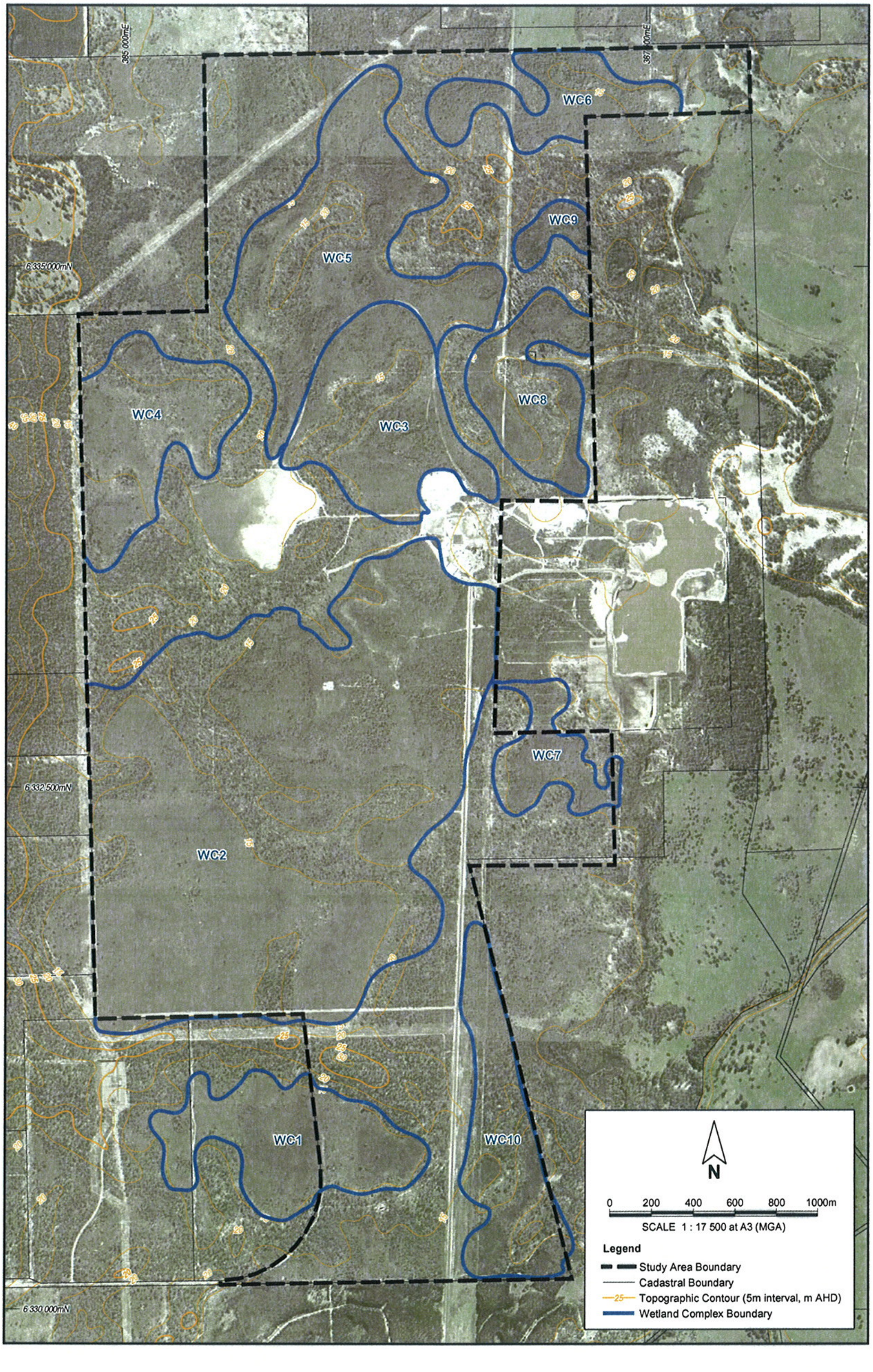
LOCATION OF WETLANDS

BENNETT ENVIRONMENTAL CONSULTING

Drawn: EB

Figure 1

Date: 06/04



MBS Environmental
KEMERTON SILICA SAND

WETLAND COMPLEXES

BENNETT ENVIRONMENTAL CONSULTING

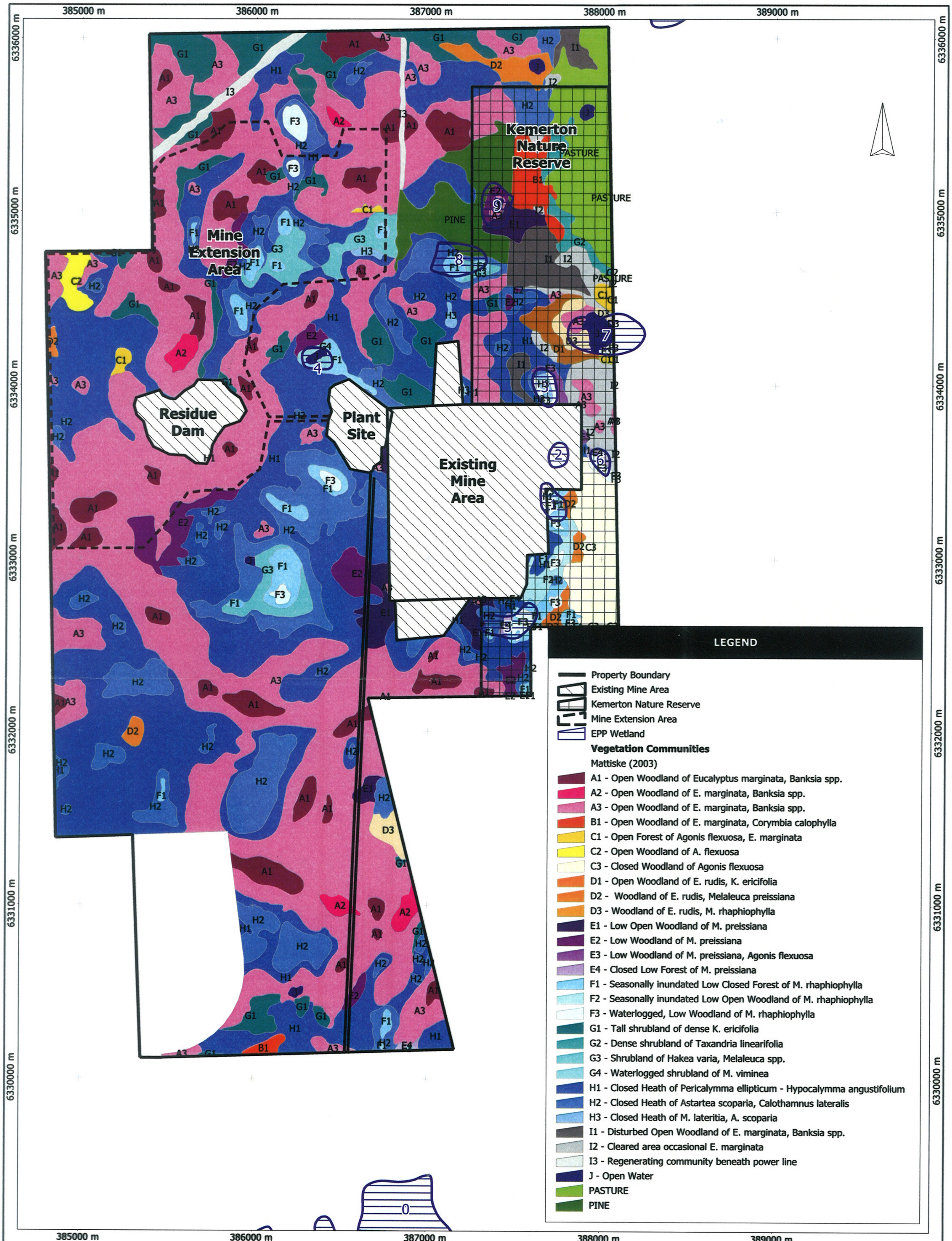
Drawn: EB

Figure 3

Date: 02/04

APPENDIX D

Wetland Assessment



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Scale: 1:30,000
Original Size: A3
Grid: Australia GDA94 (50)

0 500 m

Kemerton Silica Sand Pty Ltd

Vegetation Communities within Kemerton Silica Sand

Figure 12

W:\Kemerton Silica Sand\Drawings\Maps 2009\Flora and Wetlands.map 18/02/2009 Veg Communities Layout

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UPDATED REVIEW OF VEGETATION COMMUNITIES - KEMERTON SILICA SAND PTY LTD

This brief report provides an updated assessment of the plant communities at the Kemerton Silica Sand Pty Ltd (KSS) property in relation to the Threatened Ecological Communities and the Priority Ecological Communities.

The initial mapping project was undertaken in 1993 by qualified botanists on a grid system. The area was assessed along east-west grid lines spaced 250 metres apart. Regular recordings were taken along these gridlines. The location of the recordings along the gridlines was based on the variation in the communities, but tended to be between 50m and 150m apart. At each recording site the trees were recorded in a 20m radius and understorey in a 5m radius.

The vegetation was mapped at a detailed level by E.M.Mattiske and Associates (1993a,b,c, d) which defined a total of 24 plant communities and 27 vegetation mapping units for the KSS survey area, with three of the mapping units comprising disturbed stages of plant communities (E.M. Mattiske and Associates 1993a; 1993b; 1993c; 1993d; Mattiske Consulting Pty Ltd 2002; 2003).

The similarities were calculated using both all species and only native species data. The Sorenson Index of Similarity is based on qualitative (Presence/absence) data:

$$ISs = \frac{2a}{2a + b + c}$$

Where:

a =	number of species common to both sites
b =	number of species found in the first site only
c =	number of species found in the second site only

The species by site data was analysed utilising the association measures (Austin and Belbin 1982, Belbin 1995) and flexible UPGMA technique with the PATN program (Blatant Fabrications Pty Ltd 2006). The PATN clustering analysis (Belbin 1995) on all species by sites and native species by sites, see Tables 3 and 4.

$$D = \square\, [D_{ik} - D_{jk}] \,/\, \square\, \{D_{ik} + D_{jk}\}$$

The attached Tables and the Dendrograms indicate that there are very low similarities between the communities as defined by Mattiske in the previous mapping. This is a pattern repeated and appears to relate to the continuum nature of many species across the landscape and the need to rely on presence/absence data only (rather than quantitative and structural dominance).

The Sorenson Similarity analysis reflected very low similarities (less than 0.4 in most cases) and the latter is supported by the lack of Mattiske mapping units clustering with those of Gibson et al. (1994). In the analysis of the native species only the majority of the Mattiske sites did not cluster with the Gibson sites, with the exception of F3 with 14, F2 with 18 and 13 and G4 with 12. The latter in part results from the presence of species that prefer wetter or moister sites on low lying depressions. In the analysis of all species, C1, C3, D1 and G2 were clustered broadly with 14 and D3 was clustered broadly with 15, 12, 13, 18, 16, 17 and 19. These once again reflect the presence of species that prefer wetter or moister sites on low lying depressions or swales.

Therefore it appears that the analyses as undertaken indicate a lack of similarity. Therefore comparisons are based on more subjective interpretations of the dominant species, the general descriptions of the communities and the site/landform considerations. The latter is not surprising as there may be differences in survey techniques. The latter more subjective approach leaves interpretation open to mis-leading summaries on relationships. This was indicated in the 2003 report (see Table 3 and associated text of Mattiske Consulting Pty Ltd 2003). At this stage it was noted that there were some similarities between the communities but are not necessarily direct comparability.

The differences noted during the previous assessments was based on comparisons on dominant species, rather than structural components and in view of the lack of quantitative data it is not surprising that there was some confusion in the various interpretations. The Sorensons Similarity Index and the clustering techniques have been used on a variety of projects with little success and the latter may in part reflect the continuum nature of the communities (with species occurring in a range of environments and the determinant factors in their distributions differing across the Coastal Plain. Therefore there is a need to be subjective in its interpretation and this then leads to different opinions placed on the significance of floristics, dominance, indicator species and structure. Hence the confusion that occurs in these interpretations.

In relation to the potential for the Muchea Limestone community, this matter has always been one of debate between the various parties and whilst the *Eucalyptus decipiens* was recorded in the reserve area (south east of any proposed disturbance), it should also be noted that the communities in this area are not reliant on this one species for definition and that previous reports (Mattiske Consulting Pty Ltd 2003) have indicated that this species is relatively widespread (based on Florabase, Department of Environment and Conservation 2009). Keighery (1998) reported that the project area also contains *Eucalyptus decipiens* Closed Tree Mallee populations associated with Muchea Limestone communities within plant communities D2, F1 and F3. Based on interpretations from geological records limestone was not recorded within these areas at Kemerton and therefore the issue of whether the *Eucalyptus decipiens* reflects a particular community or not is still open to interpretation. After reviewing the distribution of this mallee species on FloraBase it appears that although it is associated with the limestone it is not confined to these Muchea limestone areas.

In conclusion, it appears that there is little evidence to indicate a strong similarity with the Gibson *et al.* (1994) communities as defined utilizing the Sorenson's Similarity Index or the PATN analyses (Belbin 1995). The presence of some dominant species or species that reflect seasonal swamps do not necessarily indicate a presence of the respective TEC or PEC's. Therefore there is some subjectivity on this matter and it really relies on the significance of the remnant areas within the Kemerton area.

Heterogeneity (vegetation sites) sites uncontrolled
(size, spatial arrangement = subjective)

Mattiske Vegetation Community	Comparison with Floristic Community Type			Comments
	Mattiske comparison with Gibson 2009	EPASU comments to Draft PER	TEC/PEC status	
A1	21a			Some similarity with dominants
A2	21a			Some similarity with dominants
A3	21a			Some similarity with dominants
B1		1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain
C1		21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra Plain
C2		21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra Plain
C3	11	1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain, some overlap with dominants
D1	11			Some similarity with dominants
D2	4	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants, question over significance
D3	12			Some similarity with dominants
E1	4			Some similarity with dominants
E2	4			Some similarity with dominants
E3	4			Some similarity with dominants
E4	4			Some similarity with dominants
F1	12	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants
F2		7	TEC Vulnerable	7 on Pinjarra Plain, some similarity with dominants
F3	13	Muchea Limestone	TEC Endangered State & Federal	7 on Pinjarra Plain, 13 due to dominance of Melaleuca
G1	5/11			Differences based on dominance of shrubs or tree species
G2	5/11			Differences based on dominance of shrubs or tree species
G3	5/13			Differences based on dominance of shrubs or tree species
G4		7	TEC Vulnerable	7 on Pinjarra Plain
H1	5/11			Differences based on dominance of shrubs or tree species
H2	5/11			Differences based on dominance of shrubs or tree species
H3	5/12			Some similarities with 5 and 12 based on dominants only
I1	21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge Hill/Pinjarra Plain
I2	21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge Hill/Pinjarra Plain
I3	Disturbed 21a			Disturbed and Degraded

Note: Only low similarities and unclear associations were observed in analyses and therefore the re has been variable interpretations on the PEC and TEC's. This largely relates to the reliance on different qualitative measures.

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Table 1: All Species Sorenson's Similarity

	A1	A2	A3	B1	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4	F1	F2	F3	G1	G2	G3	G4	H1	H2	H3	1a	1b	2	3a	3b	3c	4	5	6	7	8	9	10a	10b	11	12	13	14	15	16	17	18	19	20a	20b	20c	21a	21b	21c	22	23a	23b	24	25	26a	26b	27	28	29a	29b	30a	30b
A2	0.64
A3	0.66	0.49
B1	0.35	0.30	0.34
C1	0.34	0.20	0.09	0.12
C2	0.28	0.29	0.23	0.35	0.24
C3	0.24	0.23	0.18	0.27	0.20	0.24
D1	0.21	0.23	0.20	0.36	0.25	0.30	0.24
D2	0.25	0.20	0.28	0.32	0.14	0.25	0.38	0.29
D3	0.07	0.10	0.08	0.09	0.07	0.20	0.26	0.21	0.24
E1	0.40	0.38	0.35	0.58	0.09	0.31	0.19	0.36	0.37	0.24
E2	0.40	0.37	0.35	0.58	0.26	0.38	0.21	0.43	0.35	0.14	0.63
E3	0.05	0.04	0.10	0.13	0.00	0.14	0.16	0.07	0.18	0.32	0.20	0.14
E4	0.03	0.00	0.03	0.10	0.00	0.08	0.18	0.08	0.16	0.29	0.17	0.05	0.40
F1	0.12	0.13	0.20	0.22	0.03	0.12	0.16	0.18	0.45	0.19	0.31	0.25	0.20	0.21
F2	0.05	0.04	0.06	0.04	0.00	0.07	0.16	0.07	0.24	0.16	0.10	0.05	0.25	0.20	0.33
F3	0.03	0.04	0.03	0.10	0.00	0.17	0.06	0.09	0.13	0.20	0.11	0.11	0.32	0.40	0.14	0.32
G1	0.60	0.54	0.59	0.45	0.14	0.30	0.30	0.28	0.39	0.15	0.49	0.46	0.10	0.10	0.24	0.07	0.05
G2	0.19	0.16	0.16	0.36	0.25	0.12	0.34	0.38	0.14	0.14	0.27	0.26	0.29	0.33	0.09	0.07	0.09	0.19
G3	0.05	0.06	0.16	0.19	0.00	0.17	0.23	0.18	0.39	0.19	0.35	0.29	0.27	0.23	0.39	0.27	0.24	0.23	0.06
G4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.15	0.25	0.00	0.00	0.11
H1	0.42	0.31	0.41	0.36	0.10	0.18	0.26	0.20	0.46	0.21	0.41	0.42	0.11	0.11	0.29	0.08	0.09	0.47	0.20	0.25	0.00
H2	0.16	0.20	0.19	0.25	0.03	0.19	0.20	0.19	0.46	0.20	0.32	0.26	0.17	0.22	0.38	0.10	0.12	0.35	0.13	0.38	0.04	0.37
H3	0.05	0.07	0.08	0.33	0.00	0.19	0.21	0.07	0.29	0.22	0.24	0.18	0.46	0.55	0.32	0.23	0.38	0.14	0.13	0.44	0.13	0.20	0.40
1a	0.25	0.24	0.33	0.19	0.07	0.10	0.11	0.07	0.12	0.06	0.15	0.12	0.04	0.02	0.08	0.00	0.00	0.28	0.10	0.04	0.00	0.22	0.11	0.01
1b	0.27	0.26	0.32	0.21	0.08	0.11	0.14	0.11	0.16	0.07	0.15	0.14	0.05	0.01	0.10	0.00	0.00	0.29	0.09	0.07	0.00	0.23	0.13	0.03	0.75
2	0.12	0.14	0.21	0.23	0.02	0.08	0.11	0.10	0.19	0.06	0.20	0.16	0.07	0.05	0.20	0.02	0.02	0.21	0.08	0.12	0.00	0.23	0.22	0.09	0.50	0.54
3a	0.19	0.16	0.28	0.19	0.07	0.06	0.10	0.08	0.13	0.04	0.12	0.14	0.06	0.03	0.15	0.01	0.01	0.22	0.10	0.07	0.02	0.23	0.16	0.07	0.55	0.56	0.56
3b	0.27	0.23	0.35	0.20	0.10	0.08	0.15	0.11	0.14	0.04	0.12	0.11	0.03	0.01	0.08	0.00	0.00	0.28	0.11	0.03	0.00	0.22	0.09	0.01	0.66	0.67	0.46	0.65
3c	0.14	0.11	0.21	0.18	0.07	0.05	0.11	0.10	0.11	0.05	0.09	0.10	0.05	0.02	0.12	0.02	0.00	0.17	0.08	0.03	0.00	0.18	0.12	0.03	0.48	0.51	0.43	0.66	0.65
4	0.29	0.24	0.37	0.28	0.09	0.14	0.16	0.15	0.24	0.09	0.28	0.20	0.08	0.05	0.16	0.03	0.03	0.36	0.14	0.13	0.00	0.32	0.19	0.09	0.49	0.58	0.52	0.58	0.62	0.48
5	0.24	0.17	0.35	0.21	0.04	0.12	0.15	0.13	0.24	0.05	0.17	0.16	0.07	0.06	0.20	0.09	0.06	0.34	0.09	0.16	0.07	0.29	0.19	0.13	0.44	0.45	0.46	0.57	0.56	0.52	0.63
6	0.22	0.15	0.27	0.22	0.04	0.10	0.16	0.14	0.19	0.08	0.18	0.15	0.08	0.06	0.15	0.06	0.06	0.26	0.10	0.10	0.02	0.22	0.15	0.10	0.34	0.33	0.33	0.51	0.44	0.49	0.49	0.56
7	0.08	0.03	0.19	0.11	0.05	0.02	0.08	0.05	0.13	0.07	0.08	0.08	0.02	0.06	0.20	0.11	0.04	0.12	0.11	0.08	0.02	0.20	0.13	0.13	0.25	0.26	0.33	0.48	0.42	0.52	0.45	0.63	0.52
8	0.08	0.04	0.16	0.12	0.04	0.03	0.10	0.09	0.15	0.06	0.08	0.09	0.06	0.05	0.13	0.06	0.02	0.15	0.07	0.07	0.07	0.20	0.15	0.08	0.37	0.41	0.46	0.64	0.51	0.64	0.48	0.58	0.52	0.69
9	0.11	0.08	0.23	0.13	0.03	0.08	0.15	0.10	0.20	0.06	0.20	0.14	0.13	0.09	0.24	0.08	0.04	0.24	0.14	0.20	0.02	0.24	0.26	0.16	0.40	0.41	0.55	0.55	0.40	0.46	0.50	0.55	0.41	0.59	0.60
10a	0.08	0.09	0.16	0.15	0.06	0.04	0.09	0.10	0.18	0.06	0.10	0.15	0.08	0.00	0.17	0.06	0.02	0.15	0.08	0.11	0.02	0.17	0.18	0.10	0.37	0.38	0.57	0.57	0.42	0.48	0.44	0.55	0.46	0.60	0.66	0.65
10b	0.16	0.17	0.20	0.20	0.05	0.08	0.15	0.11	0.12	0.07	0.15	0.13	0.07	0.02	0.13	0.02	0.02	0.24	0.08	0.08	0.00	0.21	0.18	0.07	0.45	0.51	0.63	0.60	0.51	0.56	0.56	0.57	0.45	0.53	0.62	0.58	0.62
11	0.18	0.17	0.32	0.22	0.10	0.07	0.16	0.16	0.23	0.12	0.19	0.18	0.11	0.09	0.30	0.13	0.07	0.25	0.16	0.15	0.02	0.27	0.22	0.14	0.33	0.37	0.38	0.47	0.43	0.47	0.46	0.60	0.46	0.58	0.51	0.47	0.41	0.44
12	0.09	0.11	0.17	0.15	0.06	0.03	0.11	0.13	0.22	0.17	0.19	0.16	0.14	0.07	0.27	0.14	0.15	0.17	0.16	0.22	0.04	0.23	0.24	0.23	0.20	0.18	0.22	0.25	0.21	0.21	0.37	0.40	0.33	0.42	0.32	0.34	0.36	0.35	0.44
13	0.03	0.02	0.15	0.14	0.03	0.06	0.14	0.12	0.23	0.16	0.13	0.13	0.20	0.11	0.24	0.13	0.11	0.15	0.09	0.24	0.04	0.20	0.25	0.25	0.15	0.21	0.29	0.29	0.15	0.26	0.25	0.39	0.31	0.46	0.38	0.48	0.41	0.35	0.40	0.40
14	0.11	0.09	0.12	0.19	0.17	0.11	0.18	0.34	0.16	0.13	0.17	0.20	0.13	0.22	0.18	0.19	0.23	0.14	0.23	0.11	0.00	0.16	0.09	0.18	0.07	0.09	0.08	0.11	0.15	0.20	0.18	0.21	0.19	0.17	0.15	0.14	0.07	0.11	0.25	0.15	0.26
15	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.08	0.09	0.06	0.08	0.19	0.02	0.00	0.00	0.00	0.04	0.07	0.07	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.04	0.08	0.14	0.05	0.04	0.06	0.05	0.16	0.27	0.22	0.06
16	0.00	0.00	0.03	0.00	0.11	0.00	0.00	0.00	0.05	0.06	0.00	0.00	0.06	0.07	0.11	0.18	0.14	0.00	0.00	0.10	0.09	0.02	0.03	0.11	0.00	0.01	0.02	0.07	0.04	0.06	0.06	0.10	0.17	0.25	0.11	0.08	0.09	0.05	0.23	0.18	0.17	0.10	0.33
17	0.00	0.00	0.04	0.03	0.12	0.08	0.13	0.04	0.20	0.24	0.06	0.06	0.17	0.09	0.21	0.17	0.05	0.06	0.08	0.15	0.00	0.13	0.12	0.16	0.05	0.04	0.05	0.09	0.05	0.10	0.09	0.16	0.16	0.25	0.18	0.18	0.16	0.13	0.31	0.27	0.38	0.22	0.20	0.41
18	0.06	0.07	0.13	0.05	0.07	0.00	0.12	0.07	0.17	0.15	0.12	0.08	0.08	0.04	0.20	0.19	0.04	0.11	0.11	0.10	0.05	0.16	0.12	0.11	0.17	0.13	0.18	0.23	0.14	0.25	0.19	0.28	0.19	0.33	0.32	0.28	0.26	0.23	0.34	0.26	0.31	0.17	0.07	0.16	0.29
19	0.02	0.03	0.07	0.03	0.16	0.04	0.07	0.04	0.11	0.09	0.06	0.06	0.04	0.05	0.14	0.13	0.00	0.06	0.04	0.08	0.00	0.07	0.08	0.04	0.05	0.06	0.05	0.09	0.08	0.13	0.08	0.09	0.13	0.18	0.20	0.10	0.13	0.11	0.27	0.10	0.17	0.11	0.08	0.32	0.43	0.30
20a	0.27	0.23	0.33	0.14	0.03	0.08	0.09	0.03	0.09	0.05	0.09	0.09	0.03	0.00	0.04	0.00	0.00	0.27	0.05	0.02	0.00	0.20	0.09	0.03	0.58	0.53	0.34	0.51	0.51	0.39	0.45	0.40	0.34	0.23	0.27	0.23	0.28	0.37	0.26	0.13	0.11	0.03	0.00	0.00	0.07	0.17	0.07
20b	0.27	0.23	0.32	0.18	0.04	0.07	0.11	0.06	0.09	0.03	0.10	0.08	0.01	0.01	0.05	0.00	0.00	0.27	0.07	0.01	0.00	0.20	0.08	0.01	0.63	0.63	0.37	0.57	0.67	0.51	0.51	0.41	0.44	0.28	0.37	0.29	0.27	0.38	0.28	0.13	0.08	0.08	0.00	0.04	0.05	0.12	0.04	0.68
20c	0.28	0.24	0.31	0.18	0.05	0.08	0.10	0.09	0.10	0.03	0.09	0.11	0.02	0.02	0.06	0.00	0.00	0.25	0.08	0.00	0.00	0.16	0.11	0.02	0.54	0.53	0.36	0.58	0.55	0.54	0.53	0.46	0.46	0.30	0.38	0.32	0.34	0.45	0.33	0.16	0.16	0.11	0.00	0.03	0.07	0.14	0.05	0.68	0.68
21a	0.31	0.24	0.41	0.19	0.09	0.11	0.13	0.10	0.18	0.07	0.17	0.14	0.04	0.02	0.10	0.03	0.01	0.34	0.09	0.07	0.00	0.27	0.13	0.03	0.62	0.64	0.37	0.56	0.67	0.53	0.62	0.56	0.49	0.37	0.46	0.37	0.33	0.43	0.47	0.23	0.18	0.13	0.03	0.08	0.15	0.25	0.17	0.63	0.67	0.62
21b	0.38	0.33	0.40	0.20	0.12	0.15	0.17	0.11	0.18	0.08	0.18	0.14	0.05	0.02	0.10	0.02	0.02	0.37	0.11	0.05	0.00	0.28	0.13	0.03	0.65	0.66	0.36	0.51	0.61	0.44	0.62	0.51	0.41	0.28	0.32	0.33	0.28	0.45	0.33	0.24	0.15	0.12	0.00	0.01	0.07	0.16	0.04	0.64	0.67	0.63	0.70
21c	0.37	0.30	0.42	0.24	0.08	0.14	0.17	0.15	0.17	0.06	0.19	0.17	0.03	0.03	0.10	0.01	0.03	0.40	0.11	0.08	0.00	0.29	0.14	0.03	0.50	0.53	0.34	0.55	0.58	0.50	0.66	0.61	0.54	0.38	0.43	0.36	0.33	0.48	0.47	0.23	0.22	0.17	0.01	0.08	0.11	0.16	0.12	0.62	0.61	0.69	0.71	0.66
22	0.29	0.23	0.37	0.22	0.00	0.16	0.11	0.14	0.17	0.04	0.19	0.17	0.02	0.02	0.10	0.02	0.04	0.36	0.04	0.13	0.00	0.28	0.14	0.04	0.43	0.43	0.40	0.42	0.42	0.30	0.58	0.55	0.42	0.26	0.28	0.32	0.32	0.34	0.34	0.23	0.22	0.13	0.00	0.04	0.08	0.16	0.07	0.54	0.43	0.48	0.50	0.54	0.58
23a	0.36	0.28	0.41	0.24	0.08	0.14	0.15	0.12	0.16	0.06	0.20	0.17	0.04	0.03	0.12	0.03	0.03	0.39	0.11	0.08	0.00	0.30	0.14	0.04	0.53	0.53	0.32	0.53	0.55	0.44	0.65	0.56	0.43	0.35	0.36	0.31	0.30	0.45	0.42	0.25	0.20	0.13	0.01	0.05	0.08	0.18	0.08	0.72	0.63	0.67	0.76	0.71	0.78	0.65
23b	0.34	0.26	0.36	0.18	0.03	0.10	0.12	0.08	0.12	0.05	0.15	0.10	0.03	0.00	0.05	0.00	0.00	0.35	0.06	0.03	0.00	0.23	0.12	0.03	0.48	0.45	0.29	0.47	0.45	0.35	0.51	0.67	0.41	0.24	0.25	0.26	0.25	0.35	0.29	0.19	0.15	0.06	0.00	0.02	0.06	0.12	0.06	0.74	0.60	0.64	0.66	0.65	0.67	0.70	0.79
24	0.27	0.23	0.33	0.13	0.11	0.07	0.12	0.07	0.10	0.04	0.09	0.12	0.03	0.00	0.07	0.01	0.00	0.23	0.09	0.02	0.00	0.21	0.07	0.03	0.42	0.44	0.23	0.45	0.52	0.44	0.45	0.46	0.41	0.34	0.39	0.24	0.28	0.36	0.42	0.15	0.18	0.15	0.03	0.11	0.21	0.23	0.31	0.53	0.44	0.52	0.68	0.52	0.57	0.38	0.60	0.53
25	0.23	0.18	0.29	0.16	0.13	0.07	0.15	0.10	0.09	0.05	0.12	0.12	0.03	0.03	0.08	0.02	0.00	0.23	0.13	0.03	0.00	0.20	0.06	0.03	0.41	0.42	0.18	0.35	0.52	0.46	0.44	0.42	0.39	0.38	0.37	0.27	0.22	0.31	0.49	0.17	0.17	0.16	0.04	0.13	0.22	0.26	0.25	0.43	0.41	0.42	0.65	0.47	0.53	0.29	0.53	0.40	0.71
26a	0.13	0.10	0.17	0.14	0.09	0.03	0.10	0.05	0.13	0.04	0.10	0.09	0.04	0.00	0.07	0.00	0.00	0.13	0.07	0.02	0.00	0.13	0.07	0.02	0.29	0.28	0.17	0.35	0.35	0.41	0.36	0.37	0.34	0.34	0.37	0.25	0.26	0.35	0.35	0.22	0.15	0.10	0.05	0.10	0.19	0.29	0.33	0.35	0.32	0.37	0.49	0.40	0.42	0.27	0.45	0.40	0.67	0.61
26b	0.23	0.19	0.78	0.21	0.10	0.06	0.10	0.06	0.13	0.05	0.08	0.09	0.01	0.00	0.06	0.01	0.00	0.23	0.06	0.03	0.00	0.17	0.06	0.03	0.42	0.42	0.22	0.44	0.48	0.45	0.40	0.45	0.40	0.34	0.38	0.27	0.27	0.35	0.41	0.19	0.17	0.13	0.04	0.07	0.19	0.28	0.25	0.49	0.43	0.50	0.67	0.51	0.55	0.33	0.56	0.49	0.79	0.70	0.72
27	0.16	0.14	0.18	0.10	0.02	0.05	0.09	0.05	0.08	0.02	0.08	0.08	0.00	0.00	0.02	0.00	0.00	0.15	0.02	0.00	0.00	0.12	0.04	0.00	0.31	0.31	0.19	0.33	0.34	0.28	0.27	0.27	0.23	0.16	0.24	0.16	0.17	0.25	0.23	0.11	0.09	0.07	0.00	0.00	0.08	0.22	0.22	0.38	0.33	0.30	0.40	0.40	0.34	0.29	0.37	0.36	0.53	0.44	0.61	0.56
28	0.27	0.20	0.34	0.15	0.07	0.08	0.09	0.09	0.12	0.04	0.11	0.12	0.02	0.01	0.09	0.02	0.01	0.27	0.08	0.03	0.00	0.23	0.09	0.02	0.52	0.52	0.30	0.57	0.60	0.53	0.53	0.53	0.46	0.34	0.43	0.30	0.31	0.41	0.43	0.17	0.15	0.13	0.02	0.07	0.14	0.20	0.17	0.66	0.65	0.67	0.80	0.63	0.70	0.50	0.75	0.69	0.74	0.64	0.55	0.70	0.43
29a	0.08	0.05	0.13	0.05	0.09	0.02	0.04	0.02	0.09	0.02	0.04	0.04	0.04	0.00	0.06	0.02	0.00	0.08	0.04	0.02	0.00	0.11	0.03	0.02	0.18	0.20	0.11	0.21	0.23	0.28	0.25	0.28	0.27	0.27	0.27	0.17	0.17	0.25	0.34	0.16	0.16	0.10	0.07	0.18	0.30	0.34	0.39	0.21	0.17	0.21	0.36	0.27	0.27	0.15	0.28	0.22	0.59	0.51	0.65	0.59	0.48	0.47
29b	0.11	0.05	0.16	0.03	0.10	0.04	0.06	0.04	0.10	0.04	0.06	0.05	0.02	0.00	0.05	0.02	0.00	0.07	0.04	0.02	0.00	0.11	0.03	0.02	0.20	0.19	0.07	0.23	0.26	0.27	0.25	0.29	0.30	0.26	0.23	0.18	0.19	0.22	0.31	0.13	0.15	0.14	0.04	0.12	0.24	0.25	0.33	0.25	0.21	0.25	0.42	0.26	0.29	0.18	0.32	0.28	0.62	0.55	0.70	0.63	0.52	0.46	0.72
30a	0.02	0.02	0.05	0.03	0.11	0.03	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.09	0.08	0.12	0.13	0.21	0.10	0.15	0.19	0.16	0.16	0.08	0.08	0.11	0.23	0.07	0.04	0.07	0.04	0.29	0.26	0.17	0.29	0.08	0.10	0.09	0.17	0.10	0.16	0.21	0.10	0.09	0.37	0.34	0.39	0.35	0.29	0.26	0.55	0.39
30b	0.05	0.05	0.13	0.04	0.12	0.05	0.07	0.00	0.05	0.05	0.04	0.02	0.05	0.00	0.05	0.00	0.00	0.04	0.02	0.02	0.00	0.08	0.02	0.03	0.17	0.20	0.11	0.19	0.23	0.29	0.25	0.26	0.25	0.25	0.25	0.18	0.13	0.22	0.35	0.14	0.14	0.07	0.05	0.16	0.34	0.25	0.34	0.16	0.14	0.17	0.33	0.24	0.26	0.13	0.22	0.19	0.52	0.59	0.54	0.52	0.32	0.37	0.64	0.56	0.51
30c	0.07	0.07	0.09	0.13	0.07	0.10	0.12	0.04	0.06	0.04	0.03	0.06	0.04	0.00	0.02	0.00	0.00	0.07	0.07	0.03	0.00	0.06	0.05	0.00	0.17	0.16	0.13	0.15	0.14	0.19	0.14	0.20	0.27	0.20	0.18	0.11	0.14	0.22	0.27	0.09	0.18	0.07	0.04	0.16	0.34	0.17	0.27	0.15	0.12	0.16	0.24	0.17	0.22	0.13	0.21	0.16	0.37	0.35	0.39	0.37	0.31	0.28	0.49	0.38	0.41	0.49

Table 2: Native Species Sorenson's Similarity

	A1	A2	A3	B1	C1	C2	C3	D1	D2	D3	E1	E2	E3	E4	F1	F2	F3	G1	G2	G3	G4	H1	H2	H3	1a	1b	2	3a	3b	3c	4	5	6	7	8	9	10a	10b	11	12	13	14	15	16	17	18	19	20a	20b	20c	21a	21b	21c	22	23a	23b	24	25	26a	26b	27	28	29a	29b	30a	30b
A2	0.64																																																																	
A3	0.67	0.50																																																																
B1	0.38	0.33	0.36																																																															
C1	0.13	0.19	0.09	0.16																																																														
C2	0.29	0.30	0.25	0.39	0.31																																																													
C3	0.23	0.22	0.16	0.24	0.21	0.27																																																												
D1	0.20	0.20	0.20	0.41	0.25	0.31	0.23																																																											
D2	0.76	0.71	0.29	0.33	0.17	0.26	0.39	0.30																																																										
D3	0.08	0.11	0.08	0.10	0.09	0.20	0.30	0.21	0.25																																																								
E1	0.41	0.39	0.36	0.64	0.11	0.32	0.21	0.38	0.38	0.25																																																							
E2	0.40	0.36	0.34	0.66	0.26	0.39	0.20	0.41	0.40	0.14	0.64																																																					
E3	0.05	0.04	0.09	0.10	0.00	0.14	0.13	0.08	0.19	0.33	0.21	0.15																																																				
E4	0.03	0.00	0.04	0.11	0.00	0.08	0.21	0.09	0.17	0.29	0.17	0.05	0.42																																																			
F1	0.13	0.13	0.20	0.24	0.04	0.13	0.18	0.20	0.48	0.21	0.33	0.24	0.21	0.23																																																	
F2	0.05	0.04	0.07	0.05	0.00	0.07	0.19	0.08	0.26	0.17	0.11	0.05	0.27	0.21	0.36																																																
F3	0.03	0.04	0.04	0.11	0.00	0.17	0.07	0.09	0.14	0.20	0.12	0.11	0.33	0.40	0.15	0.33																																															
G1	0.60	0.54	0.60	0.48	0.13	0.31	0.30	0.27	0.41	0.15	0.51	0.46	0.10	0.12	0.25	0.08	0.05																																														
G2	0.18	0.14	0.16	0.34	0.29	0.14	0.19	0.37	0.13	0.16	0.31	0.24	0.26	0.40	0.11	0.09	0.11	0.18																																													
G3	0.05	0.07	0.16	0.22	0.00	0.18	0.27	0.19	0.41	0.20	0.36	0.30	0.29	0.24	0.42	0.29	0.25	0.24	0.07																																												
G4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.17	0.25	0.00	0.00	0.11																																										
H1	0.42	0.31	0.40	0.37	0.09	0.19	0.24	0.19	0.48	0.22	0.44	0.41	0.13	0.12	0.29	0.09	0.09	0.48	0.38	0.77	0.00																																									
H2	0.17	0.21	0.20	0.28	0.04	0.20	0.23	0.21	0.47	0.22	0.35	0.28	0.19	0.24	0.41	0.11	0.12	0.37	0.15	0.41	0.05	0.38																																								
H3	0.05	0.07	0.08	0.14	0.00	0.19	0.24	0.07	0.31	0.22	0.24	0.19	0.48	0.55	0.34	0.24	0.38	0.15	0.15	0.45	0.13	0.22	0.43																																							
1a	0.20	0.23	0.19	0.19	0.19	0.12	0.08	0.13	0.07	0.04	0.13	0.23	0.00	0.00	0.05	0.00	0.00	0.22	0.09	0.04	0.00	0.13	0.05	0.00																																						
1b	0.12	0.13	0.13	0.13	0.07	0.17	0.05	0.00	0.00	0.00	0.09	0.03	0.00	0.00	0.03	0.00	0.00	0.14	0.00	0.00	0.00	0.02	0.03	0.00	0.24																																					
2	0.03	0.04	0.02	0.06	0.00	0.00	0.08	0.10	0.07	0.11	0.13	0.06	0.00	0.00	0.08	0.00	0.00	0.06	0.00	0.09	0.00	0.07	0.13	0.21	0.00	0.00																																				
3a	0.11	0.03	0.13	0.10	0.00	0.09	0.04	0.05	0.05	0.05	0.04	0.07	0.00	0.00	0.05	0.00	0.00	0.08	0.00	0.04	0.00	0.04	0.08	0.05	0.13	0.09	0.00																																			
3b	0.23	0.24	0.23	0.21	0.14	0.18	0.17	0.13	0.20	0.10	0.16	0.18	0.03	0.00	0.09	0.00	0.00	0.24	0.07	0.06	0.00	0.14	0.13	0.03	0.20	0.24	0.04	0.26																																		
3c	0.04	0.06	0.08	0.04	0.00	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.11	0.00	0.06	0.00	0.00	0.09	0.00	0.05	0.00	0.06	0.06	0.10	0.13	0.13	0.06	0.21	0.18																																	
4	0.17	0.14	0.16	0.28	0.11	0.22	0.04	0.32	0.20	0.10	0.32	0.21	0.05	0.05	0.16	0.05	0.06	0.23	0.10	0.17	0.00	0.22	0.20	0.09	0.29	0.17	0.06	0.17	0.15	0.18																																
5	0.11	0.06	0.13	0.04	0.07	0.05	0.05	0.06	0.03	0.00	0.04	0.04	0.00	0.07	0.06	0.06	0.07	0.14	0.00	0.05	0.09	0.06	0.10	0.11	0.11	0.10	0.00	0.28	0.17	0.17	0.16																															
6	0.23	0.17	0.23	0.17	0.00	0.21	0.17	0.18	0.13	0.08	0.21	0.32	0.08	0.13	0.07	0.04	0.09	0.24	0.12	0.07	0.00	0.14	0.12	0.11	0.03	0.03	0.00	0.17	0.07	0.12	0.20	0.13																														
7	0.00	0.00	0.06	0.00	0.00	0.00	0.05	0.00	0.11	0.13	0.09	0.00	0.13	0.15	0.16	0.20	0.00	0.05	0.06	0.11	0.00	0.06	0.10	0.18	0.04	0.05	0.00	0.08	0.00	0.13	0.08	0.15	0.10																													
8	0.02	0.03	0.07	0.07	0.00	0.00	0.00	0.00	0.10	0.00	0.04	0.03	0.00	0.00	0.05	0.10	0.05	0.04	0.00	0.04	0.06	0.07	0.06	0.05	0.16	0.04	0.00	0.20	0.13	0.11	0.20	0.12	0.11	0.24																												
9	0.08	0.05	0.17	0.18	0.04	0.11	0.14	0.04	0.07	0.00	0.13	0.09	0.04	0.13	0.17	0.08	0.05	0.15	0.08	0.11	0.00	0.09	0.18	0.08	0.14	0.11	0.00	0.24	0.09	0.09	0.18	0.21	0.21	0.21	0.30																											
10a	0.06	0.07	0.11	0.09	0.04	0.04	0.03	0.11	0.18	0.12	0.12	0.15	0.08	0.00	0.24	0.12	0.04	0.11	0.04	0.15	0.05	0.12	0.23	0.15	0.20	0.11	0.14	0.15	0.23	0.18	0.33	0.07	0.15	0.21	0.29	0.21																										
10b	0.12	0.15	0.13	0.15	0.00	0.11	0.11	0.08	0.07	0.12	0.16	0.12	0.08	0.04	0.07	0.00	0.05	0.15	0.04	0.07	0.00	0.12	0.18	0.08	0.17	0.18	0.10	0.18	0.19	0.13	0.12	0.07	0.16	0.11	0.15	0.24	0.24																									
11	0.13	0.15	0.19	0.23	0.19	0.10	0.14	0.21	0.19	0.17	0.24	0.27	0.12	0.06	0.24	0.06	0.00	0.20	0.17	0.15	0.00	0.20	0.22	0.11	0.21	0.10	0.14	0.15	0.17	0.32	0.29	0.14	0.13	0.38	0.23	0.20	0.33	0.17																								
12	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.04	0.13	0.07	0.00	0.15	0.20	0.04	0.15	0.00	0.03	0.14	0.11	0.00	0.03	0.05	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00																							
13	0.02	0.00	0.08	0.04	0.00	0.05	0.00	0.05	0.16	0.11	0.08	0.04	0.06	0.00	0.17	0.17	0.06	0.09	0.00	0.15	0.08	0.10	0.15	0.21	0.11	0.05	0.07	0.23	0.08	0.04	0.19	0.22	0.13	0.14	0.19	0.20	0.23	0.13	0.09	0.00																										
14	0.06	0.04	0.06	0.18	0.00	0.19	0.08	0.21	0.07	0.00	0.19	0.18	0.13	0.17	0.08	0.13	0.36	0.06	0.13	0.19	0.00	0.07	0.04	0.11	0.00	0.00	0.00	0.00	0.04	0.00	0.06	0.08	0.09	0.00	0.00	0.05	0.00	0.05	0.00	0.00	0.00																									
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																								
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																							
17	0.00	0.00	0.02	0.00	0.17	0.23	0.11	0.07	0.09	0.21	0.00	0.00	0.08	0.09	0.03	0.08	0.09	0.02	0.00	0.00	0.00	0.02	0.00	0.07	0.00	0.00	0.00	0.00	0.06	0.00	0.05	0.00	0.11	0.06	0.09	0.04	0.08	0.12	0.05	0.00	0.10	0.00	0.00	0.00																						
18	0.02	0.03	0.08	0.04	0.00	0.00	0.11	0.06	0.18	0.20	0.09	0.04	0.07	0.08	0.23	0.36	0.08	0.07	0.07	0.12	0.21	0.11	0.14	0.23	0.04	0.00	0.09	0.09	0.03	0.05	0.04	0.05	0.04	0.17	0.17	0.04	0.15	0.00	0.10	0.11	0.34	0.00	0.00	0.00	0.00																					
19	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																				
20a	0.16	0.16	0.17	0.11	0.04	0.13	0.06	0.00	0.08	0.07	0.05	0.05	0.04	0.00	0.04	0.00	0.00	0.18	0.00	0.03	0.00	0.06	0.09	0.07	0.15	0.19	0.04	0.19	0.25	0.25	0.19	0.09	0.21	0.09	0.13	0.17	0.24	0.17	0.09	0.00	0.11	0.00	0.00	0.00	0.07	0.06	0.00																			
20b	0.13	0.09	0.23	0.14	0.04	0.10	0.06	0.03	0.06	0.00	0.08	0.08	0.00	0.04	0.02	0.00	0.00	0.09	0.04	0.00	0.00	0.11	0.07	0.03	0.21	0.16	0.00	0.25	0.24	0.08	0.25	0.09	0.24	0.06	0.11	0.17	0.12	0.17	0.09	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.16																		
20c	0.11	0.09	0.13	0.08	0.06	0.00	0.05	0.11	0.08	0.00	0.08	0.08	0.00	0.06	0.06	0.00	0.00	0.07	0.11	0.00	0.00	0.06	0.06	0.00	0.18	0.20	0.00	0.15	0.12	0.27	0.15	0.09	0.26	0.19	0.15	0.13	0.07	0.10	0.17	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.09																	
21a	0.19	0.12	0.22	0.03	0.09	0.15	0.07	0.00	0.11	0.08	0.12	0.03	0.04	0.00	0.07	0.00	0.00	0.19	0.00	0.07	0.00	0.09	0.06	0.04	0.14	0.18	0.00	0.15	0.25	0.15	0.15	0.17	0.23	0.11	0.09	0.13	0.11	0.13	0.13	0.00	0.03	0.00	0.00	0.00	0.08	0.00	0.00	0.24	0.17	0.13																
21b	0.15	0.10	0.10	0.19	0.09	0.19	0.18	0.16	0.06	0.07	0.15	0.09	0.00	0.09	0.07	0.00	0.00	0.15	0.08	0.00	0.00	0.07	0.11	0.00	0.09	0.25	0.11	0.09	0.16	0.00	0.19	0.06	0.15	0.06	0.05	0.16	0.08	0.04	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.17	0.24	0.05	0.23															
21c	0.15	0.14	0.22	0.25	0.08	0.10	0.16	0.14	0.13	0.04	0.17	0.14	0.04	0.08	0.09	0.00	0.04	0.22	0.11	0.13	0.00	0.21	0.12	0.04	0.37	0.13	0.04	0.17	0.22	0.14	0.28	0.06	0.19	0.10	0.16	0.15	0.17	0.25	0.27	0.00	0.09	0.04	0.00	0.00	0.00	0.03	0.00	0.16	0.28	0.18	0.20	0.11														
22	0.05	0.03	0.07	0.09	0.00	0.12	0.00	0.06	0.12	0.00	0.14	0.13	0.00	0.00	0.07	0.07	0.09	0.07	0.00	0.12	0.00	0.06	0.03	0.00	0.24	0.12	0.00	0.04	0.06	0.09	0.18	0.16	0.21	0.11	0.09	0.08	0.15	0.11	0.21	0.00	0.05	0.20	0.00	0.00	0.06	0.00	0.00	0.06	0.10	0.10	0.22	0.07	0.10													
23a	0.12	0.10	0.17	0.12	0.09	0.11	0.07	0.08	0.05	0.04	0.10	0.27	0.04	0.05	0.07	0.00	0.05	0.14	0.08	0.08	0.00	0.12	0.05	0.04	0.23	0.07	0.00	0.25	0.19	0.03	0.09	0.14	0.16	0.04	0.15	0.05	0.22	0.11	0.24	0.00	0.10	0.10	0.00	0.00	0.04	0.04	0.00	0.20	0.20	0.14	0.22	0.04	0.18	0.19												
23b	0.19	0.19	0.13	0.03	0.00	0.04	0.08	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.05	0.00	0.00	0.07	0.03	0.00	0.13	0.04	0.00	0.03	0.05	0.04	0.00	0.12	0.14	0.12	0.07	0.09	0.03	0.09	0.08	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.32	0.19	0.11	0.15	0.09	0.11	0.04	0.24											
24	0.17	0.23	0.13	0.22	0.15	0.12	0.11	0.06	0.09	0.07	0.18	0.17	0.07	0.00	0.06	0.00	0.00	0.19	0.21	0.06	0.00	0.13	0.10	0.13	0.16	0.06	0.00	0.04	0.12	0.14	0.13	0.00	0.11	0.11	0.04	0.07	0.07	0.11	0.20	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.10	0.05	0.11	0.06	0.13	0.00	0.15	0.21										
25	0.11	0.12	0.09	0.12	0.13	0.00	0.09	0.16	0.05	0.06	0.08	0.12	0.00	0.00	0.03	0.00	0.00	0.09	0.11	0.00	0.00	0.08	0.03	0.00	0.07	0.00	0.07	0.12	0.14	0.16	0.08	0.05	0.13	0.10	0.15	0.07	0.10	0.17	0.22	0.00	0.00	0.07	0.00	0.00	0.05	0.05	0.00	0.14	0.12	0.00	0.10	0.11	0.18	0.00	0.20	0.11	0.15									
26a	0.05	0.03	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.20	0.12	0.00	0.04	0.09	0.19	0.04	0.00	0.07	0.06	0.04	0.04	0.04	0.19	0.10	0.00	0.05	0.00	0.00	0.00	0.00	0.06	0.00	0.10	0.03	0.10	0.07	0.00	0.27	0.06	0.00	0.00	0.18	0.35								
26b	0.08	0.10	0.10	0.03	0.00	0.00	0.04	0.04	0.09	0.00	0.03	0.03	0.00	0.00	0.02	0.04	0.00	0.06	0.04	0.00	0.00	0.10	0.03	0.00	0.14	0.00	0.00	0.09	0.12	0.16	0.06	0.07	0.13	0.07	0.21	0.19	0.11	0.16	0.07	0.00	0.10	0.00	0.00	0.00	0.15	0.07	0.00	0.07	0.05	0.13	0.11	0.04	0.15	0.08	0.05	0.12	0.11	0.17	0.15							
27	0.06	0.08	0.09	0.07	0.00	0.00	0.04	0.00	0.02	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.08	0.05	0.00	0.00	0.11	0.00	0.00	0.09	0.04	0.06	0.07	0.18	0.07	0.03	0.04	0.11	0.00	0.03	0.03	0.06	0.15	0.07	0.00	0.11	0.00	0.00	0.00	0.09	0.04	0.00	0.05	0.13	0.04	0.06	0.09	0.11	0.04	0.18	0.10	0.21	0.19	0.21	0.26						
28	0.11	0.09	0.15	0.06	0.00	0.07	0.07	0.04	0.04	0.04	0.09	0.00	0.04	0.04	0.05	0.00	0.00	0.11	0.04	0.03	0.00	0.05	0.07	0.04	0.16	0.14	0.00	0.14	0.16	0.18	0.37	0.06	0.22	0.13	0.17	0.18	0.13	0.10	0.13	0.00	0.06	0.00	0.00	0.00	0.07	0.00	0.00	0.16	0.21	0.22	0.41	0.18	0.26	0.11	0.18	0.11	0.10	0.13	0.07	0.10	0.14					
29a	0.05	0.03	0.08	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.00	0.02	0.00	0.00	0.00	0.04	0.03	0.00	0.08	0.06	0.00	0.04	0.12	0.00	0.04	0.11	0.04	0.11	0.09	0.08	0.07	0.00	0.05	0.00	0.10	0.00	0.00	0.00	0.06	0.12	0.00	0.03	0.07	0.10	0.11	0.13	0.03	0.06	0.08	0.04	0.06	0.00	0.06	0.11	0.17	0.07				
29b	0.03	0.00	0.05	0.05	0.00	0.00	0.00	0.09	0.07	0.10	0.11	0.05	0.11	0.00	0.04	0.00	0.00	0.03	0.10	0.08	0.00	0.05	0.04	0.09	0.05	0.00	0.00	0.00	0.07	0.06	0.05	0.00	0.08	0.15	0.00	0.00	0.04	0.00	0.13	0.00	0.06	0.17	0.00	0.00	0.09	0.00	0.00	0.04	0.00	0.06	0.09	0.09	0.00	0.17	0.09	0.05	0.16	0.06	0.00	0.09	0.21	0.08	0.25			
30a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.05	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.17	0.28	0.20	0.18	0.11	0.24	0.10		
30b	0.05	0.07	0.07	0.00	0.15	0.06	0.05	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.12	0.00	0.00	0.09	0.09	0.00	0.13	0.11	0.07	0.17	0.17	0.11	0.04	0.07	0.20	0.00	0.10	0.00	0.00	0.00	0.19	0.00	0.00	0.10	0.10	0.05	0.04	0.00	0.10	0.00	0.11	0.09	0.12	0.20	0.00	0.22	0.13	0.10	0.06	0.00	0.07	
30c	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.07	0.20	0.05	0.11	0.00	0.10	0.00	0.00	0.10

o/ll data becomes C2. simplifies

KSS0901Table3-AllSpecies.PTN

Fusion Type: Flexible UPGMA Beta = -0.10

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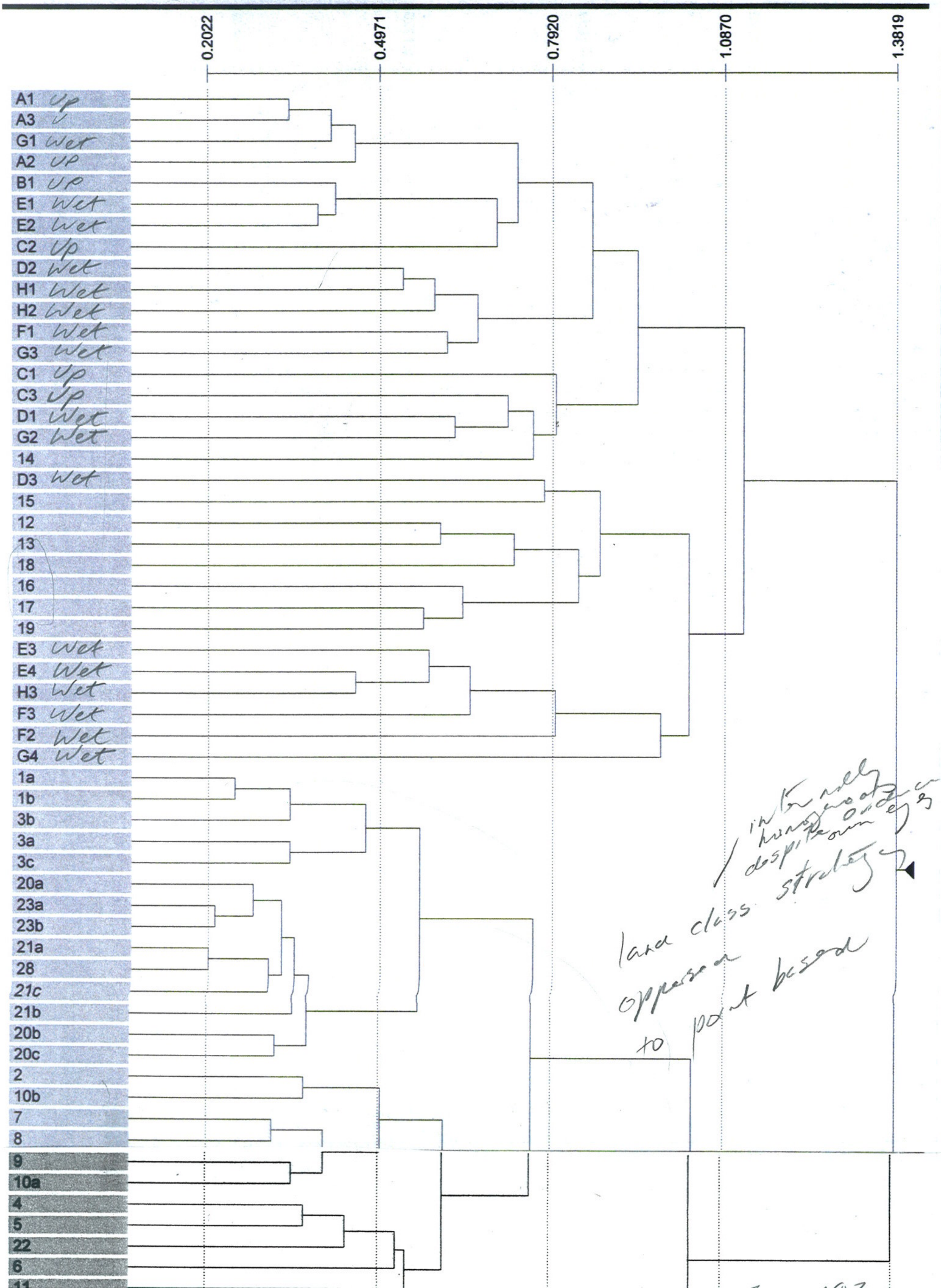

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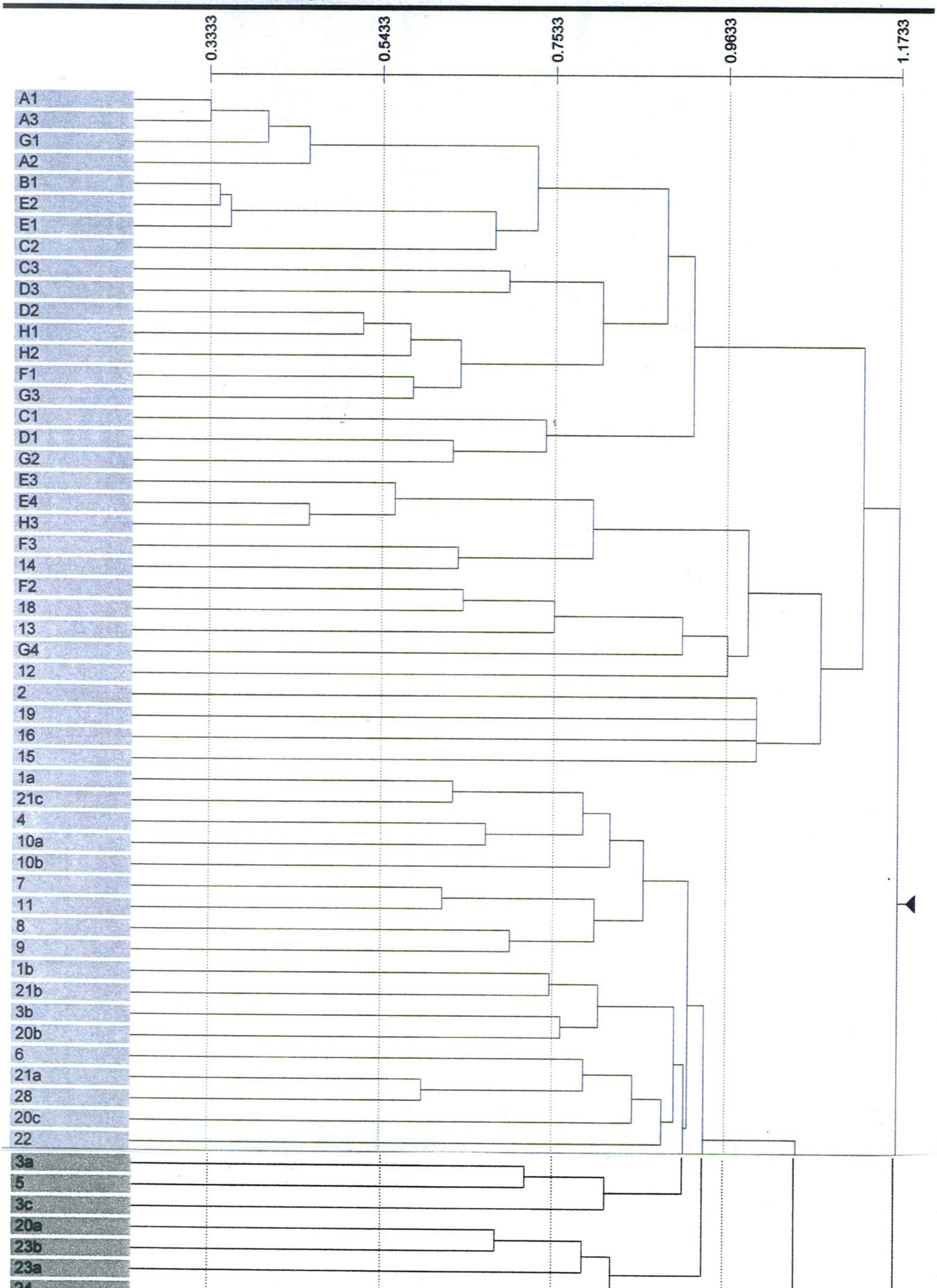

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INVITATION TO MAKE A SUBMISSION

The Environmental Protection Authority invites people to make a submission on this proposal preferably emailed to the Department of Environmental Protection/Environmental Protection Authority Project Assessment Officer.

Kemerton Silica Sand Pty Ltd proposes to extend the current silica sand dredge mining operations on freehold land in Kemerton. In accordance with the Environmental Protection Act, a Public Environmental Review has been prepared describing this proposal and its likely environmental effects. The Public Environmental Review is available for a review period of 8 weeks from -----closing on -----.

Comments from government agencies and the public will help the Environmental Protection Authority prepare an assessment report to make recommendations to government.

Why write a submission?
A submission provides information, expresses opinions and puts forward suggested courses of action, including alternative approaches. It is useful if suggestions are made to improve the proposal.

Submissions are treated as public documents unless provided and received in confidence subject to requirements of the Freedom of Information Act, and may be quoted in full or in part in the Environmental Protection Authority's report. All submissions received by the Environmental Protection Authority will be acknowledged.

Why not join a group?
If you prefer not to write your own comments, it may be worthwhile joining with a group interested in making a submission on similar issues. Joint submissions can help reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all participants' names. If your group is larger, please indicate how many people your submission represents.

Developing a submission
You may agree or disagree with, or comment on, general issues discussed in the Public Environmental Review or specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific elements of the Public Environmental Review:
- Clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind
By keeping the following points in mind, your submission will be easier to analyse:
- list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the Public Environmental Review;
- if discussing different sections of the Public Environmental Review, keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:
- your name;
- address;
- date; and
- whether you want your submission to be confidential.

The closing date for submissions is: --------------------
It is preferred if submissions are emailed to:
xxxxxx@xxxx

OR posted to:

The Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: xxxx

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

Kemerton Silica Sand (KSS) is a sand dredging operation located 35 kilometres north of the Port of Bunbury and approximately 150 kilometres south of Perth (Figure 1). The KSS property is freehold land owned by the proponent. Approval of the existing activity was granted by the West Australian Minister for the Environment in October 1994 (Ministerial Statement 366) following formal assessment of the project by a Public Environmental Review (PER).

Silica sand resources exist across the entire property. Results from baseline surveys and discussions with regulators and other stakeholders identified high environmental values over much of the KSS site. KSS recognised this was likely to constrain access to silica resources. Considerable effort has been made to develop a proposal satisfactory to competing interests of resource development and conservation. The proposed mine extension area contains sufficient silica sand resources to allow mining for about 50 years. Access to the area will enable secure long term resource extraction to take place and provide sufficient overburden to implement rehabilitation of dredge ponds in mined areas to create functioning wetland environments.

1.2 LOCATION

KSS is located in the Shire of Harvey, 2.5 kilometres north of Kemerton Industrial Park and 12 kilometres south west of the town Harvey, on the Swan Coastal Plain in the south-west of Western Australia. The KSS property consists of 1,326 hectares of freehold land owned by the proponent; mineral rights are to the landowner.

The KSS property is crossed by the north-south 132 kilovolts Bunbury - Cannington No.1 and No.2 electricity transmission line, the 415 kilovolts Harvey-Kemerton transmission line and the Perth-Bunbury natural gas pipeline.

1.3 JUSTIFICATION OF THE PROPOSED EXTENSION

The proposed extension of sand dredging operations at KSS is required to access silica sand resources suitable for both glass manufacturing and export. Approval is being sought to mine an additional 283 hectares (21.3%) of the current KSS property. This will allow long-term management of the site and implementation of long-term environmental management and rehabilitation plans.

1.4 PROPOSED SAND DREDGING OPERATIONS

It is proposed to extract approximately 30 million cubic metres of sand from the site over a period of 50 years at an annual rate of 500,000 to 1,000,000 tonnes per year. The maximum depth of dredging varies between 15 and 22 metres below the water table. Mining is carried out by a suction cutter dredge capable of mining at a rate of 350 tonnes per hour. Sand is pumped from the dredge pond to the Run of Mine (ROM) stockpiles at the processing plant using booster pumps. Slurry from the pond is dewatered using cyclones and sand is discharged onto stockpiles for processing. The water and slimes fraction are returned back to the dredge pond.

Dewatered sand is taken from the ROM stockpiles and transported via conveyor to a coarse screen that removes wood and oversized rocks. Dewatered sand enters the plant on a conveyor belt via a hopper where it is screened and oversize material removed. Sand slurry is deslimed before entering the Flat Bed Classifiers. Silt and clay fraction goes to the thickener where water is recovered and the fines are mixed with other plant tails and returned to the dredge pond for rehabilitation. The Flat Bed Classifiers split sand into course and fine fractions. Some of the course fraction is screened further to make products such as filter sand. The remainder is returned to the dredge pond.

Fine sand is cleaned by agitating the slurry in attritioning cells before feeding it into spiral circuits, which separate heavy minerals from the sand. A wet high intensity magnetic separator removes any remaining iron. Clean sand is fed to trommel screens that remove sand grains greater than 0.5 millimetres which are returned to the dredge pond. The remaining sand is pumped to cyclones on stackers where it is dewatered prior to being placed in product stockpiles. The remaining moisture drains naturally from the stockpiles.

There are no changes to the existing processing plant as part of this proposal.

1.4.1 Setback Limits

The mine extension area abuts a portion of the property's western boundary with a high voltage power line easement running immediately west of the boundary. There are no dwellings in the vicinity of the KSS property's western boundary and the area is kept clear of substantial vegetation. It is not required to maintain a vegetative setback along the western boundary as a visual screen for adjacent properties. Local government requirement of a 20 metre setback is provided to allow firebreak construction and perimeter access around the property.

1.4.2 Vegetation Clearing

The proposed mine extension area of 283 hectares has 19 hectares of cleared and 264 hectares of vegetated land that will require clearing over the 50 year project life. Vegetation will be cleared in stages of approximately five hectares per year. Vegetation clearing will be confined to areas required for dredge mining and associated activities particularly in front of the expanding dredge pond.

Approval was granted to clear 75.3 hectares of Bassendean Dune - Central and South vegetation complex, beyond the dredge pond boundary, in a dry mining program (Ministerial Statement 366). These areas identified in Figure 2 of the initial PER, dated July 1993, are reproduced and shown in Figure 2. Only 20.3 hectares of the approved dry mining area is contained in the proposed mine extension area (Figure 2). The remaining 55.0 hectares is located in Kemerton Nature Reserve and other parts of the KSS property.

These areas are now considered to have environmental values that make mining less desirable. This application proposes to seek an amendment to the mine extension area, to swap approval to clear 55.0 hectares of the Bassendean Dunes contained in the mine extension area for areas already approved (Figure 2). This will reduce the area of Bassendean woodland disturbed by the project and is discussed further in Section 10.4.

1.4.3 Access and Haulage

The final product is loaded onto trucks and transported 35 kilometres along sealed roads to the Port of Bunbury for export. A 12 kilometre private haul road has been constructed to minimise disturbance to local residents. No change is requested in this document for site access or haulage.

1.4.4 Hours of Operation

The current facility operates seven days a week on a 24 hour basis. It is expected that the proposed extension to operations will also be on a 24 hour a day seven day a week basis.

1.5 REHABILITATION

Rehabilitation will be conducted as dredging progresses and completed areas can be isolated as 'rehabilitation cells' from the active dredge pond lake.

Approximately 80% of silica sand in the extraction zone will be removed, with the post mining landform containing permanent water bodies.

Overburden and sand not suitable for sale, will be returned to the rehabilitation cell where it will be used to create graded beaches or landforms for terrestrial rehabilitation. Shallow areas will be formed to allow seasonal inundation and planted with suitable species. An ecosystem of shallows will be created for safety and to allow planting of sedges and other vegetation to encourage use of the water body by a number of different fauna species.

Rehabilitation work has provided KSS with valuable information on rehabilitation techniques for successful outcomes.

1.6 ENVIRONMENTAL FACTORS

1.6.1 Climate

The KSS property is situated in Western Australia's Mediterranean climate zone with wet, mild winters and hot dry summers. Long-term average annual rainfall for Bunbury is 733.5 millimetres with rainfall occurring predominantly during May to October (Bureau of Meteorology, 2008).

1.6.2 Geology and Landforms

The KSS property is situated within the Perth Basin, which extends approximately 20 kilometres eastwards from the coast to the Darling Escarpment. The Swan Coastal Plain lies on top of the Perth Basin. The Swan Coastal Plain is made up of five major geomorphological systems running roughly parallel to the coast. From east to west they include the Ridge Hill Shelf at the base of the Darling Scarp, the flat Pinjarra Plain, followed by the aeolian Bassendean, Spearwood and Quindalup Dune Systems (McArthur, 1991). The Bassendean Dune System forms a north–south strip approximately three kilometres wide between Pinjarra Plain to the east and Spearwood Dune System to the west. Dune crests in the Bassendean Dune System reach elevations of approximately 25 mAHD (metres above Australian Height Datum) and low areas have elevations of approximately 10 mAHD. Dune crests in the Spearwood Dune System reach elevations of approximately 50 mAHD immediately west of the KSS property. The general elevation of the Pinjarra Plain is 15 to 20 mAHD.

1.6.3 Acid Sulfate Soils

A preliminary desktop literature review of the Kemerton project area highlighted the need to investigate the potential for Acid Sulfate Soils (ASS) conditions occurring during operation expansion. The potential for ASS is evident given the high water table and low lying geomorphology of the area. As part of environmental licence conditions monitoring has not shown development of acidity in the dredge pond or surrounding monitoring bores, suggesting a very low risk of acid generation for future dredging operations. Returned sand residues, backfilled mostly below the water table in the rehabilitation cell, are exposed to minimal free oxygen, further reducing the risk of any possible acidification from Potential Acid Sulfate Soil material in these soils. This indicates that ASS is unlikely to be a problem in the remaining area.

An initial ASS assessment of the proposed extension area was undertaken by MBS Environmental in August 2007. Transects portions were sampled in 2007 during the initial assessment.

Conclusions from the initial ASS sampling program are:

1. Most potential high acid generating soils are located below the base of the final dredge pond depth (15 to 22 metres), remaining undisturbed under water.
2. There are some high potential acid generating soils within the mine extension area's mine profile.
3. There are high acid neutralising soils, which provide significant in-situ buffering capacity for the dredge pond environment.

In mid 2007, a new area south of North Lake was rehabilitated using topsoil and spreading of brush and logs. This area (ECU Site 14) is a rehabilitated sumpland near EPP5 and bordering the Muchea Limestone TEC. During monitoring McCullough and Lund (2007) observed low $Cl:SO_4$ ratios in the newly rehabilitated area and expressed concern that this may indicate some acid mine drainage/ASS-type oxidation from disturbance of the intermediate 'coffee rock' layer which may contain Potential Acid Sulfate Soil. In response to this observation, four samples of soil from this area were submitted for chemical analysis to determine the potential for acid generation following oxidation of ASS materials.

Three of the four samples tested contain insignificant amounts of ASS materials. The other sample (ASS 003) was reported with value for Titratable Actual Acidity that exceeded the Action Criteria for sands (18 mole H^+ per tonne), despite containing only trace amounts of pyritic material. It was noted that the reported value of 33 mole H^+ per tonne was obtained in only one of five replicate determinations, with the results for the other four determinations being <2 mole H^+ per tonne. It is considered extremely unlikely that significant amounts of acidity will be generated by disturbance of this soil. In terms of ASS management of these soil samples, no specific management protocols are required, although an ASS Management Plan has been prepared for any future ASS issues that may arise.

It is unlikely that ASS will be a problem in the proposed mine extension area. If any issues do arise, the ASS Management Plan will be implemented and adjusted accordingly.

1.6.4 Surface Water

Wellesley River to the east of the KSS property is the major surface drainage feature. The eastern part of the property is low lying and wetlands have formed in slight depressions. The western portion of the property has slightly higher elevation, but also drains towards Wellesley River. The river flows towards the south-west into Leschenault Estuary.

Surface water occurs on the property in the form of ephemeral wetlands. There are a number of wetlands on the property, nine of which are gazetted under the *Western Australian Environmental Protection (Swan Coastal Plain Lakes) Policy (EPP) 1992*. Six of the gazetted wetlands have been transferred from KSS ownership to the Department of Environment and Conservation (DEC) as part of an offset for project approval.

1.6.5 Groundwater

GHD (2002) undertook a hydrological review of mine extension areas as proposed at that time. The review identified the KSS property occurs within the Perth Basin and is underlain by superficial sediments that rest unconformably on the Leederville formation at a depth of approximately 30 metres.

The KSS property is within the Serpentine groundwater flow system near the crest of the Mialla mound. Recharge to the aquifer system is by direct infiltration of rainfall, particularly in winter and spring when rainfall is more intense. In the property's higher elevation areas the water table occurs at depths of more than 10 metres while in lower areas it may intersect the surface seasonally (GHD, 2002).

The water table fluctuates seasonally by approximately two metres in response to seasonal variations in groundwater recharge. Groundwater flow from the Mialla mound is constrained by hydraulic barriers formed by Harvey River to the north, the coast to the west, Leschenault inlet to the south and Wellesley River to the east. Monitoring data indicates groundwater flows south-eastwards towards Wellesley River on the KSS property. Groundwater discharge occurs by evapo-transpiration from wetlands and by discharge to the river. Some leakage occurs to the Leederville aquifer at the base of the superficial aquifer.

1.6.6 Vegetation and Flora

1.6.6.1 Vegetation Communities

Vegetation on the KSS property has been mapped in detail by E.M Mattiske and Associates (Mattiske) (1993a, b, c, d) and Bennett (2004). A list of studies identified 24 plant communities and 27 vegetation mapping units, three of which comprise disturbed stages of plant communities (Section 4.6).

Mattiske (2009) conducted detailed statistical similarities and association measures to determine the conservation status of the vegetation communities at KSS in light of the more recent TEC and PEC listings. The results indicate very low similarities between the communities defined by Mattiske (2003b) in previous mapping and the Swan Costal Plain dataset (Gibson *et al.* 1994) as defined utilizing the Sorenson's Similarity Index or the PATN analyses (Belbin 1995, Mattiske, 2009). There are some similarities between the communities, but they are not necessarily directly comparable. The presence of some dominant species or species that reflect seasonal swamps do not necessarily indicate a presence of the respective TEC or PEC's. The patterns appear to relate to the continuum nature of many species across the landscape and the need to rely on presence/absence data only (rather than quantitative and structural dominance).

A total of 65 families, 174 genera and 365 plant taxon (including varieties and subspecies) have been recorded on the KSS property (Mattiske, 2003b). Species representation was highest in the Papilionaceae (37 taxon), Myrtaceae (37 taxon), Proteaceae (18 taxon) and Cyperaceae (16 taxon) families. This flora composition is typical of the Bassendean - Central and South vegetation complex as described by Heddle *et al.* (1980). Wetland systems are dominated by species from the Restionaceae, Cyperaceae and Myrtaceae families.

1.6.6.2 Species of Conservation Significance

Detailed flora studies have been conducted for the KSS site and its immediate surrounds over a 10 year period, with 11 botanical studies conducted. A number of species listed under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* or the *Western Australian Wildlife Conservation Act 1950 (WC Act)* have been recorded at the site.

The Critically Endangered and Declared Rare Flora species, *Caladenia procera,* was located in the south-west corner of the KSS property. It was identified by Woodman (2005a) in a follow-up survey for the Kemerton Lateral Pipeline. This location is well outside the mine extension area and will not be disturbed and it is in the area proposed as an offset.

A further nine Priority flora species, defined by the DEC, have been recorded on the KSS property. These are *Boronia juncea* subsp. *juncea* (P1), *Boronia capitata* subsp. *gracilis* (P2), *Acacia semitrullata* (P3), *Dillwynia dillwynioides* (P3), *Cyathochaeta stipoides* (P3), *Goodenia filiformis* (P3), *Acacia flagelliformis* (P4), *Caladenia speciosa* (P4), and *Eucalyptus rudis* subsp. *cratyantha* (P4). One Declared Rare Flora species, *Conostylis micrantha* (R) was located in 1997 by Arbortech Pty Ltd (1997) and in 1998 by Ecos Consulting (Aust) Pty Ltd (Ecos) (1998), but has not been recorded since. Bennett Environmental Consulting Pty Ltd (Bennett) (2004) undertook a targeted search for all flora species of conservation significance, but failed to locate this species and states (pg 8) *"This species is restricted to the Dongara-Mingenew area (WA Herbarium, 2003) so it is likely that the plant collected at Kemerton was* *misidentified. If the plants were only collected in a vegetative form they could have been Conostylis juncea recorded from the area by Mattiske (2003b)".*

Within the proposed mine extension area, there are six Priority flora species: *Boronia juncea* subsp. *juncea* (P1), *Acacia semitrullata* (P3), *Dillwynia dillwynioides* (P3), *Goodenia filiformis* (P3), *Caladenia speciosa* (P4), and *Eucalyptus rudis* subsp. *cratyantha* (P4), have been recorded. Recently taxonomic division suggests that *Goodenia filiformis* (P3), is likely to be *Goodenia pulchella* subsp. Coastal Plain B (L. W. Sage 2336) which is not a Priority species (See Bennett, 2004). All Priority flora species within the mine extension area occur elsewhere on the KSS property.

1.6.7 Wetlands

Of nine wetlands on the original KSS property gazetted under the *EPP 1992*, five have been transferred to DEC to form Kemerton Nature Reserve. A portion of another (EPP8) is included in Kemerton Nature Reserve and an additional wetland was added to the reserve in a land swap for the Muchea Limestone threatened ecological communities in 2005. One EPP wetland (EPP4) and the balance of EPP8 remain on the KSS property with one EPP wetland incorporated in the approved mine area.

The Water and Rivers Commission (WRC) (2001) evaluated wetlands on the Swan Coastal Plain assigning management categories to provide guidance on the nature of management and protection required by individual wetlands. Three management categories were developed based on the geomorphical characteristics of Conservation, Resource Enhancement or Multiple Use. The geomorphic wetland classification system identifies all wetlands within the mine extension area as conservation, with two exceptions. The residue sand tailings disposal area and an upland Bassendean Dune in the north of the mine extension area are both nominated as multiple use wetlands.

A separate submission was made to DEC in January 2009 to reclassify the Geomorphic Wetland Database regarding the areas of upland Bassendean Dune within the mine extension area (Martinick Bosch Sell Environmental Pty Ltd, 2009). Contour plans and site vegetation surveys confirm the area mapped as multiple use wetland on the DEC database is elevated land containing open woodland of *Jarrah* and *Banksia*. The PER has been prepared on the basis this area is Bassendean woodland.

Wetlands of the KSS property include sumplands, damplands, floodplains and palusplains depending on the soil, shape and extent of standing water. Each wetland is a mosaic of vegetation units. A marked variation occurs between wetlands in the southern portion of the KSS property to those in the north and between wetlands on the west and east. EPP wetlands occur mostly in the east of the property in Kemerton Nature Reserve situated on clay overlying lateritic soils on the Pinjarra Plain. These wetlands belong to the Keysbrook wetlands suite.

1.6.8 Fauna

Sixteen fauna studies have been conducted within the KSS property since 1993. This included targeted surveys for the Southern Brush-tailed Phascogale (*Phascogale tapoatafa ssp.),* Chuditch (*Dasyurus geoffroii*), Carnaby's Black-Cockatoos (*Calyptorhynchus latirostris*) and Western Ringtail Possum (*Pseudocheirus occidentalis*). The Chuditch, Carnaby's Black-

Cockatoos and Western Ringtail Possum were identified as the primary reason for designating the project as a Controlled Action under the *EPBC Act.*

Studies carried out for the KSS project provide specific information regarding fauna of the KSS property. The other studies were conducted over broader areas than the KSS property alone and provide information on fauna at a more regional level (Bamford, 2003). A considerable body of information on the fauna and their habitat associations of both the KSS property and the Kemerton region are therefore available.

Bamford (2003) reviewed results of earlier studies focusing on areas of special interest in the western part of the KSS property. Bamford (2003) produced lists of fauna species present or expected to occur in the Kemerton region and specifically on the KSS property. Where species have not been recorded, but are expected to occur in the area, the preferred species habitat, where such preferences are known to be very specific, were also recorded. Bamford (2003) concluded that:

- The Kemerton region supports a rich fauna, because it includes a large area of remnant and regrowth native vegetation, while much of the surrounding coastal plain has been developed for agriculture.
- The area supports a high number of CS3 species, not formally recognised for conservation significance, but are regionally important. In the Kemerton region, these species have declined elsewhere on the Swan Coastal Plain.
- Many species of conservation significance are present in the Kemerton region because it is one of the largest contiguous areas of native vegetation on the Swan Coastal Plain between Bunbury and Perth.

Potentially, 20 native mammals (includes nine bat species), 127 bird, 10 frog, 34 reptile and six fish species could be expected to occur in or utilise at times, the KSS area. Of the 197 native animals that are listed as potentially occurring at the site, eight are considered to be endangered/vulnerable or in need of special protection. In addition 7 migratory species may frequent the site at times. Ten DEC priority species may also use the site. Eight introduced species may also be present.

1.6.9 Heritage Values

A heritage survey of the site was conducted and as no sites were found in the proposed mine extension area, there is not expected to be any impacts. The KSS property is freehold land and is not subject to Native Title Claims.

1.6.10 Noise

There are no noise issues from existing dredge or plant operations. It is unlikely that there will be any additional noise emissions from the proposed mine extension, as production will occur at a similar rate. The remote location of noise generating plant and equipment relative to the nearest noise sensitive receptor, means that compliance with regulatory standards are considered to be easily achieved.

1.6.11 Emissions and Dust Suppression

The location of the mine extension area and process plant within the larger KSS property provides a significant buffer distance from any dust generating activity to the nearest sensitive premises. The current and proposed operation is to mine silica sand through dredge mining methods rather than dry mining methods. The sand mining dredge and processing plant uses water to mine, pump and process the ore. No dust is generated from these activities.

Dust emissions have not been a significant environmental issue during the last 10 years of sand mining operations. As operations in the mine extension area will use the same wet process and dredging equipment as current operations, it is not anticipated dust emissions will pose a significant environmental impact.

1.6.12 Visual Amenity

KSS is located to the north of Kemerton Industrial Park within an area zoned as rural. The property is not in close proximity to any residential areas with the closest residence at least one kilometre from the current operation area. The extension area is well buffered by surrounding vegetation and landforms within the KSS property. Vegetated setbacks will be maintained along the property boundary.

1.6.13 Road Transportation/Traffic

Transport of silica sand has been operating from KSS for over 10 years. It is intended that plant throughput will remain at its current level, so there will not be a significant increase of traffic activity from the operation.

All trucks are well maintained and operated by licensed operators and roads are well maintained as agreed with the local council. Haulage is avoided on Sundays where possible.

1.7 SUMMARY OF ISSUES AND ENVIRONMENTAL FACTORS

Environmental factors for the proposed extension of the KSS operations, as determined by the DEC, and management proposals are summarised in Table 1.

Table 1: Summary of Environmental Factors and Management

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
Integrating Process					
Biodiversity	Maintain biological diversity representing different plants, animals and micro-organisms, the genes they contain and the ecosystems they form, at levels of genetic diversity, species diversity and ecosystem diversity. Through studies carried out for other environmental factors, demonstrate that biodiversity will not be compromised by this proposal.	The Kemerton area is bio-diverse, supporting several vegetation types and fauna of conservation significance. Much of the property is seasonally inundated and supports dampland complexes of dense shrub lands and heaths, with some localised depressions forming seasonal wetlands. *Eucalypt* and *Banksia* woodlands of the Kemerton region have been identified as being significant fauna features. Sections of the property have been subject to historic logging and there is also evidence of extensive brush cutting, particularly in wetland areas. A north-eastern portion of the property has been used historically for grazing and evidence of man-made drains is apparent on the property as past attempts to improve agricultural land productivity. A pine plantation, the majority of which has been logged, was developed in the north-east of the property. Only a few pine trees remain. Dieback disease caused by infection of *Phytophthora cinnamomi* has been identified across the property. 79% of the KSS site is either already infected or not able to be protected from	Reduction in biological diversity due to land clearing and habitat removal.	Design project to avoid areas of greatest biodiversity significance. Clearing of native vegetation to be kept to a practical minimum. Populations of Priority species also mapped outside the extension area, reducing risk of negative impact on individual species. Good populations exist within Kemerton Nature Reserve. Rehabilitation of mined areas to provide habitat for native fauna and flora. Continued suspension of grazing activities. Weed and feral animal control programs. Design project to ensure that each type of wetland from the wetland suite is represented in undisturbed areas.	Diversity protected and environmental benefits documented.

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
		infestation. The property also has 58 introduced plant taxa.			
Biophysical					
Vegetation and Flora	Maintain species diversity, geographic distribution and productivity of vegetation communities.	A number of flora and vegetation studies have been conducted on site.	The proposal will result in clearing of about five hectares of vegetation per annum over the project's life.	Clearing of native vegetation will be kept to a practical minimum. Topsoil will be stripped and reused in rehabilitation. Rehabilitation including replacing vegetation in suitable areas will be undertaken.	Some loss of vegetation will occur. Rehabilitation will return ecological functions to mined areas.
Declared Rare and Priority Flora Species	Protect Declared Rare and Priority flora, consistent with the provisions of the *WC Act 1950.*	One Rare and nine Priority flora species have been recorded on the property. Five propriety species have been recorded in the mine extension area.	The removal of individuals of Priority flora species will occur, however these species are also represented in other areas of the property which are not in the project area. The Declared Rare species occurs outside the mining extension area in land proposed as an offset.	Seed collection or plant relocation of Priority species into undisturbed sites or rehabilitation areas will be undertaken. The mine extension area has been selected to avoid impact on Priority flora species as much as possible.	Impact to individuals of Priority species but negligible impact to species diversity on the KSS property.
Fauna	Maintain abundance, diversity, geographic distribution and productivity of native terrestrial and aquatic fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	A number of fauna studies have been conducted on the site, including targeted surveys for specially protected species. Wetlands in the mine extension area did not contain surface water during the 2007 invertebrate surveys. No survey of aquatic invertebrates was possible, however sampling was	Progressive clearing of small areas has the potential to reduce the available fauna habitat.	Rehabilitation of the dredge pond and surrounds will return ecological functions to mined areas. Retention of native vegetation in non-mining areas of the KSS property, including EPP wetlands will preserve key fauna habitats.	Impact to individuals of fauna species but negligible impact to species diversity on the KSS property.

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
		carried out in the existing mine area and Kemerton Nature Reserve.			
Specially Protected (Threatened) and Priority Fauna	Protect Specially Protected (Threatened) and Priority fauna and their habitats consistent with the provisions of the *WC Act 1950* and *EPBC Act*.	Targeted surveys for specially protected species have taken place. Chuditch were not recorded in the KSS property. The KSS property does not have particular value for Carnaby's Black-Cockatoo relative to other sites surveyed in the region.	Clearing of Bassendean woodlands will temporarily reduce foraging habitat of Carnaby's and Baudin's Black-Cockatoo. Wetlands of the KSS property support vegetation types that are not suitable for Cockatoo foraging or breeding, therefore limiting the potential impact of this project on this species.	Rehabilitation will return species diversity and density and provide similar and new wetland habitat types. Rehabilitation will include relocation of possible nest sites or mounting of nest boxes in suitable habitat locations outside the project area.	Negligible impact to specially protected species. Rehabilitation will return ecological functions to mined areas.
Landform	Establish stable, sustainable landforms consistent with intended post-mining land use and surroundings.	The current landform is ephemeral wetlands interspersed by upland areas.	Shallow ephemeral wetlands will be altered to form permanent deeper lakes resulting in alteration of the current landform due to mining.	Rehabilitation will involve a combination of permanent lakes, reconstructed ephemeral wetlands and dune landforms. Monitoring and maintenance will be implemented until rehabilitation is successful.	Rehabilitation will return landform features and ensure they are safe, stable and provide ecological functions. It is acknowledged that the landform will be an altered state with the establishment of permanent wetlands. This is not in variance with the surrounding region.
Rehabilitation	Ensure proposal area and any other area affected by the proposal is rehabilitated to a standard consistent with intended post-mining long-term land use.	Rehabilitation has been undertaken in the current mining area. Rehabilitation has and will be continued to be monitored. Techniques and methods will be continually improved, using results of monitoring to research programs.	Change in landform composition as a result of mining, producing permanent lakes where there is currently no permanent surface water features.	Rehabilitation will provide the opportunity for increased habitat of iconic and regionally significant species. These include Water Rat (*Hydromys chrysogaster*), Black-striped Jollytail (*Galaxias nigrostriata*) and various frog and waterfowl species.	Rehabilitation will provide greater diversity of habitat features providing ecological functions for iconic and regionally significant species.
Wetlands	Maintain integrity, functions and	The KSS property is a system of	Establishment of dredge	Maintain buffers around remaining EPP	Negligible long term

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
	environmental values of wetlands.	wetlands interspersed with upland, Bassendean woodland areas.	ponds has the potential to cause degradation of nearby wetlands and change characteristics of others.	wetlands to avoid impact on these areas. Rehabilitation of dredge ponds and surrounds will create additional wetland habitat. Monitor water levels and ecology of control lakes to ensure impact is minimised.	impact to surrounding wetlands.
Pollution Management					
Particulates/dust	Ensure air emissions (particulates, greenhouse gases) do not adversely affect environmental values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.	Dust is most likely to be an issue during clearing. Measures have been taken to reduce the likelihood of dust/particulate emissions and no complaints have been received.	Airborne particulate concentrations will not increase due to the extension as throughput will not increase and the mining method will continue to use wet/dredging techniques. Implementation of the project will result in production of greenhouse gases. As the extension will not increase the rate of activities beyond the current approved operation, greenhouse gas emissions are expected to be the same as current generated site emissions.	Water carts will continue to be used on unsealed surfaces to complement existing auto reticulation to prevent generation of dust and wind erosion. Completed areas will be rehabilitated and revegetated as soon as practicable.	Management of dust emissions will be controlled by a number of measures. Monitoring will be implemented to confirm the success of the management program. Mitigation measures identified will ensure environmental values of air quality are maintained.
Groundwater Quality and Quantity	Maintain or improve groundwater quality to ensure existing and potential uses, including ecosystem maintenance are protected, consistent with draft WA Guidelines for Fresh and Marine Waters (EPA, 1993).	The current operation abstracts between 300 - 600 megalitres per annum under licence.	Changes to the hydrological regime may occur due to continued operations affecting adjacent wetlands.	There is valuable site specific data for hydrological modelling sourced from 10 years of operation. This data was used to define buffer distances to wetlands and landform restoration to recreate ephemeral wetland systems. No chemicals which leave harmful	Hydrocarbon storage and handling will be managed to minimise the risk of contamination of groundwater. Groundwater quality will not be adversely affected

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
				residues on the return water are used in sand processing. Groundwater monitoring programs will be expanded and continued.	by mine activities.
Surface Water Quality	Maintain or improve quality of surface water to ensure existing and potential uses, including ecosystem maintenance are protected consistent with draft WA Guidelines for Fresh and Marine Waters (EPA, 1993).	No major watercourses are located within the KSS property. Surface water occurs as wetlands due to topographic expressions of the water table.	Mining has the potential to result in localised alteration of surface run-off regimes. Potential exists for contamination of surface water run-off with sediments.	Water from potentially contaminated catchments will be captured and treated prior to release to natural catchments where necessary.	There will be negligible effect on surface water quality by mine activities.
Acid Sulfate Soils (ASS)	ASS is recognised as a potentially contaminating material, requiring specific consideration and management, if present on a development site.	No ASS problems in the dredge pond or surrounding soils have occurred during 10 years of on-site dredge pond mining. Assessment of the project area showed most potential ASS below the base of the dredge pond. Soils in the dredge profile contain both potential ASS and acid neutralising capacity. This is consistent with current conditions that show no net acid producing potential.	The potential for ASS is present, however historical data and ASS surveys indicate the net acid producing potential for the site is low.	An Acid Sulfate Soils Management Plan (ASSMP) will be prepared should any acidity problems develop.	There will be negligible development of ASS by mine activities.
Noise	Ensure that noise impacts emanating from the proposal comply with statutory requirements and acceptable standards.	The large property size, significant internal buffer distances and significant distance to the nearest residential premises suggest noise is not a key environmental factor. Noise surveys have been conducted on site and no issues have been raised. No complaints from surrounding residents have been received.	Noticeable increase in noise levels for nearby residents.	Noise emissions from equipment planned to be used that is significantly different from current equipment will be assessed. Current noise modelling will be reviewed as required.	There will be negligible effect on noise from mine activities.

Environmental Factor	Environmental Objectives	Existing Environment	Potential Impact	Environmental Management	Predicted Environmental Outcome
Social Surroundings					
Visual amenity	Visual amenity of the area adjacent to the project should not be unduly affected by the proposal.	The extension area is well buffered by surrounding vegetation and landforms within the KSS property. The property is isolated from the majority of sensitive land uses within the region.	Minimal potential impacts on visual amenity are predicted.	A 20 metre vegetated setback will be maintained along the property boundary.	There will be negligible effect on visual amenity from mine activities.
Road transportation/ traffic	Ensure roads are maintained or improved and road traffic managed to meet an adequate standard of level of service and safety and Main Roads Western Australia requirements.	Silica sand is transported by truck 35 kilometres to the port of Bunbury. A 12-kilometre private access sealed road has been established to minimise traffic conflicts. About 12 truck movements of about 70 tonnes each are conducted on a Monday to Friday basis. Campaign trucking also occurs on an as needs basis.	Approval of the extension will not increase daily truck numbers, but will extend the length of time trucks will travel the route.	All trucks will be well maintained and operated by licensed operators. Haulage will be avoided on Sundays where possible. Roads will be maintained in a manner agreed with the local council.	There will be negligible effect on road transport from mine activities.
Indigenous and non-Indigenous cultures	(i) Ensure the proposal complies with requirements of the *Aboriginal Heritage Act 1972;* (ii) Ensure changes to the biological and physical environment resulting from the project do not adversely affect cultural associations with the area.	An archaeological survey has been conducted on the site and no sites were located. A search of the local municipality heritage inventory indicated that no sites of historical significance occur on the site.	No likely impacts on Indigenous or non-Indigenous cultures as no sites have been identified.	If any archaeological sites are discovered during extraction activities, they will be reported in accordance with the provisions of the *Aboriginal Heritage Act 1972.*	There will be negligible effect on heritage matters from mine activities.

The KSS property is located within the South Western Botanical Province of Western Australia, in the Darling Botanical District and the Swan Coastal Plain subregion of the Drummond Botanical subdistrict (Diels 1906, Beard 1990). Flora and vegetation of the area has been defined by Beard (1981), Smith (1974) and Heddle *et al.* (1980) at a regional scale.

Regional mapping undertaken by Heddle *et al.* (1980) identified that the majority of the vegetation retained on the KSS property occurs within the Bassendean - Central and South vegetation complex. Vegetation ranges from woodlands of *Eucalyptus marginata* subsp. *marginata* - *Allocasuarina fraseriana* - *Banksia* spp. to low woodlands of *Melaleuca* spp. and sedgelands on the low-lying depressions and swamps. *Banksia attenuata*, *B. grandis* and *B. menziesii* are common on upper slopes. *B. ilicifolia*, *B. littoralis* and *Melaleuca preissiana* are common tree species on low lying moisture sites (Heddle *et al.* 1980).

The KSS property abuts the Karrakatta - Central and South vegetation complex to the west of the property (Mattiske, 2003b). The Serpentine River complex occurs in the north-eastern corner of the property, now part of the Kemerton Nature Reserve (Heddle *et al.* 1980). This area has been cleared and previously used as grazed pasture land.

4.6.2 Regional Vegetation Coverage

The Bassendean - Central and South Vegetation complex is the dominant vegetation complex of the KSS property. EPA (2003b) indicates that the total remaining area of vegetation of Bassendean - Central and South vegetation complex was 27% of the entire Swan Coastal Plain or 39.3% of the Greater Bunbury Region (Appendix 3, Table 9).

Table 9: Vegetation Remaining on the Swan Coastal Plain and Greater Bunbury Region

Vegetation Complex	Original Area (ha)	Total Area Remaining SCP (ha)	Remaining on SCP (%)	Original Area (ha)	Total Area Remaining in GBR (ha)	Remaining in GBR (%)
Bassendean Complex - Central and South	87,626	23,635	27	23,970	9,430	39.3

Source: EPA (2003b) Bulletin 1108, Appendix 3 Table 4.

The vegetation community types occurring in the Bassendean system are of Super Group 3, including community types 20, 21, 22 and 23 (Gibson *et al.* 1994). Community type 21 is the most likely to occur in the Kemerton region. This community type is divided into three subgroups of which 21b and 21c are more likely to occur at Kemerton:

- **Community 21(a):** This community is primarily *Eucalyptus marginata* - *Banksia attenuata* woodland, *E. marginata* - *Corymbia calophylla* - *B. attenuata* woodland or *B. attenuata* woodland. This sub-community differs from the other two sub-communities by the presence of taxa such as *Sowerbaea laxiflora*, *Drosera pallida*, *Leucopogon propinquus* and *Isotropis cuneifolia*. *Allocasuarina fraseriana* and *Eucalyptus gomphocephala* are also sometimes present.
- **Community 21(b)**: Structurally this community is naturally *B. attenuata* or *E. marginata* - *B. attenuata* woodlands. It is also likely to contain *Acacia extensa*, *Jacksonia horrida*, *Laxmannia sessiliflora*, *Lysinema ciliatum* and *Johnsonia acaulis*.

- **Community 21(c):** This community occupies the low lying wetter sites and is variously dominated by *Melaleuca preissiana*, *B. attenuata*, *B. menziesii*, *Regelia ciliata* and *E. marginata* or *Corymbia calophylla*. Structurally this community type may be either woodland or occasionally shrubland.

In addition to these vegetation communities which provide the broad vegetation structure, a number of wetland communities also occur within the KSS property. According to Gibson *et al.* (1994) these belong to Super Group 2 and include community types 4, 12 and 13.

4.6.3 Flora and Vegetation Surveys

Detailed recordings of vascular plant species have been made during numerous botanical surveys undertaken on the KSS property. Nine baseline botanical studies have been undertaken for KSS on the property area since 1993. Further studies have also been undertaken for other regional projects (Woodman, 2005a) in addition to several rehabilitation studies as detailed in Section 9.7:

1. E.M. Mattiske & Associates (Mattiske), 1993a. Gwalia Consolidated Limited - Kemerton Sand Project. Flora and Vegetation Studies. February 1993 report details December 1992 reconnaissance botanical studies undertaken throughout the entire project area.
2. E.M. Mattiske & Associates (Mattiske), 1993b. Gwalia Consolidated Limited - Kemerton Sand project. Flora and Vegetation Report. June 1993 report details April 1993 vegetation mapping in the project area.
3. E.M. Mattiske & Associates (Mattiske), 1993c. Gwalia Consolidated Limited - Kemerton Sand Project. Updated Flora and Vegetation Report. November 1993 report reviews and supplements flora and vegetation within operational areas undertaken in October 1993.
4. E.M. Mattiske & Associates (Mattiske), 1993d. Gwalia Consolidated Limited - Kemerton Sand Project. Vegetation Mapping of Proposed Transport Corridor. November 1993 report details vegetation and flora studies and mapping undertaken in a 50 metre wide strip along the proposed transport route during October 1993.
5. B. Keighery, 1998. Vegetation and Flora Conservation Values of the Kemerton Silica Sand Project Area. 1998 report for the Department of Environmental Protection.
6. Muir Environmental, 1999. Report of Biological Survey - Phase 1: Kemerton Industrial Estate. 1999 report detailing October to November 1998 biological surveys of Kemerton Industrial Estate.
7. Mattiske Consulting Pty Ltd (Mattiske), 2002c. Kemerton Sand Project Flora and Vegetation. April 2002 report providing an updated summary of previous botanical studies within the Kemerton project area.
8. Mattiske Consulting Pty Ltd (Mattiske), 2003b. Kemerton Silica Sand Review of Flora, Vegetation and Conservation Values on Kemerton Project Area. May 2003 report providing an updated summary of previous botanical studies within the Kemerton project area.
9. Bennett Environmental Consulting Pty Ltd (Bennett), 2004a. Kemerton Significant Flora and Wetlands. March 2004 report on the Declared Rare and Priority Flora and wetland assessment at the KSS site.

10. Woodman Environmental Consulting Pty Ltd (Woodman), 2005b. Kemerton Lateral Pipeline: Flora, Vegetation, and *Phytophthora Cinnamomi* Assessment. Unpublished report for Ecos Consulting (Aust) Pty Ltd.
11. Mattiske Consulting Pty Ltd (Mattiske), 2009. Updated Review of Vegetation Communities - Kemerton Silica Sand Pty Ltd. Unpublished memo for Kemerton Silica Sand Pty Ltd, February 2009.

The most comprehensive field studies for the KSS property were undertaken by Mattiske between 1993 and 2003. These have been collated into one report Mattiske (2003b) *Kemerton Silica Sand Review of Flora, Vegetation and Conservation Values on Kemerton Project Area* providing an updated summary of previous botanical studies within the Kemerton project area (Appendix 4). The initial main survey was undertaken in 1993 by qualified botanists on a grid recording basis. The area was assessed along east-west grid lines spaced 250 metres apart. Regular recordings were taken along these gridlines. The location of the recordings along the gridlines was based on the variation in the communities, but tended to be between 50 metres and 150 metres apart. At each recording site the trees were recorded in a 20 metre radius and understorey in a 5 metre radius (Mattiske, 2009).

A comprehensive survey for Declared Rare Flora (DRF) and Priority species and wetland classification was undertaken in spring 2003 by Bennett (2004). Field work was undertaken in three stages from the 22 to 26 September, 15 to 17 October and 3 – 5 November to ensure that all potential DRF and priority flora within the area was located (Appendix 5). A team of three qualified environmentalists walked transects through the area at 100 metre intervals (Appendix 5). Priority and DRF species found were lodged at the Western Australian Herbarium. Vegetation units of wetlands were recorded as transects were traversed, dominant species of each stratum within the different vegetation units was recorded, together with the presence of standing water, the wetland as a whole was described (Bennett, 2004).

Flora and vegetation surveys were conducted prior to the development of the EPA Guidance Statement; "Guidance for the Assessment of Environmental Factors No. 51 - Terrestrial flora and vegetation surveys for environmental impact assessment in Western Australia" (EPA, 2004). To summarise methods of the Mattiske (1993b, c) reports, a reconnaissance and detailed recording of vascular plant species was undertaken during April 1993 and additional opportunistic collecting of annuals and other species was undertaken in October 1993. The methods also state that the field program involved complete and thorough coverage of the survey area, where "regular recordings were taken at sites within the different communities" (Mattiske, 1993c). Bennett (2004) conducted a thorough survey of the entire KSS property in September, October and November 2003. The surveys focused on Declared Rare and Priority Flora searches in September and October and wetland identification and mapping in November (Bennett, 2004). These report method are consistent with requirements for a Level 2 survey according to the EPA Guidance Statement 51 (EPA, 2004).

KSS commissioned Mattiske in December 2008 to review and update the vegetation communities at KSS in relation to Swan Coastal Plain dataset (Gibson *et al.* 1994) (Appendix 6). A series of analyses was undertaken utilizing the Sorenson's Similarity Index (SSI) and PATN clustering analysis (Austin and Belbin 1982; Belbin 1995). The Sorenson Index of Similarity (SSI) is based on qualitative (Presence/absence) data:

$$ISs = \frac{2a}{2a + b + c}$$

NO PLOT

Where:

a = number of species common to both sites
b = number of species found in the first site only
c = number of species found in the second site only

The species by site data was analysed utilising the association measures (Austin and Belbin 1982; Belbin, 1995) and flexible UPGMA technique with the PATN program (Blatant Fabrications Pty Ltd 2006). The PATN clustering analysis (Belbin 1995) on all species by sites and native species by sites:

$$D = \square\ |D_{ik} - D_{jk}| / \square\ \{D_{ik} + D_{jk}\}$$

In addition to these surveys, other surveys on flora, fauna and environmental factors have been undertaken by parties for separate projects, within and adjacent to the KSS property. Projects for gas pipelines and a power station in and adjacent to the KSS property have undertaken a range of surveys for environmental assessments for their respective projects. Other project assessments with surveys relevant to this proposal include:

- Kemerton power station — EPA Bulletin 1121 and Ministerial statement 645.
- Kemerton lateral gas pipeline — EPA Bulletin 1204 and Ministerial statement 704.
- Kemerton power station enhancement project — EPA Bulletin 1258 and Ministerial statement 745.

Guidance 10

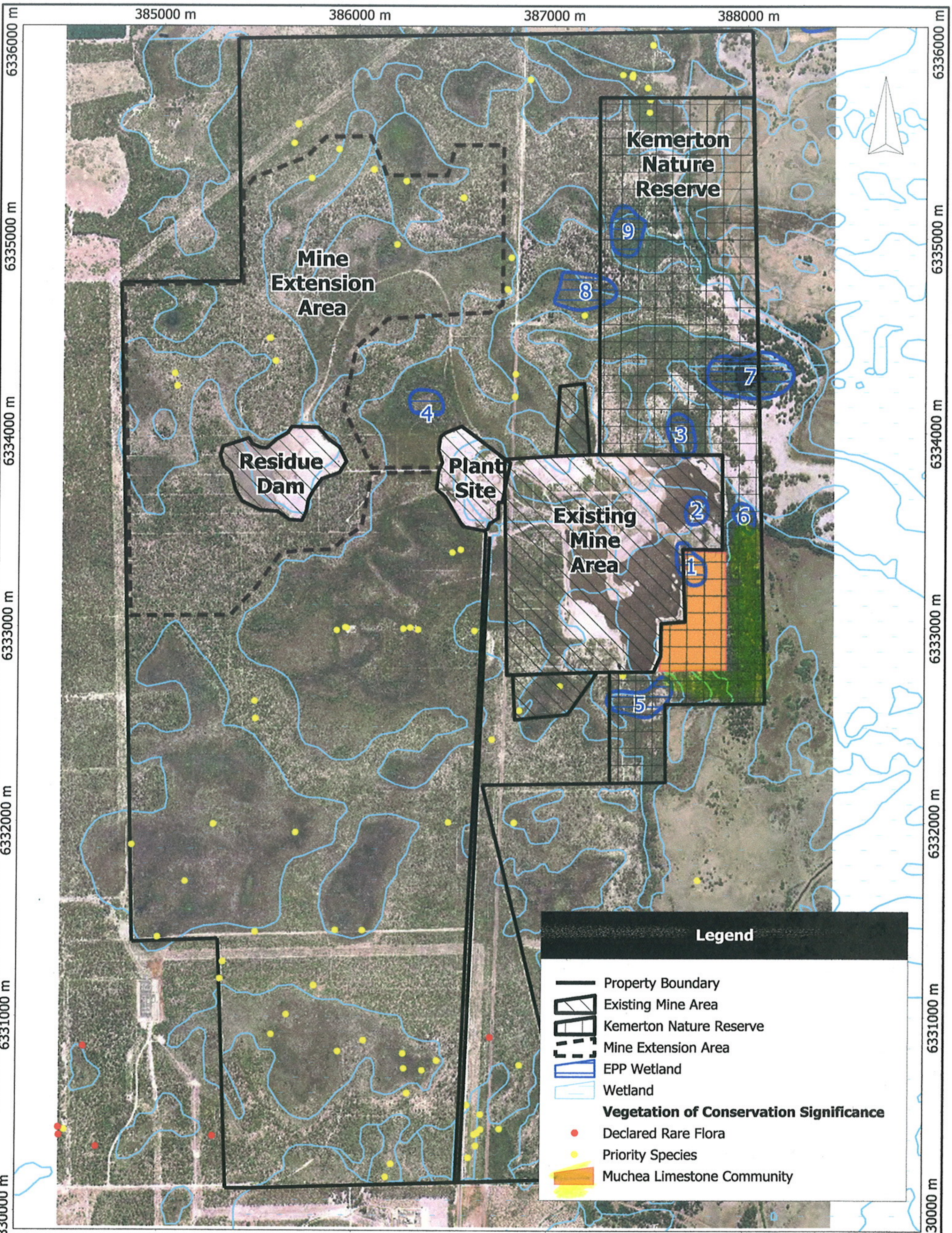
The location of conservation significant vegetation in the KSS property is shown in Figure 10. This comprises:

- Species of conservation significance (DRF and Priority species).
- Threatened Ecological Communities (TEC).
- Significant communities which have similarities to TEC (See Section 4.6.7).
- Trees with hollows suitable for Cockatoos.
- Trees with hollows suitable for other vertebrate fauna.

4.6.4 Species of Conservation Significance

Species of flora are defined as Vulnerable, Endangered or Critically Endangered under the *EPBC Act* or Rare or Priority conservation status under the *WC Act*, where their populations are restricted geographically or threatened by local processes.

Threatened species are gazetted under Subsection 18 of Subdivision C of the *EPBC Act* and actions which may or are likely to have a significant impact on listed threatened species or endangered communities are prohibited without approval.



Environmental + Water Resource Consultants MBS ENVIRONMENTAL 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:25000 Original Size: A4 Air Photo Date: 2006 Grid: MGA94(50) 0 500 m	Kemerton Silica Sand Pty Ltd	Vegetation of Conservation Significance Figure 10

W:\Kemerton Silica Sand\Drawings\Maps 2009\Flora and Wetlands.map 19/02/2009 All Conservation Significance Layout

Rare Flora species are gazetted under Subsection 2 of Section 23F of the *WC Act* and therefore it is an offence to remove or damage Rare Flora without ministerial approval. Priority Flora are under consideration for declaration as Rare Flora and are in urgent need of further surveys (P1 to P3) or require monitoring every five to 10 years (P4). DEC recognises these threats of extinction and applies regulations towards population and species protection. Table 10 presents definitions of Declared Rare and the four Priority ratings under the *WC Act* and categories of threatened species under the *EPBC Act.*

A search of the *EPBC Act* Protected Matters search tool managed by DEWHA was undertaken on 12th February 2009. Two plant species of conservation significance was potentially found in the region surrounding the KSS property, the Critically Endangered *Caladenia procera* and the Vulnerable species *Drakaea micrantha*. *Caladenia procera* is not within the mine extension area and is found at KSS within the proposed offset area. *Drakaea micrantha* has not been observed during flora surveys at the KSS property.

A search of the DEC's Threatened (Declared Rare) Flora database, the Western Australian Herbarium Specimen database for priority species opportunistically collected in the area of interest and DEC's Declared Rare and Priority Flora List managed by DEC was conducted in November 2008. The search co-ordinates used were 33°04' - 33°11' S and 115°43' - 115°50' E (GDA94). Table 11 presents the species listed by DEWHA and DEC database searches potentially being present at the KSS property. Table 11 also presents other Rare and Priority species listed in previous flora studies at the Kemerton property. A total of nine DRF, four Priority 1, four Priority 2, 17 Priority 3 and 12 Priority 4 flora species are potentially present in the region surrounding Kemerton. Of the DRF species, one is Critically Endangered, six are Endangered and three are Vulnerable. *Centrolepis caespitosa* is also listed as Endangered under the *EPBC Act,* but as Priority 4 under the *WC Act*, possibly indicating that taxonomic revision of this species is required or in process.

Table 10: Flora Conservation Category Definitions

Conservation Code	Category
West Australian *WC Act*	
R	**Declared Rare Flora – Extant Taxa** "Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection and have been gazetted as such."
P1	**Priority One – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey."
P2	**Priority Two – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but urgently need further survey."
P3	**Priority Three – Poorly Known Taxa** "Taxa which are known from several populations and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but needs further survey."
P4	**Priority Four – Rare Taxa** "Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5 - 10 years."
Commonwealth *EPBC Act*	
Extinct	Taxa where there is no reasonable doubt that the last member of the species has died.
Extinct in the Wild	Taxa where it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
Critically Endangered	Taxa that are facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
Endangered	Taxa which are not critically endangered and is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria.
Vulnerable	Taxa which are not critically endangered or endangered and is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria.
Conservation Dependent	Taxa which are the focus of a specific conservation program the cessation of which would result in the species becoming vulnerable, endangered or critically endangered; or (b) the following subparagraphs are satisfied: (i) The species is a species of fish. (ii) The species is the focus of a plan of management that provides for management actions necessary to stop the decline of, and support the recovery of, the species so that its chances of long term survival in nature are maximised. (iii) The plan of management is in force under a law of the Commonwealth or of a State or Territory. (iv) Cessation of the plan of management would adversely affect the conservation status of the species.

Table 11: Flora Species of Conservation Significance Potentially Within the KSS Property and Surrounding Region

Species	EPBC Act	WC Act	Potentially present at KSS	Present at KSS	Present within Mine Extension Area
Caladenia procera	Critically Endangered	DRF			x
Caladenia huegelii	Endangered	DRF		x	x
Centrolepis caespitosa	Endangered	P4		x	x
*Conostylis micrantha**	Endangered	DRF	x	x	x
Diuris purdiei	Endangered	DRF		x	x
Drakaea elastica	Endangered	DRF		x	x
Trithuria occidentalis	Endangered	DRF		x	x
Diuris micrantha	Vulnerable	DRF		x	x
Drakaea micrantha	Vulnerable	DRF		x	x
Diuris drummondii	Vulnerable	DRF		x	x
Boronia juncea subsp. *juncea*		P1			
Caladenia uliginosa subsp. *juncea*		P1		x	x
Carex tereticaulis		P1		x	x
Stylidium korijekup		P1		x	x
Boronia capitata subsp. *gracilis*		P2			x
Haloragis aculeolata		P2		x	x
Pterostylis frenchii #		P2		x	x
Schoenus capillifolius		P2		x	x
Acacia semitrullata		P3			
Aotus cordifolia		P3		x	x
Chamaescilla gibsonii		P3		x	x
Cyathochaeta stipoides		P3			x
Cyathochaeta teretifolia		P3		x	x
Dillwynia dillwynioides		P3			
Goodenia filiformis + 10		P3			
Grevillea prominens		P3		x	x
Hemigenia microphylla		P3		x	x
Hibbertia spicata subsp. *leptotheca*		P3		x	x
Lasiopetalum membranaceum		P3		x	x
Meionectes tenuifolia		P3		x	x
Myriophyllum echinatum		P3		x	x
Rhodanthe pyrethrum		P3		x	x

Species	EPBC Act	WC Act	Potentially present at KSS	Present at KSS	Present within Mine Extension Area
Schoenus sp. *Waroona* (GJ Keighery 12235) (pn)		P3		x	x
Stylidium trudgenii		P3		x	x
Verticordia attenuata		P3		x	x
Acacia flagelliformis		P4			x
Anthotium junciforme		P4		x	x
Caladenia longicauda subsp. *clivicola*		P4		x	x
Caladenia speciosa		P4			
Conostylis pauciflora subsp. *pauciflora*		P4		x	x
Drosera occidentalis subsp. *occidentalis^*		P4		x	x
Eucalyptus rudis subsp. cratyantha		P4			
Hemigenia platyphylla		P4		x	x
Pultenaea skinneri		P4		x	x
Senecio leucoglossus		P4		x	x
Verticordia aurea		P4		x	x

Note:

* Likely to have been mis-identified as this species is restricted to the northern sandplains around Geraldton. More likely to have been *Conostylis juncea* (See Bennett, 2004).

\+ Previously recorded as being present. Recently taxonomic division suggests that it is likely to be *Goodenia pulchella* subsp. Coastal Plain B (L. W. Sage 2336) which is not a Priority species (See Bennett, 2004).

\# Species was *Oligochaetochilus sp.* Yalgorup (G Brockman GBB463) (pn) but is now formally named as *Pterostylis frenchii.*

NO DID.

In addition to these, the Ecological Services Branch of the DEC (Keighery, 1998) suggests that other species noted as uncommon and restricted on the Swan Coastal Plain or at the southern limits of their range may occur within the KSS property. These species are associated with the Muchea Limestone TEC (Keighery and Keighery, 2003). They are:

- An unusual form of *Melaleuca systena* growing to over two metres (possibly an unnamed species of *Melaleuca* in Mattiske 1993b).
- A robust, tall form of *Melaleuca bracteosa* (referred to as *M. brachyphylla* in Keighery, 1998) an uncommon species on the Swan Coastal Plain (possibly an unnamed species of *Melaleuca* in Mattiske 1993b).
- *Hakea trifurcata,* small flowered form previously only known in the Peel-Harvey region.
- *Hibbertia perfoliata,* an uncommon poorly collected species on the plain.

Six flora species of conservation significance are found within the mine extension area: *Boronia juncea* subsp. *juncea* (P1), *Acacia semitrullata* (P3), *Dillwynia dillwynioides* (P3), *Goodenia filiformis* (P3), *Caladenia speciosa* (P4), *Eucalyptus rudis* subsp. *cratyantha* (P4).

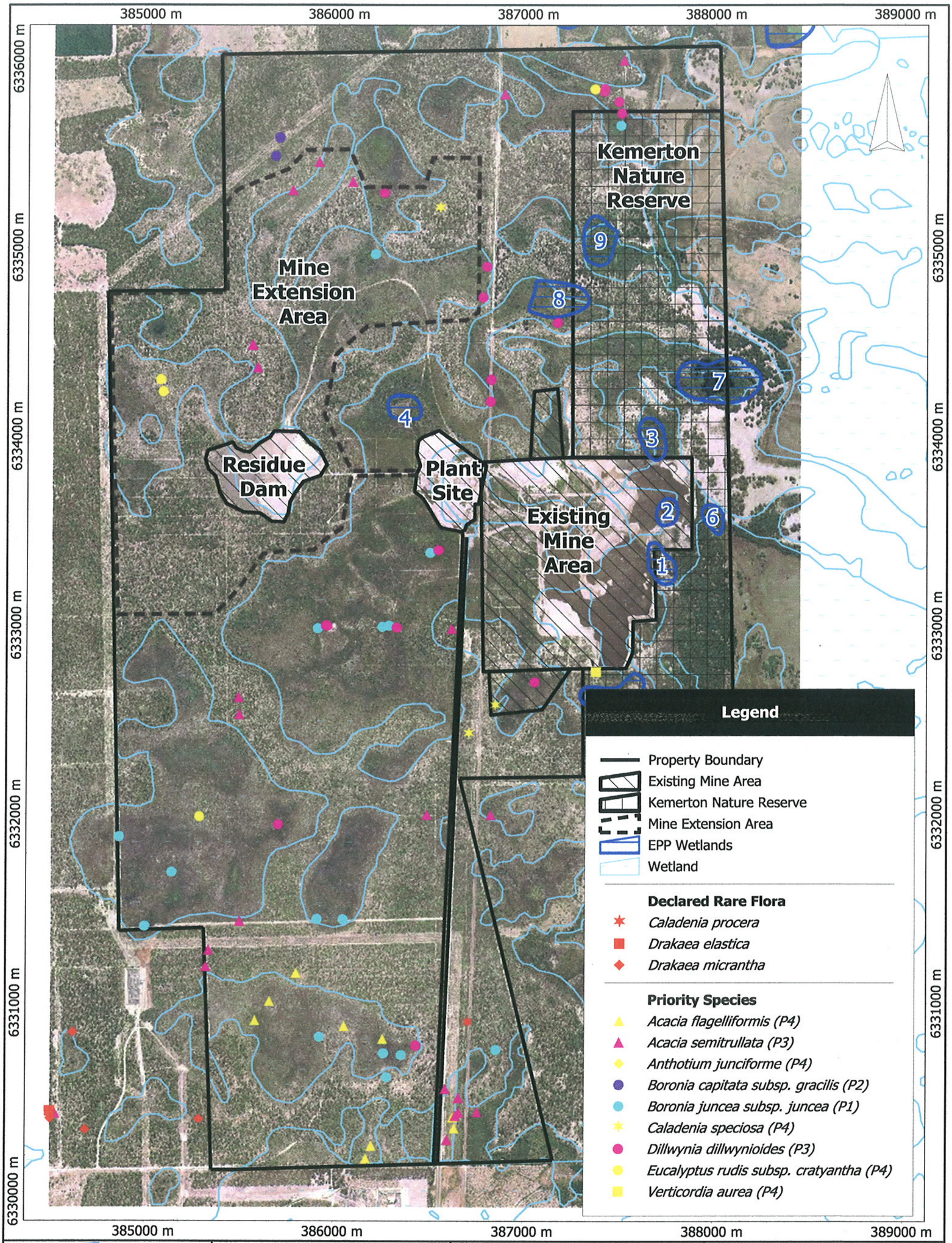
Boronia juncea subsp. *juncea* (P1) occurs in low scrub in sand between Bunbury and Mandurah, flowering in April (Mattiske, 2003b). Mattiske (1993c) located four populations in excess of 50 plants, and two of less than three plants in communities Hi, H2, F1 (and abutting F1, F3, H1 and H2). In the September 2003 survey, Bennett (2004) found the species to be common throughout many wetlands where standing water was present. Around 100 individuals of this species was recorded at Map Grid of Australia (MGA) 50 6334965 N 386199 E in the mine extension area (Bennett, 2004). *Boronia juncea* subsp. *juncea* (P1) has been recorded at 27 other locations across the KSS property. This species is relatively common throughout the region (Bennett, 2004, Appendix B).

Acacia semitrullata (P3) has been found in wetland areas and sandplains in white/grey sand. The flowering period is June to August. Mattiske (2003b) recorded this species throughout the KSS property. Muir Environmental (Muir) (1999) recorded populations along swamp fringes and damplands. During the Bennett (2004) survey, *Acacia semitrullata* (P3) was found to be very common throughout damp and slightly higher ground within the KSS property. It also occurs as scattered plants throughout the KSS property. This species has been recorded in four locations in the mine extension area. Fifty-five individuals of *Acacia semitrullata* (P3) from four locations (Figure 11) will be taken through progressive mining at KSS. *Acacia semitrullata* (P3) is very common throughout the KSS property, including good populations in the proposed offset areas.

Dillwynia dillwynioides (P3) was located by Bennett (2004) in areas that were currently or recently in standing water. Around 10 individuals of *Dillwynia dillwynioides* (P3) occurs at one site in the proposed mine extension area (Appendix 5, Figure 11). *Dillwynia dillwynioides* (P3) is common throughout wetlands on the KSS property with a further 22 sites recorded with many sites with good populations in excess of 20 individuals (Bennett, 2004).

Goodenia filiformis (P3) was located by Mattiske (1993b, c) within the KSS property, however, this taxon may not occur in the area due to taxonomic changes since work has been undertaken (Bennett, 2004). It was not recorded during the 2003 surveys by Bennett (2004). *Goodenia filiformis* (P3) is only found near Albany (Bennett, 2004). The species located by Mattiske (1993b, c) within the KSS property is likely to be *Goodenia pulchella* subsp. Coastal Plain B (L.W. Sage 2336) and is not a Priority species (L. Sage, pers. Comm. in Bennett, 2004).

Caladenia speciosa (P4) (Sandplain White Spider orchid) inhabits Eucalypt and *Banksia* woodlands in the uplands above paperbark swamps on white, grey or black sand (Mattiske, 2003b). The flowering period is September to October. Mattiske (1993c) recorded this species within the KSS property. *Caladenia speciosa* (P4) was recorded from two sites during the 2003 surveys. One individual of this species was recorded in the mine extension area (Figure 11). A further two individuals were located in the central eastern part of the property (Figure 11, Bennett, 2004).



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Scale: 1:25000
Original Size: A4
Air Photo Date: 2006
Grid: MGA94(50)
0 500 m

Kemerton Silica Sand Pty Ltd

Distribution of Species of Conservation Significance

Figure 11

W:\Kemerton Silica Sand\Drawings\Maps 2009\Flora and Wetlands.map 18/02/2009 Conservation Significance Layout

Eucalyptus rudis subsp. *cratyantha* (P4) was located by Bennett (2004). Often this species occurs as an individual tree, but it was also found in a few locations where it was the dominant tree in the upper storey, particularly in the northern section east of the limestone track (Figure 11). This species has been recorded in two locations in the mine extension area with 10 and 11 individuals recorded at these sites (Bennett, 2004, Appendix B, Figure 11). A further two locations of *Eucalyptus rudis* subsp. *cratyantha* (P4) are recorded outside the mine extension area with 10 and 15 species at these sites.

A further four flora species of conservation significance have been recorded within the KSS property: *Caladenia procera* (DRF, Critically Endangered), *Boronia capitata* subsp. *gracilis* (P2), *Cyathochaeta stipoides* (P3) and *Acacia flagelliformis* (P4).

Caladenia procera (DRF) Carbunup King Spider orchid was located just off proposed natural gas pipeline corridor from Dampier to Bunbury corridor within the south-eastern corner of the KSS property (Woodman, 2005a) (Figure 11). This location is removed from the mine extension area and will not be disturbed. The location is further discussed in Section 10.

Boronia capitata subsp. *gracilis* (P2) inhabits winter wet swamps and hillsides in white/grey or black sand between Yarloop and Yallingup (Mattiske, 2003b). Mattiske (2003b) recorded this species once on the KSS property in 1993. Bennett (2004) recorded *Boronia capitata* subsp. *gracilis* (P2) along the south-west/north-east power line track in the northern area of the property. There were hundreds of plants in the area, which had recently been disturbed for power line access. The site where Mattiske (2003b) recorded the species was thoroughly searched, but *Boronia capitata* subsp. *gracilis* (P2) was not recorded at this location by Bennett (2004). This plant appears to be a disturbance specialist and it is possible that if the area was disturbed again the plant would return (Bennett, 2004). The species has not been found in the mine extension area.

NOT CORRECT.

Cyathochaeta stipoides (P3) was found in wetland adjacent to the north margin of the dredge pond by Keighery (1998). Bennett (2004) was unable to relocate this species and believe it is likely restricted to the area of Muchea limestone.

Acacia flagelliformis (P4) inhabits sandy soils in winter wet areas, flowering between July and September. Mattiske (1993a, b, c, d) recorded this species twice within the KSS property. It was also recorded in Kemerton industrial park by Muir (1999) in a post-fire dampland complex of *Melaleuca pressiana*, *Calothamnus lateralis* and *Hakea varia*. Muir (1999) considers that other damplands are likely to contain dormant seeds of this species. During the Mattiske (2003b) surveys, *Acacia flagelliformis* (P4) was recorded as reasonably common in the southern section of the KSS property, only being recorded in the wetland to the south of the powerline track on both the east and west sides of the KSS site access road. The species has not been found in the mine extension area.

Species not of conservation significance, but of interest due to their presence at the KSS property and region include:

LOCATION

- *Banksia menziesii* (southern extension). One plant was observed just outside the area surveyed to the east of the fence line, south of the powerline track by Bennett (2004). Mattiske (2003b) observed *Banksia menziesii* in community A3 and G1. The closest known population occurs in the Peel area (Mattiske, 2003b).

Collection.

- *Verticordia nitens* (southern extension) is common north of Perth but only know from two other areas south of Perth (Mattiske, 2003b). *Verticordia nitens* (southern extension) was recorded to the east of the access road and to the south of where mining is currently occurring by Bennett (2004). Mattiske (2003b) located *Verticordia nitens* in community A3. Bennett (2004) reports that it is likely that *Verticordia nitens* may be associated with the limestone (Muchea Limestone TEC) which occurs in this area as it was not recorded in other areas of the KSS property.
- *Evandra pauciflora* was recorded in many of the wetlands; either as the dominant species or as scattered plants through the wetland (Bennett, 2004). *Evandra pauciflora* is a distinguishing sedge that grows in wetlands in this region and was common in community H1 (Mattiske, 2003b).

Fieldwork undertaken between 22 to 26 September, 15 to 17 October and 3 to 5 November 2003 by Bennett (2004) found that Kemerton Nature Reserve supports species different to those in the remainder of the property. *Gahnia trifida* was recorded in one of the vegetation units at the northern area of the property to the east of the limestone track.

?

4.6.5 Threatened Ecological Communities and Priority Ecological Communities

A search was undertaken of DEC's Threatened Ecological Communities (TECs) database in November 2008. The search co-ordinates used were 33°04' - 33°11' S and 115°43' - 115°50' E (GDA94). Two TECs and one PEC occur in the region surrounding KSS:

- Muchea Limestone – Shrublands and woodlands on Muchea Limestone (TEC Endangered).
- Dense shrublands on clay flats (SCP09) (TEC Vulnerable).
- Northern Spearwood shrublands and woodlands (SCP24) (PEC Priority 3).

7

Muchea Limestone
The Muchea Limestone TEC is listed as Endangered B) ii under Western Australia criteria and Endangered under the *EPBC Act*. An ecological community is listed as Endangered when it has been adequately surveyed and is not Critically Endangered, but is facing a very high risk of total destruction in the near future.

Dense shrublands on clay flats (SCP 9)
This TEC is listed as Vulnerable under the WA state criteria. This TEC is located to the northeast of the property. There are no known occurrences of this TEC on the KSS property.

Northern Spearwood shrublands and woodlands (SCP 24)
This PEC is listed as Priority 3 under WA state criteria. This PEC is characterised by heaths with scattered *Eucalyptus gomphocephala* occurring on deeper soils north from Woodman Point. Most sites occur on the Cottesloe unit of the Spearwood system. The heathlands in this group typically include *Dryandra sessilis, Calothamnus quadrifidus*, and *Schoenus grandiflorus*. There are no known occurrences of this TEC on the KSS property.

4.6.6 Flora

A total of 65 families, 174 genera and 365 plant taxon (including varieties and subspecies) have been recorded on the KSS property (Mattiske, 2003b). Species representation was highest in the Papilionaceae (37 taxon), Myrtaceae (37 taxon), Proteaceae (18 taxon) and Cyperaceae (16 taxon) families. This flora composition is typical of the Bassendean - Central and South vegetation complex described by Heddle *et al.* (1980). Wetland systems were found to be dominated by species from the Restionaceae, Cyperaceae and Myrtaceae families.

4.6.7 Vegetation Communities at KSS

Vegetation within the KSS property was mapped at a detailed level (1:10,000) by Mattiske (1993a, b, c, d). This defined a total of 24 vegetation communities and 27 vegetation mapping units with three of the mapping units comprising disturbed stages of vegetation communities (Mattiske, 2002c). The main communities are:

- Upper slope Open Woodland dominated by *Eucalyptus marginata*, *Banksia* spp. and *Kunzea ericifolia* over *Stirlingia latifolia* and mixed shrubs over *Dasypogon bromelifolius*.
- Lower slope Open Woodland of *E. marginata* - *Banksia* spp. and *Kunzea ericifolia* over *Melaleuca thymoides*, *Calytrix fraseri* and mixed low shrubs.
- Closed heath of *Astartea scoparia*, *Calothamnus lateralis* and *Cassytha racemosa* over mixed sedges, ranging from partially cleared to relatively pristine. The area also contains wetland vegetation.
- Low closed heath of *Pericalymma ellipticum* and *Hypocalymma angustifolium* over mixed shrubs and mixed sedges, with occasional emergent trees.

The vegetation communities present within the KSS property are presented in Table 12. The distribution of vegetation communities within the KSS property is show in Figure 12. Vegetation communities C3, D1, F2 and G2 located in Kemerton Nature Reserve have not been shown.

Mattiske (2009) conducted detailed statistical similarities and association measures to determine the conservation status of the vegetation communities at KSS in light of the recent TEC and PEC listings. The results indicate very low similarities between the communities defined by Mattiske (2003b) in previous mapping and the Swan Costal Plain dataset (Gibson *et al.* 1994) as defined utilizing the Sorenson's Similarity Index or the PATN analyses (Belbin 1995, Mattiske, 2009) (Table 13, Appendix 6). There are some similarities between the communities, but they are not necessarily directly comparable. The presence of some dominant species or species that reflect seasonal swamps do not necessarily indicate a presence of the respective TEC or PEC's. The patterns appear to relate to the continuum nature of many species across the landscape and the need to rely on presence/absence data only (rather than quantitative and structural dominance).

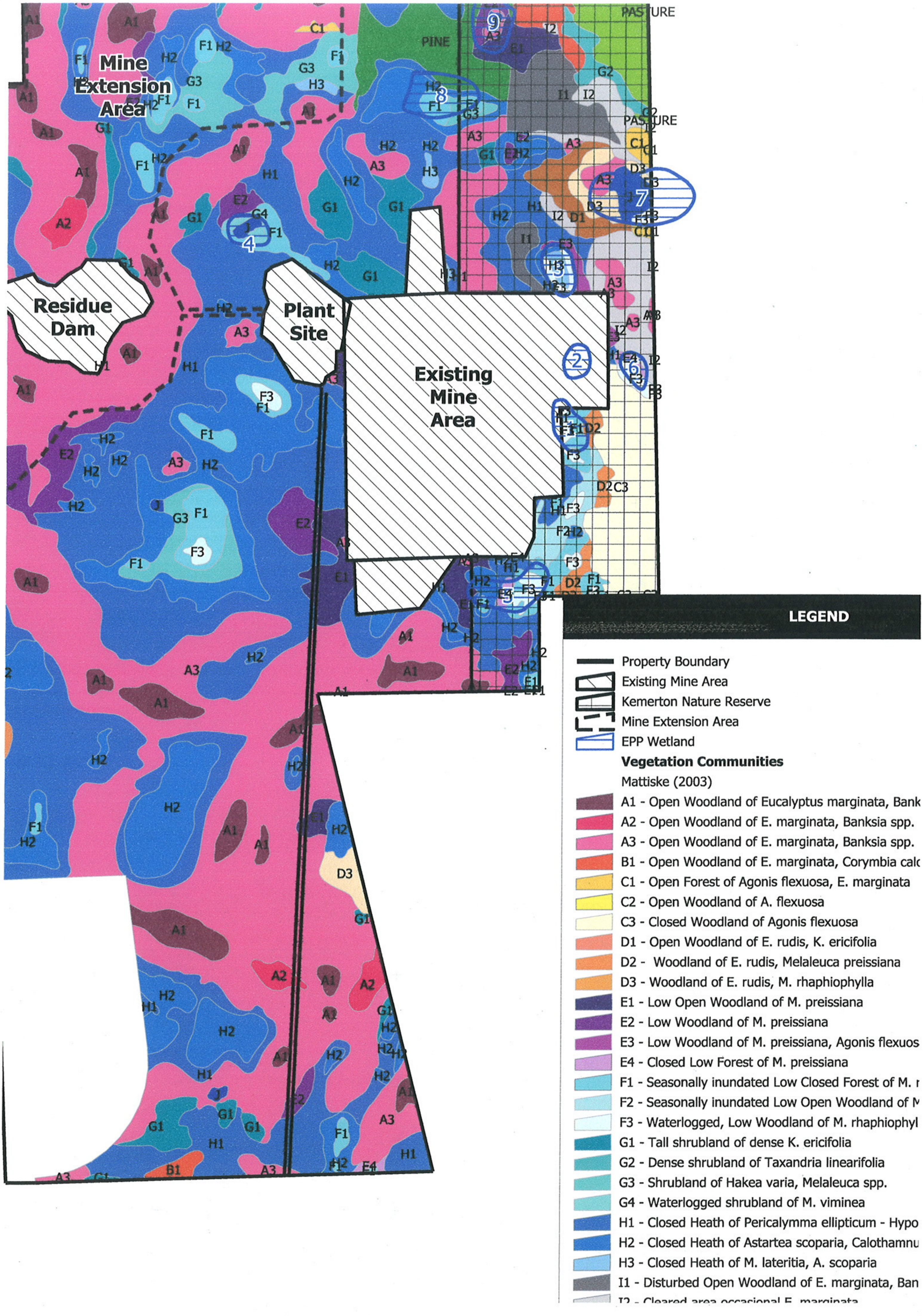

Mine Extension Area
Residue Dam
Plant Site
Existing Mine Area
PINE
PASTURE
PASTURE
LEGEND
Property Boundary
Existing Mine Area
Kemerton Nature Reserve
Mine Extension Area
EPP Wetland
Vegetation Communities
Mattiske (2003)
A1 - Open Woodland of Eucalyptus marginata, Bank
A2 - Open Woodland of E. marginata, Banksia spp.
A3 - Open Woodland of E. marginata, Banksia spp.
B1 - Open Woodland of E. marginata, Corymbia calc
C1 - Open Forest of Agonis flexuosa, E. marginata
C2 - Open Woodland of A. flexuosa
C3 - Closed Woodland of Agonis flexuosa
D1 - Open Woodland of E. rudis, K. ericifolia
D2 - Woodland of E. rudis, Melaleuca preissiana
D3 - Woodland of E. rudis, M. rhaphiophylla
E1 - Low Open Woodland of M. preissiana
E2 - Low Woodland of M. preissiana
E3 - Low Woodland of M. preissiana, Agonis flexuos
E4 - Closed Low Forest of M. preissiana
F1 - Seasonally inundated Low Closed Forest of M. r
F2 - Seasonally inundated Low Open Woodland of M
F3 - Waterlogged, Low Woodland of M. rhaphiophyl
G1 - Tall shrubland of dense K. ericifolia
G2 - Dense shrubland of Taxandria linearifolia
G3 - Shrubland of Hakea varia, Melaleuca spp.
G4 - Waterlogged shrubland of M. viminea
H1 - Closed Heath of Pericalymma ellipticum - Hypo
H2 - Closed Heath of Astartea scoparia, Calothamnu
H3 - Closed Heath of M. lateritia, A. scoparia
I1 - Disturbed Open Woodland of E. marginata, Ban

Table 12: Description of Vegetation Communities Occurring Within the KSS Property

Community	Description
A	
A - 1	Upper slope Open Woodland dominated by *E. marginata - B. attenuata – B. ilicifolia* and *Kunzea ericifolia* over *Stirlingia latifolia, Calytrix fraseri, Adenanthos meisneri* and mixed shrubs over *Dasypogon bromeliifolius.*
A - 2	Upper slope Open Woodland of *E. marginata - B. attenuata - K. ericifolia* over *Allocasuarina humilis, Stirlingia latifolia* and mixed shrubs.
A - 3	Lower slope Open Woodland of *E. marginata - B. attenuata – B. ilicifolia* and *K. ericifolia* with occasional *Nuytsia floribunda* and *Corymbia calophylla* over *Melaleuca thymoides, Calytrix fraseri, Acacia pulchella* and mixed shrubs.
B	
B - 1	Open Woodland of *E. marginata - Corymbia calophylla* and *K. ericifolia* over *Pericalymma ellipticum* and *Acacia pulchella* over Poaceae spp.
C	
C - 1	Open Forest of *Agonis flexuosa - E. marginata* over grasses.
C - 2	Open Woodland of *Agonis flexuosa* with occasional *B. attenuata, B. ilicifolia* and *Nuytsia floribunda* over mixed shrubs.
C - 3	Closed Woodland of *Agonis flexuosa - Corymbia calophylla - E. rudis* with occasional *B. littoralis*, over *Xanthorrhoea preissii, Macrozamia reidlei* and sparse mixed shrubs and sedges.
D	
D - 1	Open Woodland of *E. rudis* and *K. ericifolia* over *Hypocalymma angustifolium, Xanthorrhoea preissii* and mixed shrubs over mixed grasses and sedges.
D - 2	Woodland of *E. rudis - Melaleuca preissiana* and occasional *B. littoralis* over *Myrtaceae* spp. over mixed sedges.
D - 3	Woodland of *E. rudis - M. rhaphiophylla* over *M. teretifolia* and *Astartea scoparia* over *Lepidosperma longitudinale.*
E	
E - 1	Low Open Woodland of *M. preissiana* and occasional *E. marginata* and *Kunzea ericifolia* over *Hypocalymma angustifolium* and *Calytrix* spp. over *Dasypogon bromeliifolius.*
E - 2	Low Woodland of *M. preissiana* and occasional *Nuytsia floribunda* over *Hypocalymma angustifolium, Pelicalymma ellipticum* and mixed shrubs over mixed sedges.
E - 3	Low Woodland of *M. preissiana* and *Agonis flexuosa* over *Astartea scoparia* and mixed shrubs over *Lepidosperma longitudinale.*
E - 4	Closed Low Forest of *M. preissiana*, with occasional *Corymbia calophylla* over dense *Taxandria linearifolia* over *Pteridium esculentum* and dense *Lepidosperma longitudinale.*
F	
F - 1	Seasonally inundated Low Closed Forest of *M. rhaphiophylla* over *Myrtaceae* spp. over mixed sedges.
F - 2	Seasonally inundated Low Open Woodland of *M. rhaphiophylla* over *M. viminea* and *M. cuticularis* over mixed shrubs over mixed sedges.
F - 3	Waterlogged, Low Woodland of *M. rhaphiophylla* over *Baumea articulata.*
G	
G - 1	Tall shrubland of dense *K. ericifolia* over *Hypocalymma angustifolium* and mixed shrubs over *Meeboldina scariosa.*
G - 2	Dense shrubland of *Taxandria linearifolia*, with occasional *E. marginata* over grasses.
G - 3	Shrubland of *Hakea varia - Melaleuca* spp. and *Astartea scoparia* over *Lepidosperma longitudinale* and *Meeboldina coangustata.*
G - 4	Waterlogged shrubland of *M. viminea.*
H	
H - 1	Closed Heath of *Pericalymma ellipticum - Hypocalymma angustifolium* shrubs over mixed shrubs over *Meeboldina scariosa*, with occasional emergent *E. marginata, B. attenuata* and *B. ilicifolia.*
H - 2	Closed Heath of *Astartea scoparia – Calothamnus lateralis* and *Cassytha racemosa* over mixed sedges.

Community	Description
H - 3	Closed Heath of *M. lateritia* and *Astartea scoparia* over *Lepidosperma longitudinale* and *Leptocarpus tenax.*
I	
I - 1	Disturbed lower slope Open Woodland of *E. marginata* and *Banksia* spp.
I - 2	Cleared area with occasional *E. marginata* over *Cartonema philydroides.*
I - 3	Regenerating community beneath power line. Sparse *K. ericifolia* over *Aotus gracillima, Pimelea angustifolia* and *Pericalymma ellipticum* over mixed sedges.

4.6.7.1 Muchea Limestone Threatened Ecological Community (TEC) at KSS

The area of Muchea Limestone TEC within the KSS property was located during a brief field survey by Department of Environmental Protection staff in 1997 (Keighery, 1998). Subsequent work in the area by Muir (1999) and Mattiske (2003b) did not identify any additional areas or extension of the known area.

Keighery and Keighery (2003) visited Kemerton Nature Reserve adjacent to the KSS property in September 2003 to begin detailed documentation of the Muchea Limestone community in this area. The work focused on:

- Estimating the area in which limestone was most apparent in soils.
- Location of a transect of plots to be established in late spring/early summer.

Preliminary mapping of the Muchea Limestone TEC area was determined based on the extent of *Eucalyptus decipiens* and *Corymbia calophylla* dominated native vegetation associated with Muchea Limestone soils with surface or near surface limestone in the KSS property (Keighery, 1998). The Muchea Limestone TEC of Kemerton Nature Reserve is the southern most known location of this community. As a result, further work was undertaken in October and November 2003 and February 2004.

The known extent of vegetation associated with the Muchea Limestone's soil with surface or near surface limestone in the Kemerton region is located between 33°08.161" and 115°47.871" and 33°08.353" and 115°47.868" (Figure 10). Species associated with Muchea Limestone at Kemerton include *Eucalyptus decipiens, Pimelea rosea, Austrostipa flavescens, Gahnia trifida, Verticordia nitens* and *Logania vaginalis* (Keighery and Keighery, 1995). All but one of these species has been identified in the area shown on Figure 10. The uncommon taxa restricted to the Swan Coastal Plain (Keighery and Keighery, 2003) listed in Section 4.6.4 are also found within this TEC at KSS.

Ministerial Statement 703 documented the area of land containing the Muchea Limestone TEC as the subject of a land swap in 2005 which saw 15.6 hectares excised from the approved mine area and added to Kemerton Nature Reserve. Two areas totalling 13.2 hectares were added to the approved mine area to replace this excised portion. This work identified the extent of the communities accepted as being Muchea Limestone.

NO!!!

No
new species

Table 13: Comparison of Vegetation Communities at KSS with Gibson *et al.* (1994)

Comparison with Floristic Community Type[2]			Comments[4]
Mattiske 2009 comparison with Gibson[3]	EPASU comments to Draft PER	TEC/PEC status	
21a			Some similarity with dominants
21a			Some similarity with dominants
21a			Some similarity with dominants
	1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain
	21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra I
	21b	PEC - Priority 3	Not 21b as 21b on Ridge Hill and Pinjarra I
11	1b	TEC Vulnerable	Not 1b as 1b on Pinjarra Plain, some overla
11			Some similarity with dominants
4	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants, question o
12			Some similarity with dominants
4			Some similarity with dominants
4			Some similarity with dominants
4			Some similarity with dominants
4			Some similarity with dominants
12	Muchea Limestone	TEC Endangered State & Federal	Some similarity with dominants
	7	TEC Vulnerable	7 on Pinjarra Plain, some similarity with do
13	Muchea Limestone	TEC Endangered State & Federal	7 on Pinjarra Plain, 13 due to dominance of
5/11			Differences based on dominance of shrubs
5/11			Differences based on dominance of shrubs
5/13			Differences based on dominance of shrubs
	7	TEC Vulnerable	7 on Pinjarra Plain
5/11			Differences based on dominance of shrubs
5/11			Differences based on dominance of shrubs
5/12			Some similarities with 5 and 12 based on d
21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge
21a	21b	PEC - Priority 3	Disturbed and Degraded 21a, 21b on Ridge

Comparison with Floristic Community Type[2]			Comments[4]
Mattiske 2009 comparison with Gibson[3]	EPASU comments to Draft PER	TEC/PEC status	
Disturbed 21a			Disturbed and Degraded

(1993a, b, c).
t al. (1994).
(2009).
' similarities and unclear associations were observed in analyses and therefore there have been variable interpretations on the PEC and TEC' the reliance on different qualitative measures.

There has been considerable debate concerning the possible presence of Muchea Limestone in the western area of the property within plant community types D-2, F-1 and F-3. Besides *Eucalyptus decipiens* within community D2, none of the species listed in the Interim Recovery Plan for the Muchea Limestone are similar to those listed in any other community at Kemerton (Table 14). Furthermore, according to Keighery (1998) out of the species associated with the Muchea Limestone at KSS, only *Gahnia trifida* and *Logania vaginalis* were recorded with community D2. Keighery (1998) claims that *Melaleuca acerosa* [*Melaleuca systena*] or *M. brachyphylla* [not on Florabase] are possibly an unnamed species of *Melaleuca* in Mattiske (1993b); however neither of these unidentified species was recorded in D2 or F1 or F3.

Table 14 Taxa Present in Muchea Limestone TEC and Comparison with KSS Vegetation Communities

Taxa	Muchea Limestone IRP	KSS Muchea Limestone Keighery 1998	Mattiske Vegetation Communities		
			D2	F1	F3
Acacia leptospermoides ssp. *Leptospermoides*					
Allocasuarina lehmanniana					
Alyogyne huegelii var. huegelii					
Apium annuum					
Austrostipa flavescens					
Baeckea robusta					
Boronia juncea subsp. *juncea* (P1)					
Casuarina obesa					
Comesperma integerrimum					
Conostylis candicans					
Darwinia foetida (R)					
Diplopeltis huegelii					
Dodonaea aptera					
Eucalyptus decipiens					
Eucalyptus foecunda					
Exocarpos sparteus					
Gahnia trifida					
Goodenia filiformis (P3)					
Grevillea curviloba subsp. *curviloba* (R)					
Grevillea curviloba subsp. *incurva* (R)					
Grevillea evanescens (P1)					
Hakea trifurcata					
Haloragis aculeolata (P2)					
Hibbertia perfoliata					
Hibbertia spicata subsp. *spicata*					

Taxa	Muchea Limestone IRP	KSS Muchea Limestone Keighery 1998	Mattiske Vegetation Communities		
			D2	F1	F3
Lechenaultia linarioides					
Logania vaginalis					
Melaleuca huegelii					
Melaleuca systena					
Pimelea ferruginea					
Pimelea rosa					
Poa ?porphyroclados					
Sencio spanomerus					
Stylobasium australe					
Thysanotus arenarius					
Wilsonia humilis					

The mine extension area, while containing areas of D2, F1 and F3, does not contain plant associations that define these areas as TEC of Muchea Limestone. *Eucalyptus decipiens* at KSS is restricted to the area defined as Muchea Limestone within the Kemerton Nature Reserve (Libby Mattiske, 2009, *pers. comm.*). Whilst *Eucalyptus decipiens* was only recorded within the Muchea Limestone area within the nature reserve, *Eucalyptus decipiens* is not restricted to limestone and is relatively widespread (Mattiske, 2009). According to the Interim Recovery Plan, the Muchea Limestone TEC "occurs on soils mapped as Muchea Limestone or Plain limestone deposits" (page 3). The ASS investigation of the proposed extension area only located limestone at a depth of 32 metres at Hole 6. All other sites sampled did not find limestone, were sands and encountered shells between 26 – 34 metres below the surfaces (Appendix 1).

! Talk to BK

4.6.8 Species Richness

Species richness is defined as a measure of the number of plant species present within a specific area. Table 15 shows the species richness of the floristic communities mapped by Mattiske (1993c). As reported in Mattiske (2003a), high species diversity is considered to be 25 to 30 perennial species per 100 square metres. A large portion of vegetation communities recorded on the KSS property is highly diverse, as indicated in Table 13.

no

4.6.9 Weeds

A total of 58 weed species have been recorded on the KSS property during vegetation surveys. Weed species were most numerous in the Asteraceae (11 taxon), Poaceae (10 taxon) and Papilionaceae (seven taxon) families. The complete list of species identified in the survey is presented in Appendix 4. Weed encroachment into bushland areas has been observed as low with the exception of tracks, and pasture and cleared areas adjacent to farming properties (Mattiske, 2003b).

Table 15: Species Richness of Vegetation Communities at the KSS Property

Not PEC's

Vegetation Community	Floristic Type [1]	Species Richness [2]
A1	21a	71
A2	21a	46
A3	21a	117
B1	-	36
C1	21b	18
C2	21b	17
C3	11	27
D1	11	16
D2	4	57
D3	12	14
E1	4	28
E2	4	36
E3	4	13
E4	4	9
F1	12	53
F2	7	13
F3	13	7
G1	11	73
G2	11	18
G3	13	19
G4	7	1
H1	11	91
H2	11	54
H3	12	14
I1	21b	-
I2	21b	-
I3	11	-

1 Mattiske (2003b) Table 4
2 Mattiske (2002c) Table 4

The most common weed species are annuals or short lived perennials, dominated by *Briza maxima* (Blowfly grass), *Briza minor* (Shivery grass), *Hypochaeris glabra* (Smooth catsear) and *Lagurus ovatus* (Hairs tail grass).

Five aggressive weed species have been recorded at the KSS property:

- *Gomphocarpus fruticosus* (Cotton Bush) (P1 and P4 requirements), a Declared Plant pursuant to section 37 of the *Agriculture and Related Resources Protection Act, 1976*:
  - P1 requirements - The movement of plants or their seeds is prohibited within the state. This prohibits the movement of contaminated machinery and produce including livestock and fodder
  - P4 requirements - The infested area must be managed in such a way that prevents the spread of seed or plant parts within and from the property on or in

livestock, fodder, grain, vehicles and/or machinery. Treat to destroy and prevent seed set all plants:

- Within 100 metres inside of the boundaries of the infestation.
- Within 50 metres of roads and high water mark on waterways.
- Within 50 metres of sheds, stock yards and houses.

Cotton Bush control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing.

- *Typha occidentalis* (Bullrush) occurs seasonally in inundated woodlands. Mattiske (2003b) reported that the disused settling pond is a major area of *Typha orientalis* invasion. Typha control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing.
- *Watsonia meriana* var. *bulbillifera* (Bulbil Watsonia) on the lower slopes of *E. marginata- Banksia* spp. Woodlands. Control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing.
- *Chamaecystis palmensis* (Tagasaste) in cleared pasture areas. Control programs have been implemented across the KSS property and have successfully managed infestations. Weed management is ongoing.
- *Centaurea melitensis* (Maltese Cockspur). Control programs have been implemented across the KSS property

4.7 DIEBACK STATUS

Phytophthora cinnamomi is a soil borne fungus that is a major plant pathogen in the south west of Western Australia. It is the cause of the plant disease known as dieback. Dieback mapping of the KSS property undertaken by the Department of Conservation and Land Management (CALM) in 2002 indicated that approximately 75% of the property is either dieback infested or can not be protected from dieback. The location of dieback infested and unprotectable areas within the KSS property is shown in Figure 13. The main areas of dieback free and protectable land are the larger Bassendean Dunes. Wetland and lowland areas of the property are either already infested or are unprotectable from the natural spread of the fungus.

The main dieback management tool used on-site is quarantine. Site activities are concentrated around the dredge pond and plant site. With the exception of access to production and monitoring bores, there is no reason for access to other parts of the property. Movement of vehicles into non-production areas of the property is restricted, with permission required from the General Manager with access only made on existing tracks.

4.8 FIRE HISTORY

There have been no fires on the KSS property for the past 15 years apart from a small lightning fire just north of EPP4 which burnt about 2.4 hectares on 26 April 2007. This fire was actively extinguished by KSS.

8. ENVIRONMENTAL PROTECTION AND BIODIVERSITY CONSERVATION ACT TRIGGERS

Matters protected by the Commonwealth *EPBC Act* are known as matters of National Environmental Significance and include:

- World and National Heritage Places.
- Wetlands of International Importance.
- Listed Threatened species.
- Listed migratory species.
- Nuclear actions.
- Commonwealth Marine Area.

The KSS project was deemed a Controlled Action under the *EPBC Act* on 14 March 2003. The controlling actions triggered by the proposal are:

- Wetlands of International Importance (Sections 16 and 17B).
- Listed Threatened species and communities (Sections 18 and 18A).
- Listed migratory species (Sections 20 and 20A).

8.1 POTENTIAL SOURCES OF IMPACT TO MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

Potential sources of impact to Wetlands of International Importance, listed Threatened species and listed migratory species were identified in Section 8.2.1, 8.2.2 and 8.2.3 respectively. In summary the key potential sources of impact to matters of National Environmental Significance include:

- Clearing of about 264 hectares of land resulting in temporary and in some instances permanent loss of vegetation and habitat.
- Altered vegetation distribution patterns post rehabilitation. Rehabilitated landforms and associated vegetation will differ in total area compared to the pre-existing condition (Table 47).
- Change in post mining landform to create permanent lakes with fringing ephemeral wetlands. This will result in reduced upland habitats compared to the existing landform.

8.2 ASSESSMENT OF POTENTIAL RISKS AND IMPACTS

8.2.1 Wetlands of International Importance

The KSS extension area occurs on the Swan Coastal Plain, bound by Wellesley River to the east and south-east, and Harvey River to the north of the property. The Peel-Yalgorup system is listed as a Wetland of International Importance under the 1971 Ramsar Convention on

Wetlands, especially as a habitat for Waterfowl. This site lies about five kilometres to the north-west of the KSS extension area and is separated from the mine by Harvey River.

The Peel-Yalgorup system incorporates the largest and most diverse estuarine complex in south-west Australia and is an important area for waterbirds. The system supports more than 20,000 waterbirds annually with in excess of 150,000 birds recorded on an individual occasion (Ramsar Convention of Wetlands, 2005). The Peel-Yalgorup system regularly hosts over 1% of the populations of at least six migratory shorebird species including Red-necked Avocet (*Recurvirostra novaehollandiae*), Red-necked Stint (*Calidris ruficollis*), Red-capped Plover (*Charadrius ruficapillus*), Banded Stilt (*Cladorhynchus leucocephalus*), Caspian Tern (*Sterna caspia*) and Fairy Tern (*Sterna nereis*) (Ramsar Convention of Wetlands, 2005). Of these, only the Red-capped Plover (*Charadrius ruficapillus*) has been recorded in the Kemerton region and is expected to occur on the KSS property (Bamford and Bamford, 2003).

Groundwater level data from the KSS mine site indicates that groundwater flow is in a south-east direction towards Wellesley River, which lies between KSS and Benger Swamp (GHD, 2002). The Harvey River forms a hydraulic barrier between the KSS site and the Peel-Yalgorup system. The addition of permanent water bodies within the post-mining landscape has the potential to provide an additional summer refuge for waterbirds, adding conservation value to this area (Bamford and Bamford, 2003). This is highly likely to occur given the current use of the existing dredge pond by Pacific Black Ducks, Australian Shellducks, sandpipers and plovers. Therefore the proposed mine extension is not likely to have a significant adverse impact on the ecology of the Peel-Yalgorup System. Rather, the addition of permanent water features will likely enhance the ecology of the wider region.

8.2.2 Listed Threatened Species

A search of the *EPBC Act* Protected Matters database was completed on 19 June 2002 between coordinates -33.10 degrees south, 115.80 degrees east, -33.10 degrees south, 115.77 degrees east, -33.16 degrees south , 115.76 degrees east and -33.16 degrees south , 115.79 degrees east with a one kilometre buffer. Given the time since the initial database search and preparation of this assessment document, an additional *EPBC Act* Protected Matters database search was completed on 12 February 2009 between coordinates -33.08 degrees south, 115.73 degrees east, -33.08 degrees south, 115.82 degrees east, -33.17 degrees south , 115.72 degrees east and -33.17 degrees south , 115.82 degrees east with a two kilometre buffer.

Three mammals, nine plant and two bird species listed as Threatened under the *EPBC Act* were identified as potentially occurring in the project area. Numerous flora and fauna surveys have been undertaken at KSS and the surrounding area over a number of years as described in Section 0 and 4.11.2 respectively. This included targeted surveys for the Chuditch (*Dasyurus geoffroii*), Carnaby's Black-Cockatoo (*Calyptohynchus latirostris*) and Western Ringtail Possum (*Pseudocheirus occidentalis*) and a targeted DRF and Priority flora search (Bennett, 2004). Species listed as Threatened under the *EPBC Act* likely to be found at KSS are presented in Table 60. They are discussed in more detail in the following sub sections.

Table 60: Species Listed as Threatened under the *EPBC Act* Likely to be Found at KSS

Species	Type	Common Name	*EPBC Act* Status	Recorded in Site Specific Surveys
Dasyurus geoffroii	Mammal	Chuditch	Vulnerable	x
Pseudocheirus occidentalis	Mammal	Western Ringtail Possum	Vulnerable	x
Setonix brachyurus	Mammal	Quokka	Vulnerable	x
Calyptohynchus baudinii	Bird	Baudin's Black-Cockatoo	Vulnerable	x
Calyptohynchus latirostris	Bird	Carnaby's Black-Cockatoo	Endangered	✓
Caladenia procera	Plant	Carbunup King Spider Orchid	Critically Endangered	✓
Caladenia huegelii	Plant	Grand Spider Orchid	Endangered	x
Centrolepis caespitosa	Plant		Endangered	
Diuris purdiei	Plant	Purdie's Donkey Orchid	Endangered	x
Drakaea elastica	Plant	Glossy-leaved Hammer Orchid	Endangered	x
Trithuria occidentalis	Plant	Swan Hydatella	Endangered	x
Diuris micrantha	Plant	Dwarf Bee-orchid	Vulnerable	x
Drakaea micrantha	Plant	Dwarf Hammer-orchid	Vulnerable	x
Diuris drummondii	Plant	Tall Donkey Orchid	Vulnerable	x

8.2.2.1 Chuditch *(Dasyurus geoffroii)*

Whilst the Chuditch originally utilised a wide variety of habitats across Australia, including woodlands, forests, beaches and deserts, they are now restricted to south-western Australia occupying around 5% of their original range with the population believed to be less than 6,000 individuals (Orell and Morris, 1994). The major remaining populations occur in remnant Jarrah forest, although small numbers are patchily distributed. Dense vegetation undergrowth is important for Chuditch.

Chuditch tend to rely on large trees for habitat and breed in areas where predators are not controlled. This species requires dense bush and scrub in order to provide abundant cover also thought to reduce their vulnerability to predators (Orell and Morris, 1994). Over a year, an adult female Chuditch may utilise an estimated 66 to 110 logs and burrows within her home range. Typically female Chuditch have a home range of three to four square kilometres and seldom overlap with other females. The male Chuditch has a home range of 15 square kilometres (Orell and Morris, 1994). Given these home ranges, if the Chuditch does occur on the property, it is expected to be in very low numbers (Bamford *et al.* 2004).

Bamford *et al.* (2004) conducted a trapping survey in the western portion of the KSS property to provide specific survey information on the possible presence of the Chuditch. No Chuditch, or any other mammals, were trapped during the survey. Bamford *et al.* (2004)

report that although no Chuditch were trapped during this survey, small numbers are clearly present in the region. They have also been recorded in the Leschenault Peninsula Conservation Park, 10 kilometres to the west. In a trapping study carried out across the Kemerton Industrial Park in 1998, no Chuditch were caught (M. Bamford pers. records). This suggests that at least at that time, the Chuditch was scarce in the region.

Survey results on this specially protected species confirm that the mine extension area has not been identified as containing known populations. While low numbers of animals may inhabit the wider region, there are no records of animals on the KSS property or the mine extension area. Despite this, the habitat available on the KSS property is considered suitable for Chuditch. Vegetation clearance associated with the proposed mine extension has the potential to have a small impact on the habitat and population of the Chuditch.

Vegetation clearance associated with the proposed mine extension has the potential to impact on the habitat and population of the Chuditch by removing an area of thick remnant vegetation, thereby reducing the possible habitat range of this species. Given Chuditch have not been recorded in recent (Bamford *et al.* 2004) or historical (Ninox Wildlife Consulting, 1994) surveys, it seems unlikely that the KSS property provides a preferred habitat for this species.

8.2.2.2 **Western Ringtail Possum *(Pseudocheirus occidentalis)***

Western Ringtail Possum's tend to be restricted to near coastal areas of peppermint (*Agonis flexuosa*) woodlands and peppermint/tuart (*Eucalyptus gomphocephala*) associations from Bunbury to Albany (Karrakatta – Central and South and Yoongarillup vegetation complexes located on the Spearwood Dune System). Tree hollows and dreys in tree canopies are used for nest sites. The Western Ringtail Possum has a home range between one and five hectares and can overlap by about 70%, however individual possums use between three and eight different nest sites a year and numerous nest sites are required to support high-density populations. The Western Ringtail Possum is nocturnal and so most active at night (DEWHA, 2008b).

The predominant vegetation complex on the property is Bassendean - Central and South, with some minor woodlands and forest of *Agonis flexuosa*. However, the Western Ringtail Possums prefer peppermint dominated forest near the coast, so it seems the habitat available on the KSS property is unfavourable. Bamford (2003) listed the Western Ringtail Possum as a species known or believed to have become extinct in the Kemerton region since European settlement. It had not been recorded in fauna surveys undertaken at the KSS property prior to 2004.

A targeted survey for Western Ringtail Possum was undertaken in January 2009 in response to consultation with DEC and DEWHA that indicated reintroduction of this species to areas north of KSS had occurred in recent years and individuals had reportedly been observed adjacent to KSS. The results of a targeted inspection of the site for evidence of Western Ringtail Possum failed to find any sign of this species and it is concluded that they are not present on site or are only present rarely as transient individuals, suggesting that the Western Ringtail Possum is currently not utilising vegetation on site as potential habitat. This is thought to be primarily because of the general poor quality of the habitat present and because of historical events that have resulted in the localised extinction of the species in this specific area. There is some potential for individuals to either be present now in very low densities or to at times move into the area from nearby areas of better habitat quality or known extant populations (Harewood, 2009).

8.2.2.3 Quokka *(Setonix brachyurus)*

The Quokka (*Setonix brachyurus*) is endemic to south-western Australia and is now restricted to Rottnest and Bald Islands and only 25 mainland site, most of which are National Parks. One record is known from a swamp in State Forest near Dwellingup and other may still occur in forest near Manjimup and Collie (Maxwell *et al.* 1996). Quokkas used to occur in low lying scrub from the coast to jarrah-marri forest, but they are now restricted to swamps with dense vegetation (Maxwell *et al.* 1996).

Quokkas have not been recorded in site fauna surveys of the KSS site. Bamford (2003) lists this species as known or believed to have become extinct in the Kemerton region since European settlement. It is considered unlikely that the mine extension will have adverse impacts on this species given the known range is highly restricted to undisturbed areas.

8.2.2.4 Baudin's Black-Cockatoo *(Calyptohynchus baudinii)*

Baudin's Black (or Long-billed) Cockatoo is endemic to the south-west of Western Australia, and the KSS mine extension area is located within the known distribution range for this species. It is a more specialised feeder of Eucalypts and tends to be favour moist, heavily forested areas dominated by Marri, Karri and Jarrah species (DEWHA, 2008c). Suitable habitat is limited on the KSS area as historic logging has removed most large Eucalypt trees.

Baudin's Black-Cockatoo was not recorded in site surveys in November 2003 and May 2004 (Craig *et al.* 2004). Evidence of Baudin's Black-Cockatoo foraging (chewed marri nuts) were observed within the mine extension area, while numerous Banksia cones showing signs of cockatoo foraging (seeds and grubbing) were observed (Harewoood, 2009). Some or all of this activity could be attributed to the Carnaby's and not the Baudin's Black-Cockatoos (Harewoood, 2009). While Baudin's Black-Cockatoo may visit woodlands of the property, it is unlikely to use the area extensively. Significant impacts on this species from the proposed action are likely to be a reduction in habitat due to an altered post-mining landscape.

8.2.2.5 Carnaby's Black Cockatoo *(Calyptohynchus latirostris)*

Carnaby's Black (or Short-billed) Cockatoo is endemic to south-western Australia. Carnaby's Black-Cockatoo is reliant on native remnant woodlands, predominantly Salmon Gum (*Eucalyptus salmonophloia*) or Wandoo (*E. wandoo*), shrubland or heath dominated by Proteaceous species. Carnaby's Black-Cockatoo use large hollows in live or dead eucalypts to breed. They then forage in higher rainfall coastal areas including woodlands, heath, pine plantations and orchards. The habitat range has significantly decreased and become fragmented since 1970 and the Cockatoos have disappeared from a third of their breeding range. A breeding population is known to occur around the Bunbury region. The KSS site is within foraging range of this population (Bamford, 2003; Cale, 2003).

Craig *et al.* (2004) conducted surveys of the KSS property in November 2003 and May 2004 to provide specific survey information on the possible utilisation by Carnaby's Black-Cockatoos of the mine extension area. The value of the KSS property for breeding was assessed to be low in the regional context, with no evidence of breeding and few potentially suitable nest hollows present. The value of foraging habitat on the KSS property was assessed to be similar to or less than the value of foraging habitat at control sites. However, the value of foraging habitat is very difficult to assess as usage of different plant species varies seasonally and information is not available on seed density in different vegetation types. Carnaby's Black-Cockatoo has been recorded in site surveys in November 2003 and May 2004 (Craig *et al.* 2004). Harewood (2009) sighted several small flocks of Carnaby's Black-Cockatoo within the proposed mine extension area at KSS. Numerous examples of foraging activity (chewed jarrah nuts and Banksia cones, pine cones and marri nuts) were observed within the mine extension area. Some or all of this activity could be attributed to Baudin's or Forest Red-tailed Black-Cockatoos (Harewoood, 2009). Carnaby's Black-Cockatoo is a frequent visitor to the general area for foraging. Two potential nest hollows are present within the mine extension area, although the probability of breeding on site is considered low (Harewood, 2009).

The survey concluded the mine extension area did not possess any unique value for cockatoos, above other wooded areas in the region (Craig *et al.* 2004). Carnaby's Black-Cockatoo does use the KSS property for foraging and it is likely to be an important area given much of the Swan Coastal Plain has been cleared (Bamford and Bamford, 2003). Craig *et al.* (2004) considered the KSS property is likely to provide opportunistic pickings from woodlands rather than a continual, reliable food source and as such, Carnaby's Black-Cockatoo is likely to be a transitional species and a seasonal visitor. The proposed action will result in a temporary reduction in foraging habitat for Carnaby's Black-Cockatoo, although the post mining landform will contain Proteaceous species, which the Cockatoo favours (Cale, 2003). The proposed action is not considered likely to have significant long-term impact on Carnaby's Black-Cockatoo.

8.2.2.6 Carbunup King Spider Orchid *(Caladenia procera)*

Caladenia procera (Carbunup King Spider Orchid) is listed as Critically Endangered under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous, perennial herb growing up to 90 centimetres high with linear hairy leaves and the flowers are greenish-yellow with heavily clubbed sepals, labellum with a purple tip from September to October.

The Carbunup King Orchid is known from five small scattered populations over an area from Bunbury to Carbunup. The Carbunup King Spider Orchid prefers rich clay loam, alluvial flats. Dominant vegetation type is Jarrah-Marri woodland amongst dense low shrubs and sedges. Prior to settlement, this was probably a common species, but its distribution has been heavily cleared (Pers comm., Ryan Phillips, 2008).

Carbunup King Spider Orchid has been located just off the corridor within the south-eastern corner of the KSS property (Figure 11). This location is removed from the mine extension area and will not be disturbed. The location is further discussed in Section 10.

8.2.2.7 Grand Spider Orchid *(Caladenia huegelii)*

Caladenia huegelii (Grand Spider Orchid) is listed as Endangered under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous, perennial herb growing up to 60 centimetres high with linear hairy leaves and the flowers are red with cream margins.

The Grand Spider Orchid is known from 39 small scattered populations over a wide area from Perth to Albany. The Grand Spider Orchid does not require fire to germinate, however tends to be restricted to Bassendean sands or where they meet with Spearwood sands. Dominant vegetation type is *Banksia* woodland (often fairly low in the landscape, but not always) sometimes with a *Jarrah* or *Marri* overstory and usually occurs with mixed *Banksia/Kunzea* (Pers comm., Ryan Phillips, 2008). Prior to settlement, this was probably a common species, but its distribution has been heavily cleared (Pers comm., Ryan Phillips, 2008).

Caladenia huegelii has not been recorded within the KSS property or surrounding area (Mattiske, 1993a, b, c, d , 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Caladenia huegelii.*

8.2.2.8 Centrolepis caespitosa

Centrolepis caespitosa is listed as Endangered under the *EPBC Act*, but is currently only listed as Priority 4 under the *WC Act.* Given that this species in listed as Priority 4 under the *WC Act*, taxonomic revision may indicate it needs to be removed from the federal listing. It is a minute annual herb (forming a rounded cushion up to 25 millimetres across) with green leaves and flowers from October to December.

Centrolepis caespitosa is known from 34 small scattered populations over a wide area from Perth to Albany. *Centrolepis caespitosa* prefers wet flats in brown grey clay loam and laterite in *Eucalyptus decipiens*, *E. marginata* low open mallee open shrubland over very open herbland/grassland/sedgeland.

Centrolepis caespitosa has not been recorded within the KSS property or surrounding area (Mattiske, 1993a, b, c, d, 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Centrolepis caespitosa.*

8.2.2.9 Purdie's Donkey Orchid *(Diuris purdei)*

Diuris purdei (Purdie's Donkey Orchid or Double Tails) is listed as Endangered under the *EPBC Act* and DRF under the *WC Act.* It is tuberous perennial herb growing up to 35 centimetres high, with yellow flowers from September to October.

Purdie's Donkey orchid is known from 10 small scattered populations around Perth and requires fire to germinate. The few recent records of this species in the Western Australian herbarium are recorded from wet grey/black sand or sandy loam. There has been considerable variation between sites in the composition of the surrounding vegetation (Pers comm., Ryan Phillips, 2008).

Diuris purdei has not been recorded within the KSS property or surrounding area (Mattiske, 1993a, b, c, d ,2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Diuris purdei.*

8.2.2.10 Glossy-leaved Hammer Orchid *(Drakaea elastica)*

Drakaea elastica (Glossy-leaved Hammer Orchid or Praying Virgin) is listed as Endangered under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous perennial herb growing up to 30 centimetres high, with glossy green heart-shaped leaves with and a solitary stem.

Glossy-leaved Hammer-orchid is known from 16 small scattered populations over a wide area from Perth to Busselton. Glossy-leaved Hammer-orchid or Praying virgin does not require fire, although habitat preferences are predictable. It occurs low in the landscape (but not seasonally wet), generally under *Kunzea* thickets among *Banksia* (Pers comm., Ryan Phillips, 2008). For the most accurate census of population numbers, survey in July-August are best for looking for leaves. The leaves will start to wilt in a dry year by late September. It usually grows with other *Drakaea* species (Pers comm., Ryan Phillips, 2008).

A population of 35 plants of *Drakaea elastica* was found in 2007 growing with *Drakaea micrantha* (DRF), approximately 830 metres to the south-east of the KSS property. *Drakaea elastica* has not been recorded within the KSS property (Mattiske, 1993a, b, c, d, 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Drakaea elastica.*

8.2.2.11 Swan Hydatella *(Trithuria occidentalis)*

Trithuria occidentalis (Swan Hydatella) is listed as Endangered under the *EPBC Act* and DRF under the *WC Act.* It is a reddish annual herb growing up to 30 centimetres high, with red flowers and purple-red anthers.

Swan Hydatella is known from 11 small scattered populations around Perth. It prefers grey-brown clay, soft and damp low-lying situations adjoining winter-wet swamps in Open shrubland of *Melaleuca lateritia* to 1.5 metres tall with open ground between shrubs.

Trithuria occidentalis has not been recorded within the KSS property or surrounding area (Mattiske, 1993a, b, c, d, 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Trithuria occidentalis.*

8.2.2.12 Dwarf Bee-orchid *(Diuris micrantha)*

Diuris micrantha (Dwarf Bee-orchid) is listed as Vulnerable under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous, perennial herb growing up to 60 centimetres high with yellow spotted brown flowers from September to October.

The Dwarf Bee-orchid is known from six small scattered populations around Perth. Dwarf Bee-orchid does not require fire to germinate, however the soil type and co-occurring vegetation is very variable. It is probably dependent on seasonal moisture rather than specific vegetation or soil type (Pers comm., Ryan Phillips, 2008).

A population of six plants of *Diuris micrantha* has been found growing with *Drakaea micrantha* (Vulnerable, DRF), approximately 2.8 kilometres to the south of the KSS property along the Dampier to Bunbury natural gas pipeline corridor (Woodman, 2005a). *Diuris micrantha* has not been recorded within the KSS property (Mattiske, 1993a, b, c, d , 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Diuris micrantha.*

8.2.2.13 Dwarf Hammer-orchid *(Drakaea micrantha)*

Drakaea micrantha (Dwarf Hammer-orchid) is listed as Vulnerable under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous, terrestrial herb growing up to 30 centimetres high with a flower 1.2 to 2.5 centimetres long. It has silvery-grey heart-shaped leaves with prominent green veins.

The Dwarf Hammer-orchid is known from 32 small scattered populations over a wide area from Perth to Albany with secure populations in Frankland National Park. The Dwarf Hammer-orchid prefers infertile grey sands in *Banksia*, *Jarrah* (*Eucalyptus marginata*) and Common Sheoak (*Allocasuarina fraseriana*) woodland or forest. It is often found under thickets of Spearwood (*Kunzea ericifolia*) (DEWHA, 2008d). The species likes disturbed areas, including cleared fire breaks or open sandy patches where competition from other plants has been removed. The Dwarf Hammer-orchid does not require fire to flower and is known to occur in the same habitat on the coastal plain as *D. elastica* (Pers comm., Ryan Phillips, 2008).

Drakaea Micrantha has been found in a number of locations to the south and south-east of the KSS property from 2004 to 2008. *Drakaea micrantha* has not been recorded within the KSS property (Mattiske, 1993a, b, c, d , 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Drakaea micrantha.*

8.2.2.14 Tall Donkey Orchid *(Diuris drummondii)*

Diuris drummondii (Tall Donkey Orchid) is listed as Vulnerable under the *EPBC Act* and DRF under the *WC Act.* It is a tuberous, perennial herb growing up to 95 centimetres high with yellow and brown flowers from November to January.

The Tall Donkey Orchid is known from 24 small scattered populations over a wide area from Perth to Albany with secure populations in Frankland National Park. It occurs on a wide variety of soil types, but requires swamps that are moist well into summer. No areas in the proposed extension area stay moist well into summer, so it is unlikely that this species is present. The structure and composition of the vegetation does not appear to be important, however, flowering generally requires fire, but some populations appear to be able to flower well without fire (Pers comm., Ryan Phillips, 2008).

A population of 34 plants of *Diuris drummondii* was found in 2007 growing one kilometre to the south of the KSS property along the Dampier to Bunbury natural gas pipeline corridor (Woodman, 2005a). *Diuris drummondii* has not been recorded within the KSS property (Mattiske, 1993a, b, c, d , 2003b; Bennett, 2004; Woodman, 2005a). The proposed action is not considered likely to have significant impact upon the population of *Diuris drummondii.*

8.2.3 Listed Migratory Species

As well as the *EPBC Act*, migratory species may also be protected under three international treaties to which Australia is a signatory. These treaties are:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn).
- China – Australia Migratory Bird Agreement (CAMBA).
- Japan – Australia Migratory Bird Agreement (JAMBA).
- Republic of Korea – Australia Migratory Bird Agreement (ROKAMBA).

A search of the *EPBC* Protected Matters database identified five migratory bird species that might occur in the KSS area. Species together with their *EPBC Act* status, habitat requirements and an indication of whether they have been recorded in the project area are presented in Table 61. These species in relation to KSS are discussed in more detail in the following subsections.

Table 61: Migratory Species Listed Under the *EPBC Act* that May Occur Within the KSS Area

Species	EPBC Status	Habitat[1]	Recorded in Site Specific Surveys
Migratory Wetland/Marine Birds			
White Egret (*Ardea alba*)	Migratory (CAMBA, JAMBA)	Shallows of rivers, estuaries, tidal mudflats, freshwater wetlands	x
Cattle Egret (*Ardea ibis*)	Migratory (CAMBA, JAMBA)	Wetlands, tidal mudflats, pastures, croplands.	x
Fork-tailed Swift (*Apus pacificus*)	Migratory (Marine only) (CAMBA, JAMBA, ROKAMBA)	Largely aerial	x
Glossy Ibis (*Plegadis falcinellus*)	Migratory (CAMBA, JAMBA)	Well vegetated wetlands, pastures, rice fields, floodwater, floodplains or occasionally saline wetlands, mangroves and mudflats.	x
Migratory Terrestrial Birds			
White-bellied Sea-Eagle (*Haliaetus leucogaster*)	Migratory (CAMBA)	Coasts, islands, estuaries, inlets, large rivers, inland lakes and reservoirs.	x
Rainbow Bee-eater (*Merops ornatus*)	Migratory (JAMBA)	Open woodlands with sandy/loamy soil.	✓

Source: [1] Pizzey and Knight (2003).

8.2.3.1 Migratory Terrestrial Bird Species

Two terrestrial bird species have potential to occur in the KSS project area, namely the White-bellied Sea-Eagle (*Haliaetus leucogaster*) and the Rainbow Bee-eater (*Merops ornatus*). The White-bellied Sea-Eagle has been observed in the region, but not on the KSS property, while the Rainbow Bee-eater was recorded on the KSS site in January 2002 and in the Kemerton region (Bamford and Bamford, 2003).

The White-bellied Sea-Eagle is normally found inland along major rivers and requires trees greater then 30 metres in height or coastal/riverine cliffs in which to nest. The species may occasionally fly over the site due to its proximity to the ocean and Leschennault Inlet, but is very unlikely to forage or nest on site (Harewood, 2009).

The Rainbow Bee-eater is a common summer migrant to southern Australia but in the north they are resident (Morcoombe, 2003). The Rainbow Bee-eater prefers open woodlands with sandy or loamy soils and open country of woodlands, open forest, semi arid scrub, grasslands, clearings in heavier forest and farmlands (Morcombe 2003). Breeds underground in areas of suitable soft soil firm enough to support tunnel building (Harewood, 2009). Recorded in the KSS property it is probably a relatively common seasonal visitor to the general area.

The mine extension area will result in the loss of habitat during the mining phase and the period after, when rehabilitation is developing and ecological functions slowly return to the post mining landform. An average of only five hectares per year will be cleared of the 283 hectares, over the 50 year life of mine. With this slow rate of habitat removal in a local area surrounded by vegetation, it is considered birds will naturally relocate to adjacent areas in advance of clearing.

Eighty percent of vegetation on the property will be retained, including heavily vegetated seasonal wetlands. It is unlikely that proposed sand extraction will have a significant impact on migratory terrestrial bird species.

8.2.3.2 Migratory Wetland Bird Species

Three migratory wetland bird species have potential to occur in the KSS project area namely the White or Great Egret (*Ardea alba*), Cattle Egret (*Ardea ibis*) and the Glossy Ibis (*Plegadis falcinellus*). All these species inhabit tidal mudflats and margins or shallows of watercourses, inland swamps or dams.

The Great Egret has been observed in the Kemerton region in previous studies, but not on the KSS property (Bamford and Bamford, 2003). The Cattle Egret has not been observed in the region or on the KSS property (Bamford and Bamford, 2003).

The Glossy Ibis is both migratory and nomadic. Its range expands inland after good rains, but its main breeding areas seem to be inn the Murray-Darling Basin of New South Wales and Victoria, the Macquarie Marshes in New South Wales, and in southern Queensland. Glossy Ibis often move north in autumn then return south to their main breeding areas in spring and summer (Pizzey and Knight 2006). Infrequently recorded in south west, there is small potential for it to use some inundated open areas in wetter months of year.

The EPP wetlands may be utilised from time to time by the listed migratory waterbird species. The EPP wetlands occur mostly to the eastern side of the KSS property with six of these EPP wetlands transferred to DEC to ensure their long-term protection. Site investigations into groundwater indicate that significant impacts on wetlands and associated values for listed species are not likely (GHD, 2002). The mine extension area has been defined based on groundwater modelling work which identified the buffer distance required to protect EPP4 and its surrounding wetland catchment from mining induced groundwater changes (Appendix 17).

Fauna surveys reflect that fauna associated with permanent water are currently poorly represented on the site (Bamford and Bamford, 2003). Site observations indicate North Lake has become a major attraction for waterbirds that would not normally occur on the property. This lake is still in early stages of rehabilitation and is likely to become more attractive to a range of waterbirds as riparian vegetation continues to establish. There will be an increased number of permanent water bodies in the post mining landform, providing a greater diversity of habitats on the property. The mine extension area currently contains no permanent water bodies and the creation of new open water will be a major environmental advantage for migratory wetland species.

Wetlands on the KSS site are not recorded as providing important habitat for listed migratory waterbirds. There is not expected to be any adverse impacts upon the conservation status of any migratory wetland bird species.

8.2.3.3 Migratory Marine Bird Species

One migratory marine bird species, the Fork-tailed Swift (*Apus pacificus*) might occur in the KSS project area.

The Fork-tailed Swift is potentially a very occasional summer visitor to the study area but is entirely aerial and largely independent of terrestrial habitats (Harewood, 2009). It migrates to Australia from Siberia and northern Asia, and is found throughout the mainland, particularly in the centre and west.

No impact on this species is anticipated as it is likely to be only a very infrequent visitor to the general area. No specific management measures recommended.

8.3 MANAGEMENT AND MITIGATION MEASURES

Potential impacts to matters of National Environmental Significance will be addressed through

- Create north to south designed dredge ponds and rehabilitated lakes to reduce water loss by evaporation and impacts associated with easterly and westerly winds **(Commitment 7.4.4h).** These areas have the potential to increase the conservation significance of the area by providing additional habitat for migratory waterbirds.
- Conducting surveys to identify potential Cockatoo tree hollows prior to annual land clearing to ensure hollows are not currently being used for breeding. Tree hollows suitable for Cockatoos will be relocated to other areas, preferably within newly rehabilitated areas. Hollows will either be remounted on trees outside the mine extension area, or if this is not practical, replaced with similar sized nest boxes **(Commitment 7.7.4a)**. Tree hollows suitable for Cockatoos may be used by Carnaby's Black-Cockatoo, but Baudin's Black-Cockatoo is not expected to nest in the Kemerton region. Relocated tree hollows may provide habitat for other fauna species. Utilisation will be recorded in scheduled rehabilitation monitoring programs.
- Planting of tree species likely to develop hollows and provide Cockatoo habitat in the long term **(Commitment 7.7.4b)**.
- Progressive clearing of an average of five hectares per year will be carried out in Autumn when species are less likely to be breeding **(Commitment 7.7.4d).** This will enable any Threatened or Migratory Fauna species to migrate to other areas of the KSS property.
- Progressive rehabilitation with local provenance seed to encourage colonisation from surrounding vegetative areas, to re-establish vegetation and hence fauna **(Commitment 7.7.4e).**
- Conducting targeted survey for Chuditch, Western Ringtail Possum and Quokka prior to annual land clearing to ensure that populations of these Threatened species will not be affected by the planned clearing. If evidence of their presence is found, trapping will be

undertaken and captured individuals relocated to suitable alternative sites on the property **(Commitment 7.7.4f).**

- Erecting nest boxes suitable for use by Western Ringtail Possums where annual surveys show Possums are present in areas planned to be cleared in the short term. Nest boxes will be placed in adjacent undisturbed areas where suitable foraging habitat is present **(Commitment 7.7.4g)**.
- Planting areas of peppermint (*Agonis flexuosa*) within upland woodland areas to be rehabilitated post mining. Peppermint trees will be planted in clumps to encourage interlocking branches **(Commitment 7.7.4h)**.
- Mitigation measures include assisting with rehabilitation of 11 hectares of degraded Bassendean woodland within and adjacent to Kemerton Nature Reserve, weed and feral pig control in Kemerton Nature Reserve to increase habitat quantity and quality for Cockatoos and other fauna species.
- Kemerton Nature Reserve established and expanded as a north-south ecological link between remnant vegetation.
- Providing offset areas in addition to the previously agreed offsets areas of the Kemerton Nature Reserve and the current mining area. Offsets are discussed in more detail in Section 10.

area to 46.7 hectares (i.e. existing approved is 75.3 hectares, this proposal requests clearing of 122 hectares).

- Consolidate all mine activities into two discrete areas of the KSS property.
- Make maximum use of sand resources in designated mine areas.
- Prevent disturbance of catchments of five EPP wetlands (EPP3, 4, 5, 8 and 9). Mining of the approved areas, whilst not directly disturbing the EPP wetlands, would detrimentally impact their environmental values.
- Prevent future mining of 12.6 hectares within the existing Kemerton Nature Reserve.

10.5 ASSESSMENT OF POTENTIAL RISKS AND IMPACTS

10.5.1 Impacts on Critical Assets

KSS considers the residual impact from implementing the proposal will not result in a significant adverse impact on Critical Assets. Table 69 shows the land area of Critical Assets contained within the existing Kemerton Nature Reserve, proposed mine extension area, proposed additional offset areas and the residual KSS property. From this it can be seen that impacts on Critical Assets have been minimised and significant areas of these have either been formally protected in perpetuity by transfer of ownership to the State or given long term protection through contributory offset commitments made by KSS i.e. protection from grazing.

Table 69: Critical Asset Summary for KSS

Critical Asset Type	Kemerton Nature Reserve	Mine Extension Area#	Proposed Offset	Dry Mining Area^	Remaining KSS Property
Remnant Native Vegetation (ha)					
Bassendean – Central and South vegetation complex	72.7	104.9	70.0+	46.7	428.1
Spearwood vegetation complex	-	31.9	-	-	-
Wetlands (ha)					
EPP Wetlands	18.2	-	0.01	0.31	5.6
Conservation Category wetland	51.8	107.6	24.1	8.0	422.85
Multiple Use wetland	62.6	-	2.6	-	6.5
Resource Enhancement wetland	1.3	-	4.0	-	18.9
Not Assessed	0.3	-	-	-	-
Threatened Ecological Communities (ha)					
Muchea Limestone TEC	15.6	-	-	-	-
DRF Species (number of plants)					
Caladenia procera (Critically Endangered, DRF)	-	-	1	-	-
Priority Flora Species (number of plants)*					
Acacia flagelliformis (P4)	-	-	9	-	99
Acacia semitrullata (P3)	-	55	29	-	192
Boronia capitata subsp. *gracilis* (P2)	-	-	-	-	11

Critical Asset Type	Kemerton Nature Reserve	Mine Extension Area#	Proposed Offset	Dry Mining Area^	Remaining KSS Property
Boronia juncea subsp. *juncea* (P1)	20	100	1	-	1,423
Caladenia speciosa (P4)	-	1	2	-	-
Dillwynia dillwynioides (P3)	20	10	-	-	540
Eucalyptus rudis subsp. *cratyantha* (P4)	-	17	-	-	108
Verticordia aurea (P4)	1	-	-	-	-

Note: # Includes existing approved dry mining area.
+ Does not include restoration of 11 hectares of degraded woodland within Kemerton Nature Reserve.
^ Does not include proposed mine extension area.
* Some records contain no population numbers; therefore it is assumed that at least one plant was recorded.

When considering the Critical Assets potentially affected by the mine extension proposal, three critical elements can be identified:

1. Where adverse impacts to a native terrestrial vegetation complex would result in a 30% or less representation of the pre-clearing extent of that vegetation complex in a bioregion (noting however that this threshold has been exceeded in some areas).
2. Having regard for DRF and the Priority Species List prepared by DEC.
3. Conservation Category Wetlands not included in an Environmental Protection Policy may be viewed in the context of whether they have medium to long term survival of their environmental values. The underlying presumption is that they would normally be considered a Critical Asset.

The following explanation is provided for each of these Critical Asset elements.

10.5.1.1 Representation

The EPA (2007) acknowledges that most vegetation complexes on the Swan Coastal Plain are already below the recommended threshold level for biological diversity. Targets of retaining greater than 30% natural vegetation in each complex can not be uniformly met. This is the case for the Bassendean - Central and South vegetation complex, which is the main vegetation complex within the KSS property. Implementing the project will not create the condition where these vegetation units fall below the 30% threshold. The lowest recommended level for conservation has been recommended to be 'at least 10%' although it is believed that at least 20% should be retained under natural vegetation to ensure biodiversity and soil conservation (EPA, 2007).

The extent of the 'area' is also extremely important in placing this threshold for biological diversity in context. The bioregion referenced against the current proposal is the entire Swan Coastal Plain, a large and diverse area encompassing the Perth Metropolitan Region. KSS submits that reference of the project against the entire Swan Coastal Plain is inappropriate, given extensive clearing has occurred in the Perth Metropolitan Region. Only 27% of the Bassendean – Central and South vegetation complex remains on the whole of the Swan Coastal Plain (EPA, 2004). This area is below 30%, stated in the *National Objectives and Targets for Biodiversity Conservation 2001-2005* (Commonwealth of Australia, 2001) and the Offsets Guidance Statement. The 'average' for the entire Swan Coastal Plain is made up of

39.3% remaining in the Greater Bunbury Region and only 24% remaining in the Perth Metropolitan Region (EPA, 2004). By using an average of the entire Swan Coastal Plain, development in the Greater Bunbury Region is potentially penalised and constrained due to significant historical clearing that has occurred in the Perth Metropolitan Region.

The proponent requests that this project is assessed against criteria within its local geographical region; that is the Greater Bunbury Region.

It is further acknowledged the EPA has approved other public and private proposals on the Swan Coastal Plain within and surrounding the KSS property, indicating that this factor is not an 'absolute' determinant of a project's acceptance or rejection by the EPA (and a degree of judgement is applied).

The finalisation of the Greater Bunbury Regional Scheme by the West Australian Government is addressed in Section 4.15. The southern portion of the KSS property lies within the Kemerton Industrial Zone Buffer Area – Special Control Area (SCA No. 2). The primary purpose of SCA No. 2 is to provide a buffer for industry at Kemerton, not conservation or recreation. State Forest No 16 lies 0.5 kilometres north of the KSS boundary and a large area of native forest which predominately occurs within the Bassendean – Central and South vegetation complex. Two reserves that lie to the south of the KSS property in the Kemerton Industrial Zone buffer also occur within the Bassendean – Central and South vegetation complex. Section 4.10 details the number of regional reserves within close proximity to the KSS property.

The inclusion of the KSS property as a designated mineral resource area in the final Greater Bunbury Regional Scheme Strategic Minerals and Basic Raw Materials Resource Policy (WAPC, 2005) confirms the West Australian Government position that at a regional level, this property has been identified for ongoing extraction of minerals. While the boundaries of the policy area are not exactly consistent with the current mine extension area (they conform to earlier proposals that were current at the time of the submission on the Greater Bunbury Regional Scheme), they do show an area significantly larger than the current approved mine area. The boundaries were changed in this proposal to have less of an environmental impact. Inclusion of the KSS property in this planning policy and showing an area greater than the existing approved mine limit reinforces the presumption of expansion of extraction of mineral resource beyond the current approved area.

Over the 50 year mine life, 122 hectares of Bassendean Dune System within the Bassendean - Central and South vegetation complex will be disturbed, representing 19% of this category in the entire property. Sixty five hectares will be rehabilitated over the life of mine, implementing the rectify component of on-site mitigation shown in Table 65.

KSS proposes to assist with a contributory offset package to rehabilitate 11 hectares of degraded Bassendean upland areas in Kemerton Nature Reserve.

10.5.1.2 DRF and Priority Species

Vegetation and flora surveys show the proposed mine extension area contains no DRF and few Priority species relative to other locations on the property (Section 7.5). KSS has used the principle of avoidance as much as possible to limit impact on Priority species. These species are also represented in other locations on the property which will not be disturbed, so the biodiversity 'risk' to any Priority species on the total property is considered low. Rehabilitation can include seed/tissue collection from these species to replace individuals lost due to mining. KSS considers implementing avoid and rectify components of on-site mitigation to totally replace any loss of Priority species associated with the project. There is no residual impact on this Critical asset which needs to be addressed in an offset proposal.

The south-eastern area proposed as a direct offset contains a known record of *Caladenia procera* (Critically Endangered, DRF) species according to the *WC Act* (Woodman, 2005a). This and other proposed offset areas contain good populations of Priority flora in addition to good quality remnant vegetation. KSS consider that these areas are critical assets and as part of mitigation for proposed mining, commit to managing these areas in a similar manner to Kemerton Nature Reserve. This includes weed and feral pig control.

10.5.1.3 Conservation Category Wetlands

Over the 50 year mine life, 110.7 hectares of Conservation Category wetlands will be disturbed, representing 16.0% of this category in the entire property. Forty-eight hectares (43.6%) will be rehabilitated over the mine life, implementing the rectify component of on-site mitigation shown in Figure 24.

A total of approximately 170 hectares of lakes and beaches will be formed, representing a wetland type not currently represented in the mine extension area. This comprises a mixture of approximately 63 hectares of shallow beach area and 107 hectares of deep open water. Developing ecological functions in these lakes provides additional habitat and biodiversity previously absent or limited on the property. This includes summer refuge for waterbirds and expanded habitat for iconic species such as the Black-striped Jollytail and Water Rat. KSS considers creation of this new habitat type represents a further environmental benefit to be offset against the net loss of former Bassendean woodland and ephemeral wetland.

10.5.2 Impacts on Landform Types

Table 70 shows the impact of the total mining extension proposal in terms of impact on landform units. From this it can be seen that a total net difference of +145.0 hectares will result after rehabilitation and implementation of offsets.

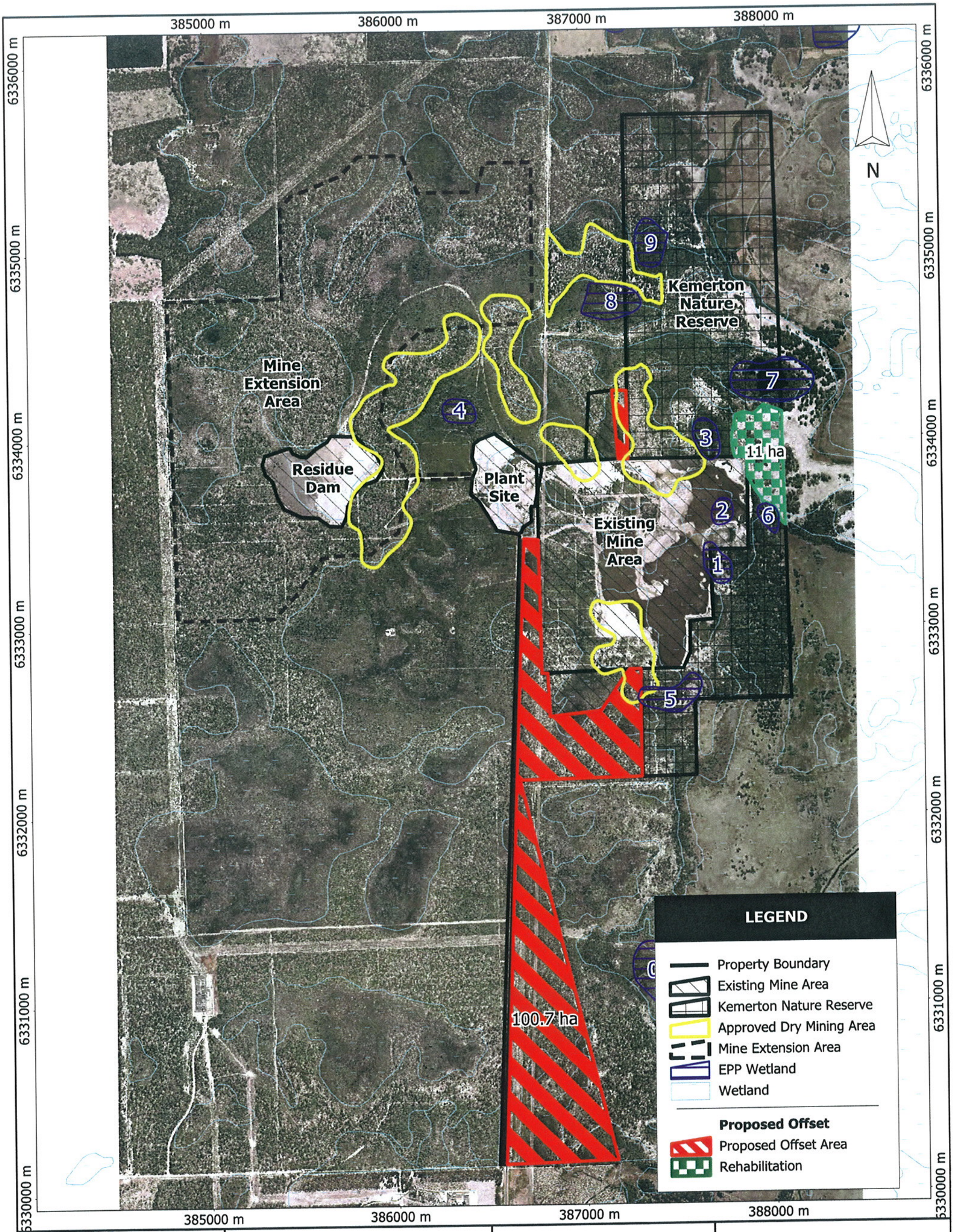
Table 70: Impacts on Landform Units

	Upland Bassendean Areas (ha)	Upland Spearwood Areas (ha)	Disturbed Land	Ephemeral Wetlands (ha)	Lakes (ha)	Lake Beach (ha)	Total (ha)
Mining Extension Proposal							
Proposed mine area	122.1	31.9	19.0	110.7	0	0	-283.7
Dry mining approved area	17.2	0	0	3.1	0	0	-20.3
Rehabilitated after mining	65.0	0	0	48.0	107.0	63.0	283.0
Post mining difference	-74.4	-31.9	-19.0	-65.8	+107.0	+63.0	-21.1
Offsets							
Forgo dry mining	46.7	0	0	8.3	0	0	+55.0
Land transfer	70.0	0	0	30.7	0	0	+100.7
Land rehabilitation	11.0	0	0	0	0	0	+11.0
Total offset	+127.7	0	0	+39.0	0	0	+166.7
Total Net Difference	**+53.3**	**-31.9**	**-19.0**	**-26.8**	**+107.0**	**+63.0**	**+145.6**

10.6 RESIDUAL ENVIRONMENTAL IMPACT

Review of the proposed mine extension and implementation of the offset package described within this section shows that.

- As a result of proposed mining, there is a net change in landform type with permanent lakes fringed with ephemeral wetlands and shallow lake beaches separated by uplands being created to replace ephemeral wetlands and Bassendean and Spearwood Dune uplands.
- Post mining rehabilitation will return approximately 48 hectares of ephemeral wetlands and 65 hectares of upland. This is a net change of 43.8% and 59% respectively.
- Potential exists to create additional habitat for the nationally significant Western Ringtail Possum within the upland areas as part of the rehabilitation program. This would assist with its long term conservation in the Bunbury region.
- Creation of approximately 170 hectares of permanent lakes (including up to 63 hectares of shallow beaches) post mining represents a reduction in net loss associated with the project. It has potential to provide expanded habitat for conservation significant fauna such as the Black –striped Jollytail present on the property in restricted locations and additional habitat for waterbirds including migratory species. Creation of permanent water sources in a drying climate is seen to have value for a range of conservation significant species.
- Significant offsets will be made to compensate for losses. This will result in:
  - 165.4 hectares of additional offsets being made.
  - 116.7 hectares of existing Bassendean uplands being protected in perpetuity in addition to the 11.0 hectares of existing degraded Bassendean upland being restored and 65 hectares to be rehabilitated after implementation of the mining proposal.
  - 39.0 hectares of existing ephemeral wetlands being protected in perpetuity.
  - 100.7 hectares of additional Critical Assets being protected in perpetuity.
  - Protection of one DRF and eight Priority flora species with an estimated total of approximately one and 41 plants respectively in perpetuity.
  - Creation of the desired north-south ecological linkage in the Kemerton area with a total of 417.0 hectares having being transferred to the State to form the Kemerton Nature Reserve as a direct result of silica sand mining activities in the Kemerton area.



Environmental + Water Resource Consultants MBS ENVIRONMENTAL 4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale: 1:25000 Original Size: A4 Air Photo 2006 Grid: Australia GDA94 (50) 0 500 m	Kemerton Silica Sand Pty Ltd	Proposed Offset Area Figure 28

W:\Kemerton Silica Sand\Drawings\Maps 2009\Offsets.map 18/02/2009 Offset Layout

10.7 PREDICTED RESIDUAL ENVIRONMENTAL RISK

By implementing both site rehabilitation and direct and contributory elements of the proposed offset package, KSS considers the EPA objective of achieving a 'no net environmental loss' or aspirationally a 'net environmental benefit' is reached.

Rehabilitation will return a proportion of landform types disturbed by mining. New permanent lakes will supplement rehabilitation of ephemeral wetlands and Bassendean woodland.

The offset proposal provides protection in perpetuity of additional Critical and high value assets and formalisation of a long term contributory partnership of management of the Kemerton Nature Reserve. The offset area directly contributes to establishment of the North-South Ecological Linkage in the Kemerton area stated as desirable by the EPA in Bulletin 1108.

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