Evaluation of Soils, Landforms & Potential Tree Performance

Plantagenet Locs 1425 & 1511

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1. Summary

The soils and landforms of a 195 ha farming property, comprised of CG 1425 and CG 1511, 6 km south of Mt Barker, were examined and estimates made of their suitability for plantation establishment.

The property comprises the crest and upper slopes of a broad interfluve, and three Soil Associations based on different land elements were identified. Soil Association A comprises the soils of the gently undulating, deeply weathered upland, Soil Association B the soils of upland swamps and concavities, and Soil Association C the deep sandy soils which occur on sand dunes and sheets. Soils were mapped on the basis of factors likely to be of importance for the establishment, survival and performance of trees such as depth of root penetrable horizons, the occurrence and nature of impenetrable layers and likely soil water relations. Seven soils were identified, within these Associations, and these varied in their silvicultural potential.

Only one soil, Soil A1, with areas of 33 ha and 26 ha, in locations 1425 and 1511 respectively, is considered to be immediately suitable for the establishment of plantations. Soils such as A2, S1 and S3 have root impenetrable pans which will require ripping to depths of up to 100 cm. These soils, Soil A3, and parts of D1 and D2 are also affected by waterlogging which will most likely limit the survival and growth of a range of tree species. All soils have sandy surface horizons, which are likely to be relatively infertile. While farming has improved the fertility of shallower soils, such as Soil A1, nutrient deficiencies in soils with deeper sandy horizons will limit growth. Each limitation can be remedied, however these remedies should be carefully costed to determine their economic viability.

Although trees can undoubtedly be established on each location, the combination of root impenetrable pans, waterlogging and deep sand mean that the prospects of future growth on all soils, apart from Soil A1, can be considered economically marginal. Brief notes are made of the suitability of the site for the establishment of a wood pulp-mill.

2. Introduction

A soil survey was undertaken on Plantagenet Locations 1425 and 1511 to:

- identify the distribution and properties of the soils
- allow an assessment of the potential limitations to tree growth and survival
- indicate the site factors of importance for the establishment of a wood pulp processing facility

Soil attributes considered likely to inhibit the growth and survival of plantations were those consistently identified in the literature (ie Valentine, 1986). These included those factors which could limit the depth of root penetration, such as hardpans, impenetrable clays and waterlogging and other factors which are also known to limit tree growth, such as deep infertile sands.

3. Property details

3.1. Location and area

The property comprises a total area of 194.69 ha, in two parcels of land, CG 1425 (64.75 ha) and CG 1511 (129.94 ha). It is 6 km south of Mount Barker and 40 km north of Albany, and lies between Albany Highway and the Great Southern Railway (Mt Barker 1:250 000 (Sheet SI 50-11), and the Mt Barker 1:50 000 (Sheet 2428—IV) map sheets). Approximate coordinates are 562 000 mE and 6 161 000 mN (117°41′ E, 34°42′ S).

3.2. Present land use

The property is mostly cleared, and currently pastured. Internal fences are in a good condition, and paddocks are mostly clear of debris.

3.3. Remnant vegetation

Native vegetation has now been mostly removed from the property, with Map 1 indicating locations of major remnants. Most clearing has proceeded from the period of 1957 onwards. Isolated trees, mostly *Eucalyptus calophylla, Nuytsia floribunda* and *Meleleuca spp* also occur through the properties. These remnants have total areas of 3.0 and 13.4 ha in Locations 1425 and 1511 respectively. The remnants have not been fenced, consequently their conservation value will have been reduced by stock damage.

4. Methods

4.1. Soils

4.1.1. Field inspection of soils

Soils were surveyed by the free survey method of Dent and Young (1981) using an 1: 5 000 enlargement from photography flown in March 1991, at a scale of 1: 40 000 (WA 2967; frame 5036), as a base.

Holes were augered at selected sites to depths of up to 3 m and soils described according to the techniques of McDonald and Isbell (1990). Attributes routinely assessed included colour, texture, and the depth and nature of hardpans. Soils were described at 98 sites, at an average sampling density of 0.5 observations/ha. The sampling density varied across the site. The spatial distribution of soils identified at each of these points was estimated by reference to landforms, remnant vegetation, and aerial photography from 1957, a time when native vegetation had only been partially cleared. Typical soil profiles of the major soils are described in Appendix 1. The soil classification, depth of sand, and area of each of the 44 mapped polygons are given in Appendix 2.

Pits were dug with a back-hoe to depths of 3 m, on completion of mapping, to allow examination of the nature and continuity of hardpans, and the structure and drainage of underlying clayey horizons. Profiles were described and photographed.

4.1.2. Construction of the mapping units

A hierarchical field classification of the soils was devised. The landscape was divided on the basis of dominant land elements, into three Soil Associations, each of which contained several soils. Soils were separated on the basis of differences in the depth of the sandy surface horizon, the occurrence and nature of hardpans, and factors likely to affect drainage. It should be stressed that the silvicultural potential of the soils within each of these Soil Associations can be quite different.

4.2. Topography

Contour intervals on available maps are at 10 m intervals, this being greater than the relative relief within most of the two properties. Contours at 2 m intervals were derived stereoscopically from 1:40 000 aerial photography, using a Wild BC-2 plotter, with CALM 1:50 000 scale mapping as a control, by Mr Don Daams, Land Information Branch (Map 2). Without adequate ground survey these lines should be regarded as tentative.

5. Geomorphology

5.1. Landscape setting

The property occurs on the crest of a broad ridge, 190 m a.s.l., which rises from the south, where the general elevation is around 130 m a.s.l. Drainage is impeded on this ridge and two named swamps occur, Kokokup Lake, and Quechinup Swamp, these being immediately adjacent to the property. Distinct drainage lines occur within 1 km to the east and west of the ridge, the western drainage entering Lake Barnes, and the eastern drainage being an upper tributary of the Hay River. The property is mostly contained within the Perillup Unit of Churchward et al (1988).

5.2. Landscape elements

The crest of the inter-fluve is broad with total relative relief of around 8 m. Although most of Location 1425 comprises gently undulating terrain, the north eastern portion drops away to the north-east giving a total of 20 m relief (Map 2). Location 1511 has less than 8 m relative relief, with a broad central area, comprising swamps, and other areas of impeded drainage.

Three major land elements have been distinguished, and these form the basis of the soil map. These are:-

- ➡ The gently undulating upland plain, and upper slopes.
- ➡ Swamps and poorly drained concavities
- ➡ Sand dunes and sheets, which overlie both the other land elements.

5.3. Parent materials

The country rock underlying the area is most likely gneissic (Muhling and Brakel, 1985), however this has been deeply weathered, and does not outcrop. The depth of weathering is not known, but is likely to be the order of several metres. The soils of Association A have formed on the upper horizons of the deep weathering ("laterite") profile and are characterised by the presence of ferruginous gravels within the soil profiles, and an abundance of coarse, angular quartz.

The swamps and depressions contain quartzose sand deposits, of variable depth, and these are likely to represent deposits derived from the surrounding terrain.

The sand dunes are also comprised of quartzose sand, and are evidence of previous wind activity. These overlie both the the undulating lateritised uplands, and the swampy terrain. These have a north-south orientation, which is unusual in inland Western Australia, where similar features are usually orientated NW-SE.

6. The soils

6.1. General soil pattern and areal estimates

Three soil associations were related to different land elements, and contained a total of seven soils. The major properties of the soils are summarised in Table 1 and the areal extent of each soil is given in Table 2. Each soil is briefly described in this section, with a local descriptive name, and classifications according to Northcote (1979), and Stace et al (1968).

Table 1 Major features of the soils

SOIL	DEPTH OF SANDY HORIZON (CM)	HARDPAN	WATER RELATIONS
A1	<100		well drained
A2	<100	Ferruginous, to 60 cm thick	poorly drained
A3	<100		waterlogged
S1	<100	Iron/organic	waterlogged
S2	100->300	Iron/organic	waterlogged
D1	>200	?	Surface 200 cm well drained, water logged at depth
D2	>200	?	Surface 200 cm well drained, water logged at depth

6.2. Association A — Soils of the lateritised uplands

The soils of the lateritised uplands consist of sand of various depths overlying a deeply weathered profile. Three soils have been identified, these being separated on the basis of the occurrence and nature of ferruginous materials within the soils.

Soil A1 *Sandy gravels Dy 4.84 Lateritic podzolic*
Comprised of soils with up to 100 cm of medium to coarse grained sand overlying an uncemented ferruginous gravel horizon, up to 20 cm thick, and yellow brown and white, medium clay (Figure 1). The soil occurs on the crests and mid-slopes of low rises. The depth of the sandy surface horizon varied with slope position, being around 20 cm deep on crests, and becoming increasingly deeper down-slope. Small sand dunes (to 50 cm high) occur in some areas, particularly in Location 1425. The subsoil clays have weak structural development; with roots from the prior native vegetation apparent along faces, and therefore must

be considered root penetrable. The soil appears to be relatively well drained, with no indications of water logging within the profiles.

Table 2 **Areal extent of the soils at each of the two locations**

	CG 1425 (HA)	CG 1511 (HA)	TOTAL AREA (HA)
A1	32.7	26.2	58.8
A2	10.4	24.7	35.1
A3	11.2	1.5	12.7
S1	0.0	22.2	22.2
S2	0.7	24.2	24.9
D1	0.5	8.5	9.0
D2	9.2	22.7	31.9
Total	*64.7*	*129.9*	*194.7*

Soil A2 *Sandy gravel Dy 5.84 Lateritic podzolic*

Comprised of soils similar to Soil A1 except that the ferruginous gravel horizon is cemented and up to 60 cm thick, extending to a total depth of 100 cm (Figure 2). The soil occurs in mid-lower slope positions of the undulating uplands, often adjacent to swamps, and has indications of seasonal waterlogging. The ferruginous pan in this horizon is unbroken and will require ripping to allow root penetration.

Soil A3 *Waterlogged sand Dg 3.81 Gleyed podzolic*

Comprised of from 50 to 100 cm of light grey sand overlying a whole coloured, gleyed, medium clay. This soil occurs on the mid to lower slopes of the north-east facing slope in the north-east of Location 1425, and in a small area of Location 1511. The soil is strongly affected by waterlogging, and has small areas (1-2 ha) with surface saline seeps.

Figure 1: Soil A1 of the lateritised uplands. Note that the surface 60 cm is dominated by sand and ferruginous gravel, and although there are occasional boulders to 20 cm this soil does not have a pan.
(Profile 91/MB1/L)

Figure 2: Soil A2 of the lateritised uplands. Note the ferruginous hardpan, here 25 cm thick, and deeper pale grey waterlogged clay. Also note the roots in the clayey horizon.
(Profile 91/MB1/A)

Figure 3: A variant of Soil S1 of the swamps and concavities. Note 120 cm of white sand overlying iron/ organic *and* ferruginous hardpans to a total depth of 160 cm. Impenetrable to the backhoe beneath this.
(Profile 91/MB1/K)

Figure 4: Subsoil of Soil A1. Exposed face showing how roots mainly occur along cracks and root channels (70 and 120 cm) in the clayey horizons of this soil.
(Profile 91/MB1/E)

6.3. Association S — Soils of the swamps and upland depressions

The soils of the swamps and upland depressions are typically comprised of white quartz sand overlying iron-organic pans. These soils mainly occur in Location 1511, where they occupy 36% of the area, compared to 1% in Location 1425. The depth of the surface sand horizon varies markedly, and two soils have been distinguished on the basis of sand depth.

Soil S1 — *Waterlogged sand* — *Uc 2.33* — *Humus podzol*

Comprising soils with <100 cm of white quartz sand overlying an iron organic pan, and a gleyed medium clay (Figure 3). The soil is strongly affected by waterlogging. The iron pan is dark brown, up to 40 cm thick, continuous, and can be considered root impenetrable. There are multiple pans in some areas (see profile description).

Soil S2 — *Deep waterlogged sand* — *Uc 2.33* — *Humus podzol*

Comprising soils with white quartz sand >100 cm deep and often up to 300 cm deep, with the deeper sand horizons often having a sulphurous smell, indicative of reducing conditions. Hardpans are likely to occur at depth.

6.4. Association D — Soils of the sand dunes and sheets

Dunes occur in both locations, and are typically comprised of white quartz sand of various depths. These soils occur on both Location 1425 (15%) and Location 1511 (24%). The sand dunes overlie both swampy and lateritised terrain. Where they occur in swampy terrain hardpans may occur at depth, whereas elsewhere they may overlie ferruginous gravels. The height of the sand dunes above the surrounding terrain varies markedly and they have been divided into two phases — low dunes (Soil D1, <150 cm high) and high dunes (Soil D2, >150 cm high). These differences in elevation are reflected in the moisture relations and wind erodibility of the soils.

Soil D1 — *Deep sands* — *Uc 1.21* — *Siliceous sand*

Comprising soils with medium grained, white, quartz sand with depths ranging up to 300 cm. Where the soil occurs in lateritic terrain there is often a strong contrast in the nature of the sand grains at depth, with these being coarse and angular.

Soil D2 — *Deep sand* — *Uc 1.21* — *Siliceous sand*

Soil D2 is similar to Soil D1, and apart differences in dune height, it also tends to be deeper. This soil is often affected by wind erosion.

Table 3 **Major limitations to tree growth on each of the soils**

SOIL	WATER-LOGGING	HARDPAN		WIND EROSION	NUTRIENTS
		SHALLOW (<100 CM)	DEEP (>100 CM)		
A1	0	0	0	1	N 1, P 1, K 0
A2	2	3	0	1	N 1, P 1, K 0
A3	3	0	0	2	N 2, P 2, K 0
S1	3	3	0	0	N 1, P 2, K 0
S2	3	0	3	0	N 2, P 2, K 1
D1	1-2	0	?	2	N 2, P 2, K 2
D2	1-2	0	?	3	N 2, P 2, K 2

(Scale: 0=not limiting, 3=severe limitation)

7. Land Evaluation 1 - Plantation establishment

7.1. Soil hazards and site amelioration for tree establishment

7.1.1. Root limiting attributes and site amelioration

Factors which are likely to affect the establishment and growth of trees on the two properties are summarized in Table 3.

As all soils are sandy surfaced, with consequent poor water holding capacities, the water availability will depend on the nature of subsoil horizons, and whether they are root penetrable.

7.1.1.1. Waterlogging

Waterlogging is a major feature of the soils, and varies in duration, ranging from seasonal waterlogging to permanent, as is likely with Soils S1 and S2. Although the surface 200 cm of Soils D1 and D2 is relatively well drained, subsoil drainage depends on their location in the landscape. Where adjacent to Soils S1 and S2 it is likely that these soils are waterlogged at depth. Soil A1 is not waterlogged.

It is unlikely that plantation establishment will reduce waterlogging in Soils S1 and S2, with swamps occurring prior to clearing. Similarly, although surface water can potentially be drained to the east, waterlogging in the deeper subsoils, and root impenetrable hardpans will still exist.

7.1.1.2. Hardpans

Two types of hardpan were identified, and these can both be considered as root impenetrable:-

➠ An iron-organic pan associated with poorly drained sites, which varied in depth and thickness. This occurred in Soils S1 and S2, and sometimes at depth in Soils D1 and D2.

➠ Cemented ferruginous gravels, which occurred as pans of up to 60 cm thick, below sand of variable depth, within Soil A2 and in small areas mapped as Soil A1. Although forming a continuous sheet, it appeared amenable to ripping, however this would have to be to a depth of at least 100 cm.

7.1.1.3. Salinity

Small areas with saline scalds (approx 2 ha) are apparent in the north-east corner (polygon #10) of Location 1425. Surface waters elsewhere in the area were non-saline.

7.1.1.4. Clay

The clayey subsoils, where inspected, were weakly-moderately structured, with roots of the former native vegetation often occurring along discrete clay faces, and in root channels, to depths of up to 2 m. This is illustrated in Figure 4. Clayey subsoils are therefore assumed to be root penetrable, although the future stability of trees on such soils cannot be guaranteed. Although clayey materials can be assumed to underlie the entire landscape, these may not be accessible to roots, due to the presence of hardpans and waterlogging.

7.1.1.5. Country rock

Country rock was not exposed in the area, or encountered in any inspection holes, to depths of 300 cm, and is therefore unlikely to be limiting to tree growth and survival.

7.1.2. Waterholding capacity

Soils D1 and D2 are both comprised of deep, well drained sands, and will have a poor water holding capacity. Where these soils occur in areas with poor drainage this may not be as critical as with the soils of the Bassendean Dunes, on the Swan Coastal Plain which are deeply drained. In these areas the limiting factor may be the occurrence of deep, root impenetrable, pans.

7.1.3. Erosion

All soils in the area are sandy surfaced, and will therefore be at risk from wind erosion if the surface is bared during the establishment of trees. The sand dunes are evidence of prior wind activity in the landscape. Wind erosion has been most severe on Soil D2, with the surface horizons stripped from up to 80% of this unit. Wind erosion has also occurred on Soil D1.

Water erosion is unlikely to be a problem on most of the soils of this area, as slopes are generally gentle. Shallow drains, emplaced in the north-east corner of Location 1425 where slopes of up to 3% occur, will reduce the risk of water erosion.

7.1.4. Soil fertility

The nutrient content of the soils was not assessed, however if a decision is made to acquire the property it is recommended that soil and plant analysis be undertaken. Soil samples should be taken from both surface and sub-surface horizons, and plant samples from pastures. Although calibrations relating nutrient content to tree growth response are not available, these analyses will provide a guide to likely fertiliser requirements, and indicate areas of gross deficiency. Landholder fertiliser records should also be consulted, if available.

Soil fertility will be related to factors such as the depth and texture of the sandy surface horizons, past fertiliser applications and previous pasture management. Hay cutting and wind erosion will both deplete soils of nutrients. Soils predominantly composed of quartzose sand, such as these, are generally infertile, with nutrients concentrated in the dark stained organic horizon.

The deeper, well drained, sandy soils (Soils D1 and D2) will have smaller contents of nitrogen, than the shallower sands (Soils A1 and A2), due to poor pasture growth. Similarly Soils D1 and D2 will have lost phosphorus due to leaching, and lost an array of nutrients due to wind erosion, and will therefore require larger amounts of nitrogen and phosphorus than Soils A1, A2 and A3.

Potassium content is generally related to clay content of soils, and may be deficient in the deeper sands, dependent on past fertiliser requirements. In the soils where the clayey subsoils are available to roots (Soils A1 and A3), this will not be required. Trace element requirements will be dependent on previous applications.

7.2. Potential for tree growth — Dr J.F. McGrath

7.2.1. General comments and climate

Specific relationships between tree growth and soil conditions are unknown in the Albany-Mt Barker area, and await further research.

Table 4 Relative potential productivity of three pine species on the soils

	P. RADIATA	P. PINASTER	P. TAEDA
A1	1-2	1	3
A2	3-4	3-4	3-4
A3	5	5	5
S1	5	5	5
S2	4	4	2
D1	3	1-2	4-5
D2	3	1-2	5

(Ratings by Dr. J. McGrath, scale 1 to 5, 1=best, 5=do not plant; all ratings relative to this site only)

Subjective ratings of potential tree growth for each of the soils are given in Table 4. These are provided for three pine species (*Pinus radiata, P. pinaster* and *P. taeda*); the rating for *P. radiata* should provide a guide to the potential for *Eucalyptus globulus,* in that both species require fertile, well drained sites, with a medium to high rainfall (mean rainfall Mt Barker 735 mm). The rankings are relative to this site.

The rainfall distribution in slightly less seasonal than the Blackwood Valley, with 70% of the rainfall falling in the April-October period compared to 90%. The annual mean rainfall for the Blackwood region is higher than Mt Barker (855 mm Bridgetown; 1070 mm Kirup), however Mt Barker receives, on average a greater summer (November-March) rainfall (150 mm vs 106-113 mm). Summer rainfall is of course quite variable, and cannot necessarily be relied on.

7.2.2. Tree requirements for growth

P. radiata — Requires moderately fertile, well drained soils, with moderate to high rainfall. Waterlogging intolerant, with resultant poor growth, stability and form.

P. pinaster — Tolerates less fertile environments, and is more tolerant of drought. As with other tree species, intolerant of shallow soils.

P. taeda — Requires moderately fertile, well watered soils. Can tolerate waterlogging, with roots penetrating deep into waterlogged profiles. Intolerant of root impenetrable layers, and heavy textured subsoils.

7.2.3. Likely tree performance on different soils

Soil A1 — This soil can be considered as relatively the most fertile in the area, and possible the only soil without major limitations of some kind. It overlies a deep weathering profile, which is apparently penetrable to tree roots, and is well drained. It will be reasonable to good for *P. radiata*, and good for *P. pinaster*. It will possibly be too dry for *P. taeda*.

Soil A2 — The major problems with this soil are the occurrence of a thick ferruginous sheet, shallow surface sand and indications of seasonal waterlogging. This suggests that it will be a difficult site for all species, however this may be partially overcome by ripping.

Soil A3 — None of the three species will tolerate or perform well in waterlogged or saline conditions, with clayey subsoils. Upslope plantings may partially ameliorate the problems with this soil.

Soil S1 — Waterlogged conditions in winter, and the presence of a hardpan make this soil unsuitable for all species.

Soil S2 — This soil will be unsuitable for *P. radiata* or *P. pinaster* as both are intolerant of waterlogging. *P. taeda* may perform reasonably well on the deeper wet sands, however the occurrence of a deeper hardpan, and poor fertility, will both cause problems.

Soil D1 &D2 — *P. radiata* will grow on sand dunes, albeit at low rates, and will rely heavily on fertilization. *P. pinaster* will probably grow well on this site, whereas water supply will be insufficient for *P. taeda*.

8. Land Evaluation 2 - Industrial site

A request was also made to assess the suitability of the site for a pulp mill. The site requirements of such a facility will be obviously dependent on the design of the facility, therefore comments in this section should be regarded as tentative.

Two aspects of the site should be considered:

➠ *Strategic factors*
The location of the site with respect to factors such as transport, power and water supply, local timber resources, labour and community facilities.

➠ *Physical factors*
The physical characteristics of the site as they will affect the siting of facilities, and the treatment of wastes.

Assuming that the location of the site is optimal with respect to the strategic factors, only the physical factors will be considered here.

The siting of a pulp facility is likely to be made as much on the basis of reducing visual impact from Albany Highway, as on the sites physical factors. Those considerations aside, it is clear that the well drained nature of Soil A1 makes it the most suitable for buildings and other facilities, as this soil will require minimal site preparation. Areas of this soil, distant from Albany Highway, occur on both locations.

A pulp facility will produce quantities of treated waste water, and these could possibly be retained within Location 1511. The swampy areas on Location 1511 indicate relatively impermeable subsoils however, as a result of the relatively low local relief, total water storage capacity will be limited. Contamination of the adjacent Kokokup Lake, and Quechinup Swamp, and overflow into local drainage lines should be considered.

The economic considerations for tree establishment will change, if this is for amenity purposes such as screening. Site ameliorative measures such as deep ripping to depths of up to 100 cm, and drainage works could therefore be considered. Similarly the range of tree species which can be planted is greater, if no economic return is sought, and all soils on the property planted.

9. Acknowledgements

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10. References

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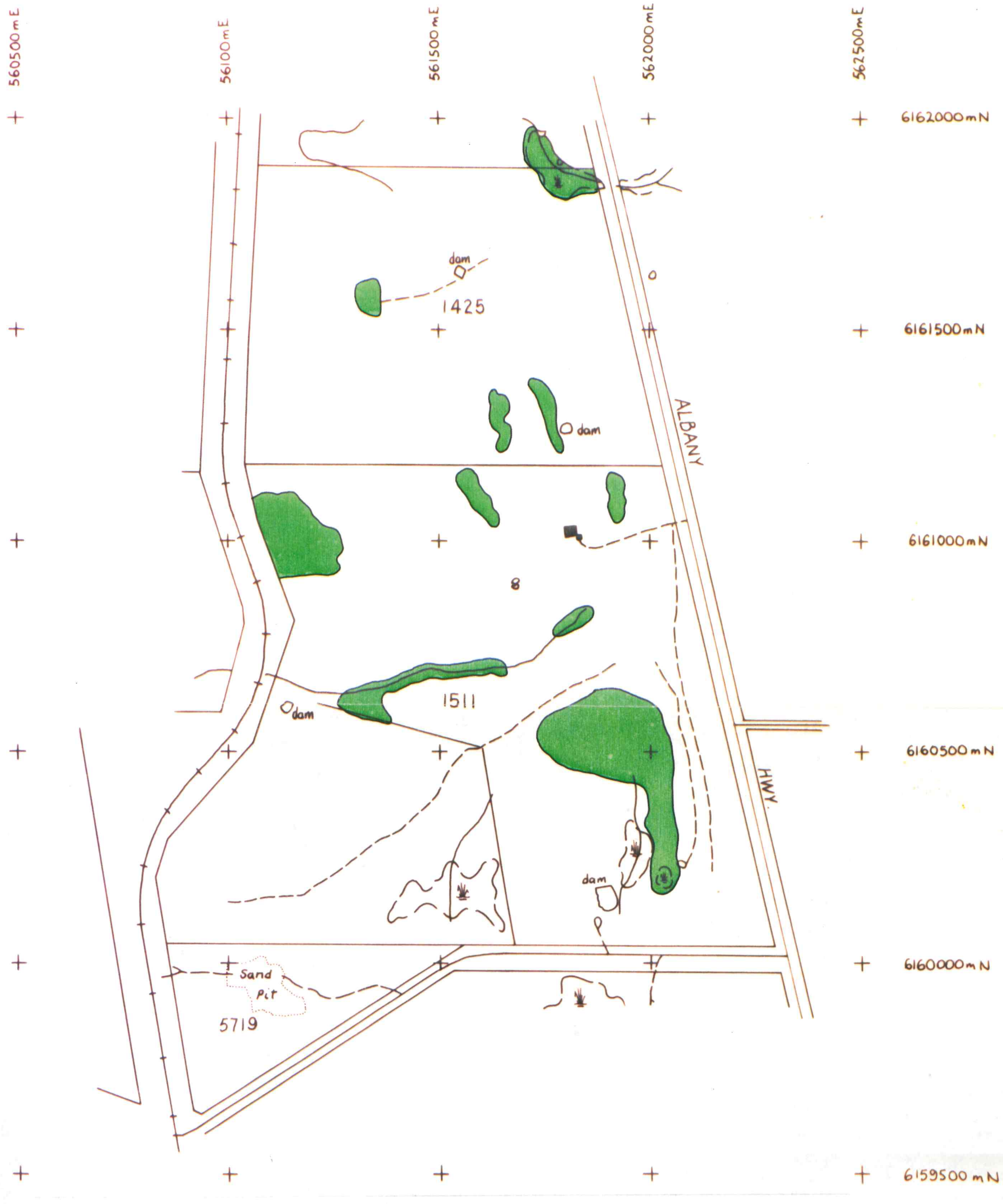
11. Maps

1: Remnant vegetation

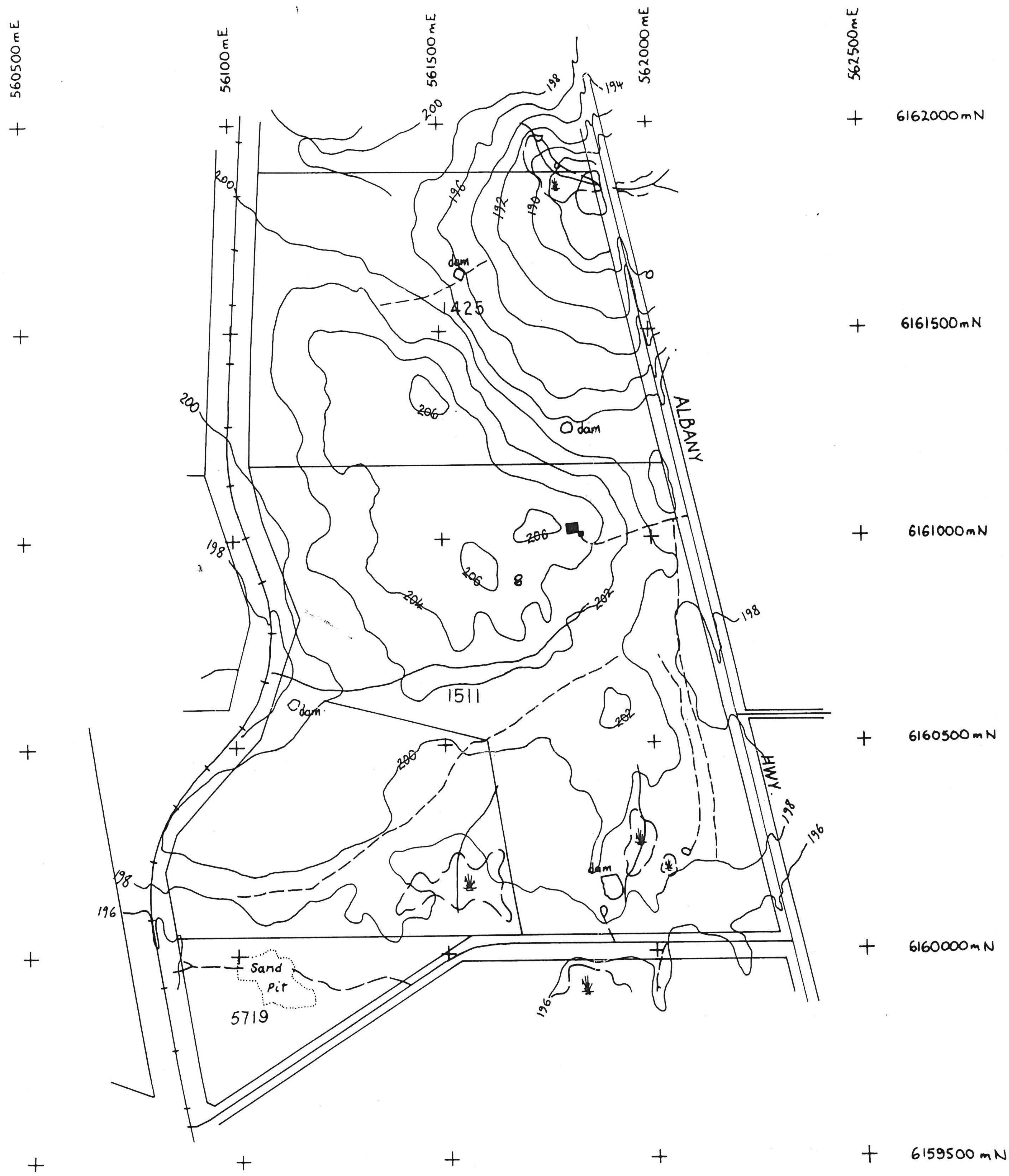
2: Contours

3: Soils



Map 1: Remnant Vegetation
(CG 1425 and CG 1511 — Mt Barker, Western Australia)

Scale 1:10 000



Map 2: Contours and drainage lines (CG 1425 and CG 1511 — Mt Barker, Western Australia)

Scale 1:10 000

Map 3: Soils
(CG 1425 and CG 1511 — Mt Barker, Western Australia)

Scale 1:10 000

6159500 mN

Association A: Soils of the lateritised uplands

A1	Sand to 100 cm deep, overlying ferruginous gravel and yellow brown medium clay. Crests and upslopes. Well drained.	(light green)
A2	Sand to 100 cm deep, overlying cemented ferruginous hardpan, and gleyed medium clay. Midslopes and flats. Poorly drained.	(dark green)
A3	Sand to 100 cm deep, overlying gleyed medium clay. Ferruginous gravel absent. Midslopes and flats. Waterlogged; saline in some areas	(olive)

Field Work and Interpretation R.J.Harper; Drafting K. Mungham; Department of Conservation and Land Management, Western Australia, July 1990

Association S: Soils of the upland swamps

S1	Sand to 100 cm deep, overlying iron organic pan ("coffee rock"). Waterlogged.	(pale pink)
S2	Sand 100 - >300 cm deep, overlying iron organic pan. Waterlogged.	(red)

Association D: Soils of the sand dunes

D1	Sand >200 cm deep, on dunes <150 cm above surrounding terrain. Well drained surface but waterlogged at depth.	(brown)
D2	Sand >200 cm deep, on dunes >150 cm above surrounding terrain. Well drained surface but waterlogged at depth.	(orange)

12. Appendices

Appendix 1 — Soil profile descriptions

Soils of the lateritised uplands

Soil A1

Profile: (91/MB1/L), upper slope of lateritised ridge

Depth	Description
0-8	Brownish black (10YR 2/2), medium sand, single grained structure, pH 7.0
8-60	Dull yellow orange (10YR 6/3), medium sand, 90% ferruginous nodules, 2-60 mm, pH 7.0.
60-90	Bright yellowish brown (10YR 6/8), medium clay (coarse sandy), moderate structure, pH 5.5.
90->250	Light grey (2.5Y 8/1), prominent yellow brown and red mottles, medium clay (coarse sandy), weak structure, pH 5.5.

Soil A2

Profile: (91/MB1/A), upland flat, adjacent to swamp

Depth	Description
0-10	Brownish black (10YR 2/2), medium sand, single grained structure
10-22	Greyish yellow brown (10YR 6/2), medium sand.
22-42	Dull yellow orange (10YR 6/4), sand with 20% ferruginous segregations 2-5 cm
42-70	Cemented ferruginous pan, unbroken
70->120	Light grey (2.5Y 8/1), 5% prominent yellow brown mottles, medium clay (coarse sandy), weak structure, roots along ped faces.

Soil A3

Profile: (91/MB1/B), upland flat.

Depth	*Description*
0-8	Greyish yellow brown (10YR 5/2), medium sand, single grained structure
8-120	Light grey (10YR 8/1), medium sand, single grained structure
120->250	Light grey (2.5Y 8/1), whole coloured, medium clay (coarse sandy), weak structure.

Soils of swamps and upland depressions

Soil S1

Profile: (91/MB1/G), upland swamp

Depth	*Description*
0-20	Brownish black (10YR 2/2), medium sand, single grained structure
20-110	Light grey (10YR 8/1), medium sand, single grained structure
110-140	Black (5Y 2/1), iron organic pan, discontinuous, variable strength weak to very strong fragments
140-190	Light grey (2.5Y 8/2), medium sand, single grained structure
190-220	Black (5Y 2/1), massive iron organic pan, continuous, very strong fragments

Soil S2

Profile: (91/MB1/F), footslope of lateritised ridge.

Depth	Description
0-3	Brownish grey (10YR 4/1), medium sand, single grained structure
3-20	Greyish yellow brown (10YR 6/2), medium sand, single grained structure
20-330	Light grey (10YR 8/1), medium-coarse sand, single grained structure
330-350	Brownish grey (10YR 4/1), iron organic pan, weak fragments

Soils of the sand dunes and sheets

Soil D1

Profile: (91/MB1/I), upland flat, adjacent to swamp, surface slightly mounded

Depth	Description
0-5	Greyish yellow brown (10YR 6/2), medium sand, single grained structure
5->300	Light grey (10YR 8/1), medium sand, single grained structure. Water in hole at depth.

Soil D2

As for D1, but on dunes >150 cm high above surrounding terrain

Appendix 2 — Major properties of the soils

Location CG 1425

Polygon	Soil	Mean sand depth (cm)	Area (ha)
1	S2	140	0.7
2	D2	207	5.6
3	A2	80	0.7
4	A1	45	14.3
5	A2	69	8.2
6	D1	200	0.5
7	A1	28	6.1
8	D2	220	1.5
9	A2	65	1.5
10	A3	70	11.2
11	A1	37	12.3
12	D2	300	2.0
Total area			**64.7**

Location CG 1511

Polygon	Soil	Mean sand depth (cm)	Area (ha)
1	S2	300	17.8
3	A2	107	1.0
4	A1		1.5
9	A2	75	2.0
11	A1		2.0
12	D2	300	6.4
13	A2	30	5.9
14	A1	20	22.7
15	S2	330	2.5
16	D1		1.3
17	S1	110	16.1
18	D1		0.5
19	D1	210	2.0
20	D1		2.5
21	D2		3.0
22	D2	220	1.5
23	D2	210	1.0
24	S1	70	4.6
25	D2	210	0.5
26	D2		0.8
27	A2	20	3.9
28	A3	130	1.5
29	A2	60	3.9
30	D2	60	5.4
31	D2		2.0
32	D2	200	1.0
33	D2		0.5
34	S1		0.3
35	A2	40	3.0
36	S2	150	3.9
37	S1	40	1.0
38	A2	40	4.9
39	D1		0.5
40	D1		1.3
41	D2		0.7
42	S1	300	0.2
43	D1	130	0.3
44	D1		0.2
Total			**129.9**