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Soils and landforms of the Manjimup area, Western Australia

Hugh Maxwell Churchward

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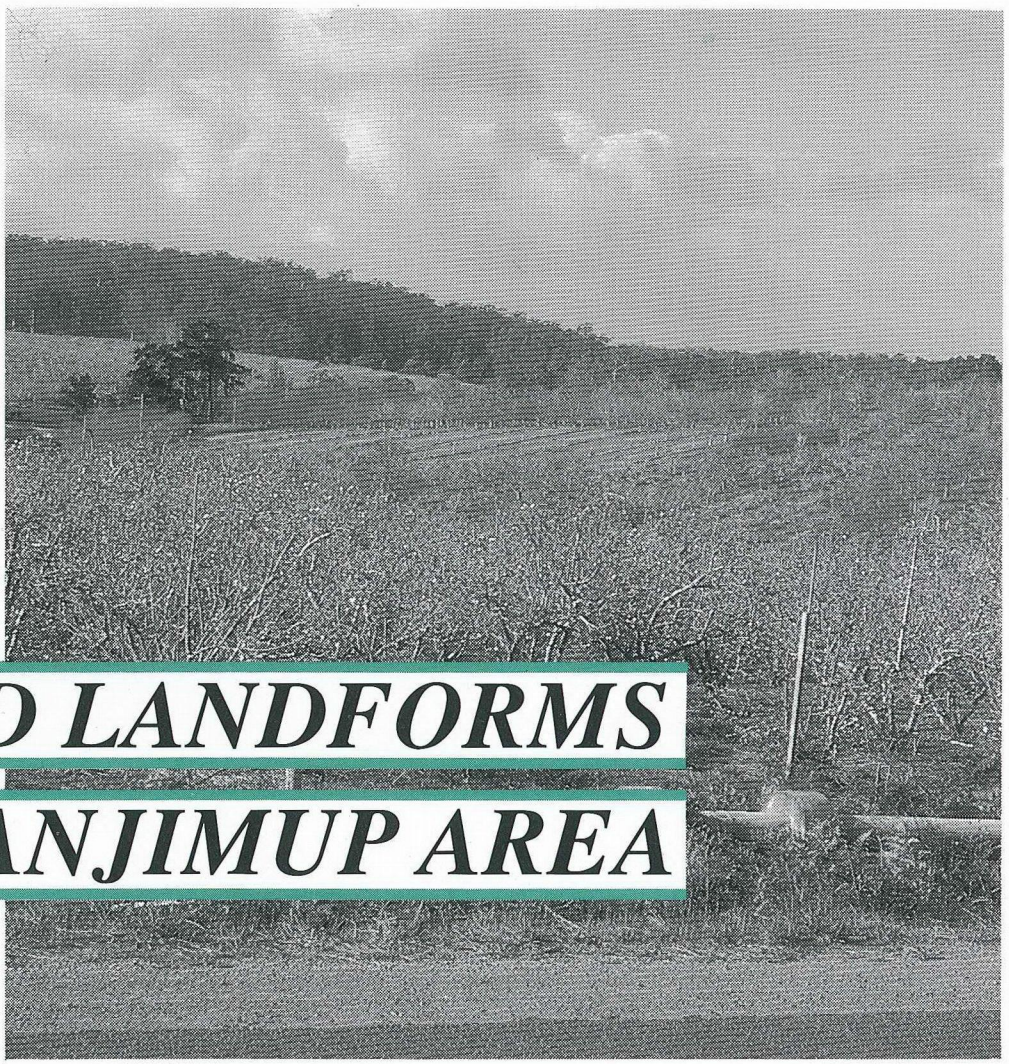

SOILS AND LANDFORMS OF THE MANJIMUP AREA

Western Australia

H.M. Churchward

DEPARTMENT OF AGRICULTURE
WESTERN AUSTRALIA

SOILS AND LANDFORMS OF THE MANJIMUP AREA

Western Australia

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Abstract

The soils and landforms of 6000 km^2 of the Manjimup area in Western Australia are presented as two map sheets at a scale of 1:100,000.

Forty-eight mapping units were recognized in the area and identified by local names. They related strongly to geology and landforms. The units were categorized into the four broad physiographic features of the area, namely the Darling Plateau, the Blackwood Plateau, the Scott Coastal Plain and the associated drainage elements. Further classification was based on the type of parent material and topography. The soils and vegetation of each unit are described.

The capability of each mapping unit for specific land uses was not interpreted.

Introduction

This report is a contribution to the record of the natural resources of the area around Manjimup in south-western Australia. Demand for this information arises from a number of activities including agriculture, town and regional planning, water conservation, afforestation and the assessment of regrowth potential of sites proposed for regeneration after clear felling. Furthermore, it is essential for environmental review and management programmes submitted by proponents of mining projects and to hydrologists as part of their assessment of catchment behaviour.

The report focuses on the nature of the soils and landforms around Manjimup which is essential for their management, particularly when they are being variously and often intensively used.

The natural resources of the Manjimup area are subject to increased and sometimes conflicting pressures. Much of the area yields timber and wood pulp. Also, forests and areas of other indigenous plant communities are a prime resource for the expanding tourist industry and some are dedicated to various types of parks and nature reserves.

Significant areas have been cleared for agriculture, particularly as a result of the Group Settlement Scheme of the 1920s and 1930s and meat, wool, fruit and vegetables are now produced. Some of these areas are being replanted to forests. In a few years the soils might be increasingly used for the growing of vegetables as more of the water resources of the Swan Coastal Plain are dedicated to urban rather than agricultural use.

There are deposits of mineral sands on the Scott Coastal Plain (Baxter 1977). These might become the subject of a land use debate in future, as might the possibility of some stream systems being declared as water catchments.

The resolution of land use conflicts and good management of an area require an adequate inventory of natural resources.

Whilst the nature and distribution of the soils and the various landforms are dealt with, their significance to a range of land uses is a separate phase of work.

The *Atlas of natural resources, Darling System, Western Australia* (Churchward and McArthur 1980) provides a map, at 1:250,000, of landform-soil units for a large part of the western Darling Plateau extending southward to within 12 km of Manjimup. Information for much of the southern part of that map came from an unpublished thesis by Finkl (1971) on the soils and landforms of the Blackwood River valley. McArthur and Clifton (1975) mapped soils, at 1:500,000, in the area from Manjimup south to the coast . Landform-soil units have been mapped along the south coast adjacent to the study area at 1:100,000 (Churchward *et al.* 1988). These maps and the broad scale patterns shown by Sheet Five of the *Atlas of Australian Soils* (Northcote *et al.* 1967), were a useful background for the present study.

Location

The area mapped (Figure 1) is about 6000 km^2 and lies mainly between the latitudes 34°00'S and 34°30'S and the longitudes 116°30'E to 115°30'E. A small part extends southward and follows the coast to latitude 34°44'S. It is encompassed by the Manjimup, Donnelly and Meerup 1:100,000 map sheets and includes much of the the shires of Manjimup and Nannup. The main towns are Manjimup, Pemberton and Nannup.

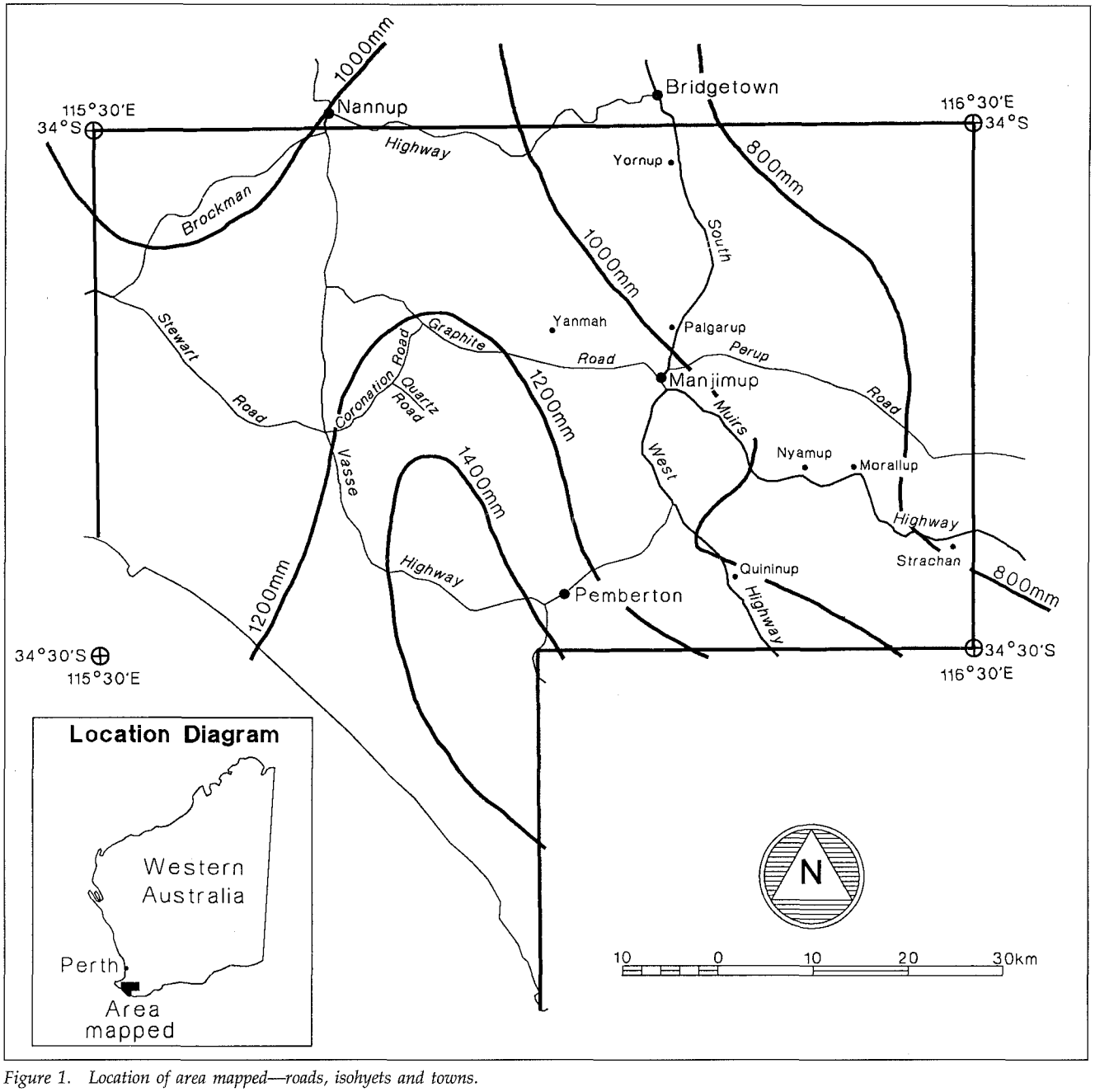


Figure 1. Location of area mapped—roads, isohyets and towns.

Climate

The climate is Mediterranean (Gentilli 1972), winters being cool and moist and summers generally dry and warm. The western sector of the area has an average annual rainfall of slightly < 1000 mm (Bureau of Meteorology 1965) but rainfall rises just east of the Darling Scarp, possibly as a consequence of an orographic effect. On the plateau, Pemberton has 1275 mm and Manjimup, 1000 mm. Rainfall decreases rapidly north of Manjimup (e.g. 850 mm at Bridgetown), and to the east (e.g. 800 mm at the property of Deeside).

Geology

Much of the area is on the Darling Plateau, the south-western part of the Great Plateau (Jutson 1934), a major physiographic element of south-western Australia. This plateau is dominated by Archaean rocks of the Yilgarn Block that is a portion of the Western Shield of Australia (Trendall 1975). It is defined on the west by the scarp of the Darling Fault. Westward beyond the scarp, the lower Blackwood Plateau is on Mesozoic sedimentary and igneous rocks of the Perth Basin. An array of unconsolidated, largely Cainozoic sediments (McArthur and Clifton 1975; Finkl and Fairbridge 1979), deep weathered profiles and soils mantle the older rock formations.

Archaean gneissic rocks of the Balingup Metamorphic Belt extend eastward from the Darling Fault. However, by about 15 km beyond Manjimup, granitic rocks are more important (Wilde and Walker 1984). Both terrains are intruded by dolerite dykes which have a general east-west trend, but near the Darling Fault north-easterly to north-westerly orientations are more prominent. Quartzite bands,

usually with a general east-west trend, are scattered throughout the area.

Mesozoic sandstones, mainly of the Leederville Formation, affect the soil pattern in areas of the Blackwood Plateau. Bunbury Basalt (McWhae *et al.* 1958), stratigraphically below the Leederville Formation, is within ancient valleys cut in the Yarragadee Formation. It outcrops along some of the major valleys and as cliff headlands on the south coast at Black Point. The occasional presence of Bunbury Basalt on the Darling Scarp (Finkl and Fairbridge 1979) indicates that uplift of the plateau was probably more recent than Cretaceous.

Some of the unconsolidated sediments on the Darling Plateau are comparable with Kirup Conglomerate (Finkl 1971). One example of this material, on the Dwalganup Road, 2.5 km north of Dwalganup Spring (ref: MH472374), occupies a local crest on the Darling Plateau at 280 m Australian Height Datum (AHD), well above the adjacent dissection of the Blackwood River. Here quartzose cobbles (25 to 50 mm diameter) are set in a sandy silcrete-like matrix. At another site west of Manjimup (ref: LH922082), coarse cobbles are exposed in a minor excavation below the floor of a gravel pit at the junction of Quartz and Coronation roads. These cobbles are set in a friable gritty clay and have a diameter of up to 30 cm. This material, which is beneath 2 to 3 m of Quagering gravels (see below), is comparable with that seen at the type locality for Kirup Conglomerate (Finkl and Fairbridge 1979), a rail cutting about 5 km north of Mullalyup (ref: LH996667).

Very sandy materials, generally with high amounts of smaller cobbles, have been included in the Quagering beds by Finkl and Fairbridge (1979). The type locality of these materials (as proposed by Finkl and Fairbridge 1979) is a pit on the south-west side of the Northcliffe road 2.5 km south of Pemberton (ref: MG088863). Here is a thick bed of coarse sand and grit with an occasional thin bed of quartzose cobbles. Some of the sands have crude cross bedding as well as associated, slightly inclined, thin laminae of silt, fine sand and clay. At most other sites, there is commonly no clear stratification in these materials and generally loose coarse sand and grit provide a sparse matrix to high amounts of cobbles (to 15 cm diameter). These beds can be at least 2 m thick and often overlie a gritty clay saprolite derived from gneissic rocks. Several large areas of these gravelly deposits, some 17 km west of Pemberton, have an elevation of 100 to 130 m AHD while an isolated pocket, 6 km south-west of Yornup township (ref: MH177292), is at 280 m AHD, well above the floor of the Blackwood River valley at 120 m.

Another type of quartzose deposit comprises sand and grit. It is dominated by coarse grains (to 3 mm diameter) that are often well rounded and have a frosted surface. Small areas of this type of sand are at Manjimup, adjacent to the cemetery, at 280 m AHD (ref: MH210096); at the junction of Fernhill and Perup roads (ref: MH287124), where they occupy a divide at 250 m AHD, about 8 km west of Manjimup; and at Hartlea (ref: MH547265), just beyond the north-east corner of the area mapped. There were traces of this round grit and coarse sand fraction in surface horizons of soils from widely distributed sites. The relatively limited size range, their frosted surface and the general lack of rounded pebbles as companion material, suggests that these quartz grains may have been transported (and worn) by wind rather than by streams.

Poorly stratified ferruginous sandstones have been observed on the Darling Plateau, especially in association with some broad, swampy tracts when quartzite is nearby. The sands appear to have been locally derived and need not necessarily indicate a regionally integrated river system. Some areas of these sandstones have been incised and the remnants cap local crests, sometimes associated with a lateritic duricrust. They occur frequently east and west of Quininup, as well as north-east of Strachan mill site adjacent to Muirs Highway, and extend eastwards beyond the map boundary (e.g. at ref: MG542924).

Finkl and Fairbridge (1979) show, in a generalized manner, the Quagering beds as having widespread occurrence, while on the Pemberton-Irwin Inlet geological map sheet (Wilde and Walker 1984) the unit Tg was proposed to represent some of the unconsolidated, generally quartzose sediments of this area. Observations during the present work suggest that many areas mapped as Tg appear to comprise colluvial sands forming the lower slope member of toposequences common to much of the western sector of the Darling Plateau (Churchward and Batini 1975; Bettenay *et al.* 1980). Furthermore, in the study area there are relatively few occurrences of Tg confirmed as being the Quagering beds. Although several authors (Finkl 1971; Taylor 1971), have reported that Kirup Conglomerate continues eastward beyond the study area, just north of the Blackwood River valley (Finkl 1971; Taylor 1971), it could not be traced further east from the Dwalganup site.

A large body of Quaternary aeolian sands forms a complex system of dunes along the seaward side of the Scott Coastal Plain. The older parts of this system are dominated by the Tamala Limestone Formation, a low-grade coastal aeolianite of Pleistocene age (Playford *et al.* 1976) and much of this is overlain by unconsolidated calcareous sands that are similar to the Quindalup sands of the west coast, considered to be of Holocene age by McArthur and Bettenay (1960).

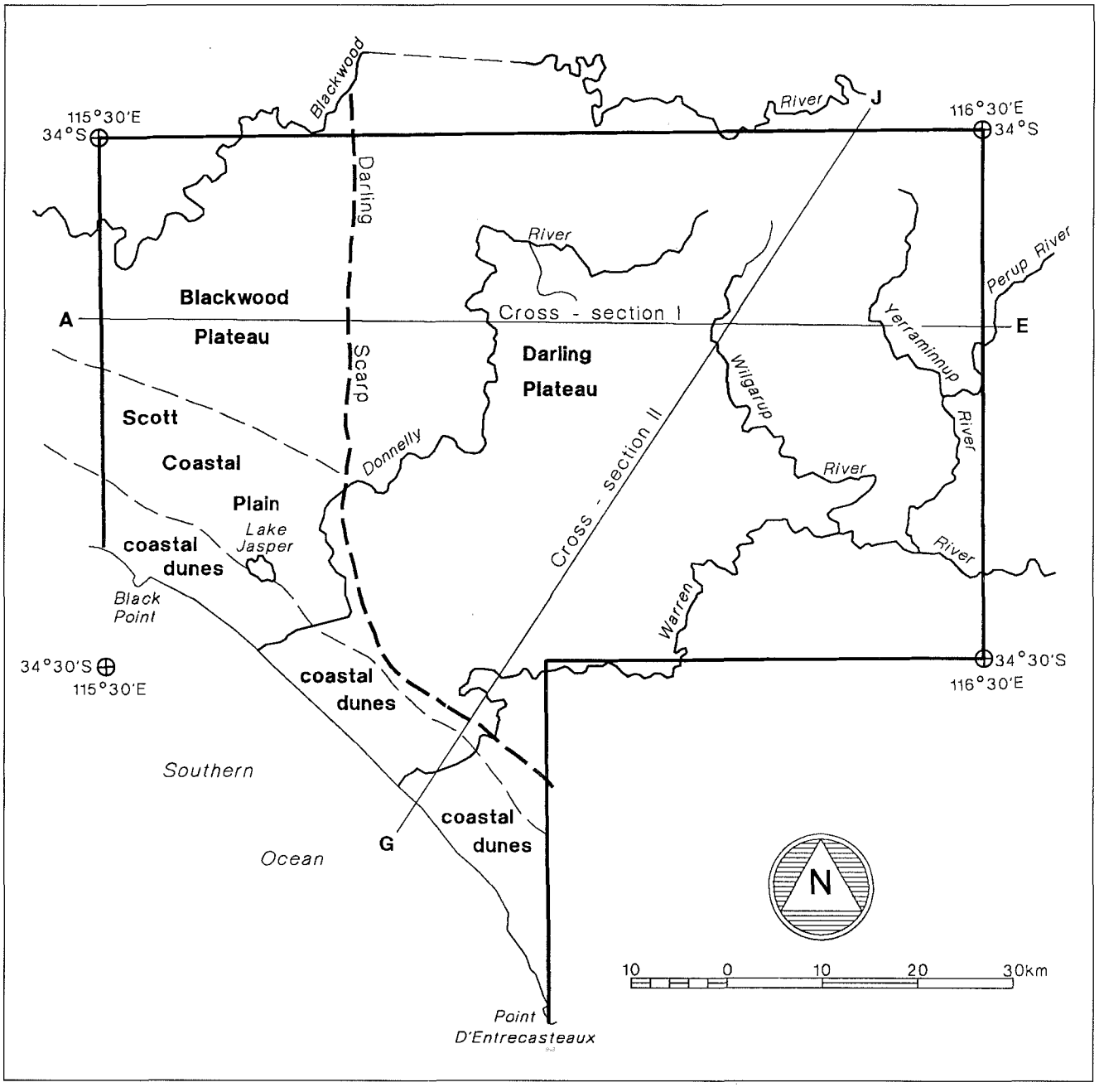


Figure 2. Broad physiographic features. Location of cross-sections.

Physiography

Broad physiographic features of this area are seen in Figure 2 while cross-sections (based on 20 m contour intervals), presented in Figure 3, illustrate the broad topographic trends.

The surface of the plateau, with an elevational range of from 260 to 330 m AHD, declines southward to much less than 100 m AHD. This is in keeping with the regional trend, across what Cope (1975) referred to as the Ravensthorpe Ramp. In more detail it can be seen that where the plateau surface is relatively undissected between Yornup and Manjimup, it comprises a complex of shallow drainage floors and broad flat interfluves with relief of less than 20 m. On this little-dissected part of the plateau some local relief is provided by low hills rising 20 to 60 m above the broad drainage floors and the poorly drained plains. Drainage from these swampy tracts concentrates along a system of shallow valleys referred to by Finkl and Fairbridge (1979) as the Darling Drainage System. This co-ordinated network is sometimes sharply truncated at the Darling Scarp and at points where it joins the deep valleys of major trunk streams, such as the Blackwood River. Finkl and Fairbridge (1979) proposed that this phenomenon indicates that the drainage pre-dated the plateau uplift and that perhaps the uplift took place in several stages.

At the general latitude of Manjimup, most of the valleys become progressively more incised downstream. However, in the case of the south-draining rivers,

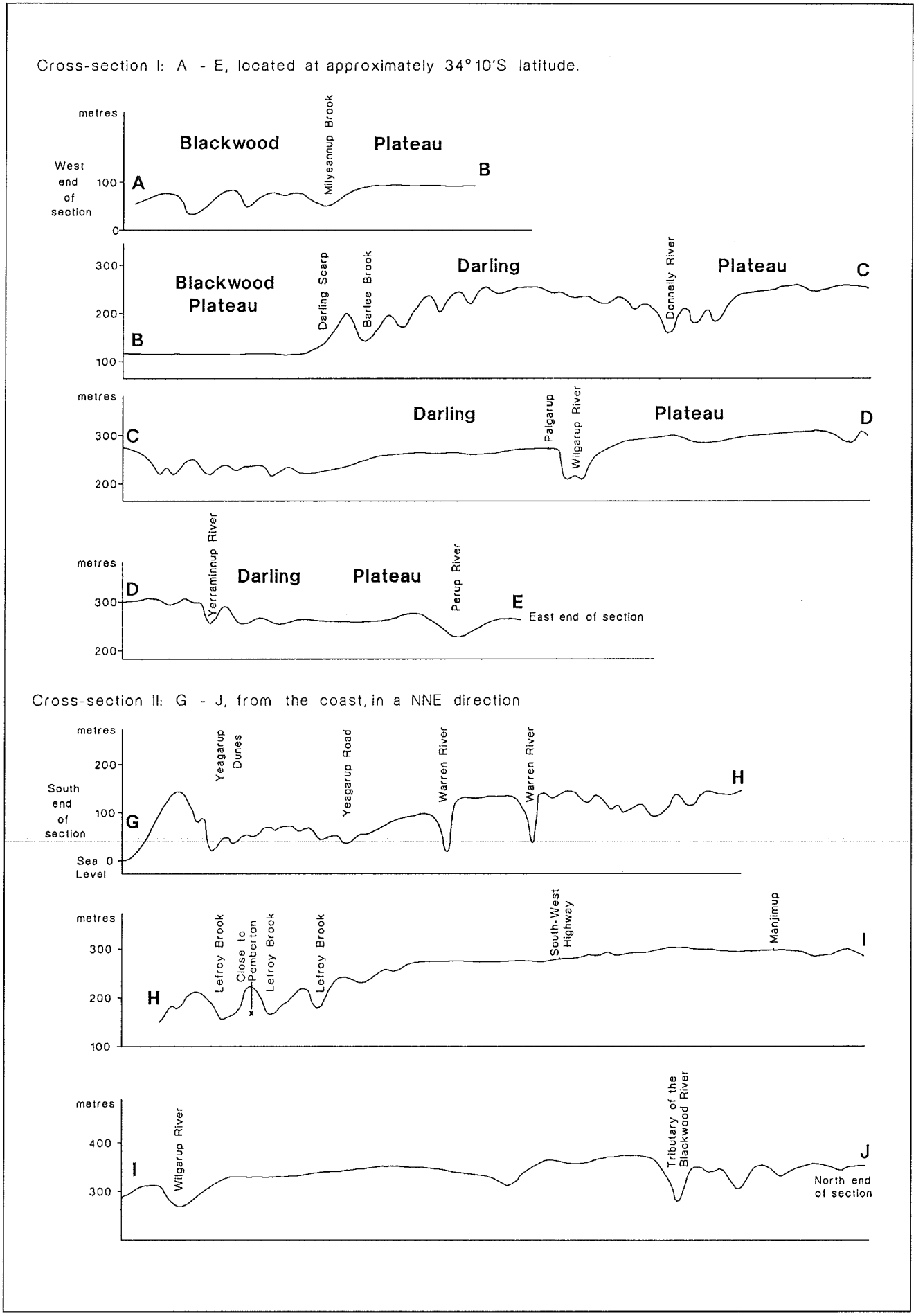


Figure 3. Cross-sections showing the broad topographic trends.

although the valley sides steepen downstream the valleys do not become much deeper since the plateau becomes lower in that direction. In the eastern sector, inclination of the valley sides for such rivers as the middle course of the Warren and much of the Perup, is variable because local, erosionally more active tracts, are a feature. These often form amphitheatres along the valleys and in these, slopes are roughened by frequent country rock outcrop; sometimes terminating as laterite-capped breakaways.

Although the Blackwood Plateau is generally lower than the Darling Plateau, it has comparable physiographic features . At the latitude of 34°00'S the skyline of the Blackwood Plateau is 120 to 140 m AHD, declining southward to about 50 m as it blends with the Scott Coastal Plain (Playford *et al.* 1976) and there is no scarp. Much of the relief variation is associated with interfluves between broad swampy tracts, which often form the headwaters of the valleys draining the Blackwood Plateau. Elements of the Darling Drainage System on the Blackwood Plateau are also truncated by the Blackwood River valley. The antiquity of this valley is also suggested by paleo-drainage features which are adjacent to the present course. Notable in this respect are traces of perched meanders. Furthermore, the skyline of the plateau declines locally towards the valley, a gradual trend that is sharply truncated by the present valley sides.

A well developed pair of terraces occupy the floor of the Blackwood River valley. Another pair occur in the floor of the Barlee Brook.

The Scott Coastal Plain (Playford *et al.* 1976) is an extensive swampy tract inland of a system of coastal dunes. On this the water table is at or close to the surface for most of the year and there are a number of ephemeral swamps and lakes, such as Jasper and Quitjup. Barlee Brook and the Donnelly River occupy shallow trenches along the eastern limits of the plain while westwards drainage is towards the Scott River. Low linear dunes < 2 m high, with a general west-north-west orientation, are scattered over the surface of the unit.

The coastal dunes form a system rising to over 100 m AHD (147 m at Dickson Trig). Surface sands here are largely a system of parabolic dunes that have an east-south-east and an east-north-east orientation. This system is comparable with the younger dunes system of the west coast, the Quindalup. However, the sands of the south coast system contain less calcium carbonate, so have been referred to as the Meerup unit (McArthur and Clifton 1975). The low carbonate content might in part reflect the more effective leaching by rain, but dilution by reworking of leached sands from soils of the older dune system (i.e. Tamala Limestone or coastal aeolianite) may have been more significant. The parabolic dunes extend from the coast over the broadly ridged mass of the Tamala Limestone and onto the swampy terrain inland. The older materials are often buried by the younger sands but their core of aeolianite is sporadically exposed on steep, unstable, seaward-facing slopes and escarpments, as scattered, steeply flanked and sometimes cone-shaped ridges and as occasional pockets of calcrete cap-rock having no specific topography. The leached surfaces of these older dunes are sometimes exposed through the discontinuous younger sand mantle.

The relief of the Darling Scarp at Nannup is about 160 m. This declines southward, so that adjacent to the southern limit of the Blackwood Plateau, it is 100 m and eventually, 10 km beyond Fly Brook, it has no clear expression. The decline is accompanied by a progressive change in the nature of the Darling Scarp. Much of the scarp north of the mapped area presents rather steep irregular slopes with much rock exposed. In contrast, south of Nannup (just beyond the northern limit of the map), there are increasing sections of the scarp which feature smooth gentle valley slopes mantled by lateritic gravels, sands and duricrust, and by kaolinitic saprolite. This suggests that deep weathering has been considerable after the final uplift of the Darling Plateau and attests to the antiquity of this feature.

Deep weathered mantle

In keeping with much of south-western Australia (Stephens 1946; Mulcahy 1973), the deep, weathered mantle comprises a deep clay, much of which is clearly saprolitic because it still has the fabric of the parent rock. The saprolite is frequently dominated by pale colours (e.g. pale yellow, grey and pale yellowish white are common) and is often referred to as the pallid zone. In the upper few metres, rock fabric is often less common and coarse mottling is more evident. Such material is often referred to as the mottled zone and it merges upwards into the laterite horizon with higher amounts of iron and aluminium sesquioxides, and is frequently indurated. It sometimes has spheroidal segregations (i.e. pisoliths and nodules) and coarse vermiform voids. This horizon is often called the lateritic duricrust. Weathering of the duricrust yields sands and lateritic gravels. Whilst much of the lateritic duricrust in this area appears to have developed *in situ*, some portions of it comprise lateritic gravels that have been transported a short distance downslope and recemented.

Erosion of the deep mantle of weathering effects its partial or complete removal, particularly on steeper slopes. Stumps of it often provide the subsoil of duplex profiles whilst debris from erosion forms a colluvial mantle that is a major contributor to the suite of soils. Many of the A horizons are of this transported material.

Lateritic duricrusts, and the associated very gravelly sands, are more common on the well drained broad convexities of divides and low hills. Where the crests are

broad and poorly drained, duricrust outcrop is limited to the convex flanks of the crests. This appears to have a significant bearing on the regional extent of lateritic duricrust. The overall extent of lateritic duricrust on the Darling Plateau in the Manjimup area is not as great as on the Darling Plateau east of the Perth area. This appears to be partly related to the more frequent occurrence of sandy, often swampy tracts (e.g. the Corbalup and Yornup units of the map in this report) forming tabular divides on the southern parts of the Darling Plateau. On a regional scale this trend is perceptible on the Darling Plateau south of the Preston River near Donnybrook. North of this river, by contrast, local interfluves of the Darling Plateau are more often broadly convex and extensively capped by lateritic duricrust.

There are also notable variations in the distribution of lateritic duricrust within the study area. In a narrow zone immediately east of the Darling Scarp, south of Manjimup, the interfluves have much lateritic duricrust. However the duricrust decreases to the east of this zone. Immediately north of Manjimup for some distance are extensive swampy divides, which may account for the general lack of lateritic duricrust on this part of the plateau. Here the duricrust is common only on the occasional summits rising above the swampy plains. Laterite is also not common on interfluves south and south-west of Manjimup where the ridge crests are occupied by the Crowea unit. The colluvium that mantles much of this unit often contains fragments of basement rock, reflecting perhaps greater stripping of the weathered mantle.

The duricrusts of the Blackwood Plateau are generally more sandy than most of those on the Darling Plateau, suggesting the rather more quartzose nature of the underlying sedimentary rocks. They often have reddish brown, brown and light brownish mottles and colours that are not as strong as the duricrusts on the Darling Plateau which range from strong brown, red-brown, strong yellowish brown and dusky red. The exception is the duricrust which appears to be over Bunbury Basalt and which has a colour closer to duricrust of the Darling Plateau. On the Blackwood Plateau, lateritic duricrust occurs more frequently on upper slope convexities. Tabular divides on this plateau are common however, and are more often occupied by deep sands than by lateritic duricrusts.

Method

The mapping units relate strongly to geology and landforms.

The soil pattern in south-western Australia is related closely to the degree of stripping of the deep weathered mantle. On the gently undulating plateau surface, sediment from broad upslope convexities is delivered to adjacent slopes and, with the lack of active streams, accumulates close to the source. By contrast, there is more stripping in the deeper valleys. Here sediment is moved down the slope and along the active streams more easily, exposing fresh rock and deeper parts of the weathered profile. Geology determines largely the amount of sand, clay, iron or quartz in the weathered mantle. These affect the susceptibility of the mantle to erosion, the nature of the colluvium, the type of weathered material exposed in the course of stripping and the array of soils.

The area's geology, landform and soils were examined while traversing roads and were delineated during stereoscopic examination of 1:40,000 black and white aerial photographs (WA1303 Pemberton; 23.12.70). A base map at 1:50,000 was first compiled and reduced to the final scale of 1:100,000.

Soil morphology and classification

The soils have been classified according to *A Factual Key for the Recognition of Australian Soils* (Northcote 1979). In this system, soils are first grouped according to field texture profile. This may be uniform throughout (U, undifferentiated), gradually increase with depth (G, gradational), or have a sharp texture break (D, duplex). The uniform soils are divided into coarse textured sands (Uc), medium textures (Um, loams), fine textures (Uf, clays) or fine textures for soils that crack seasonally (Ug, cracking clays).

There are two classes of gradational profiles: with calcium carbonate (Gc), which does not occur in the study area; and without carbonate (Gn).

Duplex soils have abrupt texture changes between the A (surface horizon) and the B horizon (subsoil). They are divided according to the colour of the clay B horizon into red (Dr) or yellow (Dy) classes.

Further subdivision in all classes is based on pH, structure, consistence and fabric to determine the Principal Profile Form (PPF). In this paper the PPF as well as the Great Soil Group (Stace *et al.* 1968) will be used to classify the soil.

The mapping units referred to in the following soil group descriptions are listed in Table 1 on pages 15-17, and are described on pages 20-40.

Uniform, coarse textured soils

The uniform, coarse textured (Uc) soils of the study area are divided on colour, incidence of calcium carbonate and induration in the B horizon. Calcareous sands (Uc1.11) with no colour differentiation down the profile other than that associated with organic matter accumulation in the surface, occupy the younger phases of coastal dunes within the Meerup mapping unit.

Undifferentiated siliceous sands (Uc1.21) have no horizon development other than organic matter accumulation in the surface. Some of the profiles possibly have a B horizon beyond examination depth. They occur in several landscapes where drainage is not restricted, in particular on some of the linear dunes in the Blackwater unit. They also occur in the Quartzite unit on the gentle lower slopes that flank quartzite ridges.

Sandy soils with weak horizon development (Uc5.11, Uc5.12, Ks-Uc5.11) have slight changes in texture, colour and consistence. No A2 horizon is evident and there may be a variable incidence of lateritic gravels. Colours are generally yellow-brown to reddish brown. These soils occur on the long gentle lower slopes of some hills and on upland concavities, especially where there are ferruginous gravels upslope. They are elements of the soil mantle in the Mattaband, Corbalup, Bevan, Kingia, Carbunup, Bidella and the Layman units.

Podzols

Many coarse-textured profiles, having marked colour differentiation with depth, can be classed as podzols. These soils have a bleached A2 horizon and a well-defined B horizon coloured by accumulations of various admixtures of iron and humus. They occur in sandy tracts; some are on well-drained sites such as sand dunes; others in swampy terrain. Podzols (Uc2.21, Uc2.22) tend to be associated with better drained sites while humus podzols (Uc2.20, Uc2.33) are common on poorly drained sandy tracts.

In the podzols, the B horizons can be friable yellow-brown to light brown sand but more often have streaks of various shades of dark brown and black. Some of these soils have a strongly convoluted interface between the A and B horizons, a feature that is often highlighted by a dark brown zone (to 40 cm thick) developed at the top of the B horizon. The B horizon is sometimes weakly cemented, forming nodules or a discontinuous pan. These soils are similar to iron podzols and are common in dunes on the swampy coastal plains (i.e. in the Blackwater unit). These profiles are an important part of some

Table 1. The mapping units

Units of the Darling Plateau		Units of the western fringe of the plateau	Scarps	Stripped slopes - irregular Weathered slopes - smooth	Dickson Wishart	DS WS
			Footslopes		Gale	GA
	Units developed on crystalline rocks	Units on the plateau	Hills emergent above general plateau surface	20 to 40 m high < 20 m high	Mattaband Collis	MT CO
			Plateau	Broadly convex to gently undulating divides; some lateritic duricrust	Bevan	BE
				Broadly convex local divides; laterite very rare	Crowea	CR (CRb, CRy, CRd)
				Slightly undulating	Corbalup	CL
				Almost flat	Cattaminup	CP
				Almost flat - some dunes	Hawk	HK
			Swampy tracts	Swampy plain Swamps	Yornup Kapalarup	YR KP
	Units developed on quartzite and unconsolidated sediments	Units on the plateau	Low ridges	Quartzite	Quartzite	QT
			Low hills	Ferruginous sandstone common	Quininup	QP
			Undulating plateau elements	Undulating divides with some quartzite Silicified Kirup Conglomerate outcrops	Toponup Forrard	TP FR
			Swampy tracts	Some low rises; rare quartzite outcrop	Cormint	CT
				Often on low, broad valley divides; loose cobbles of Quagering beds often present	Quagering	Q
				Bevelled fringes of Quagering	Angove	A
Units of the Blackwood Plateau	Units developed on Mesozoic sediments		Plateau surface	Slightly undulating local divides Slightly undulating local divides Slightly undulating - low relief	Kingia Telerah Jangardup	KI TL JN
			Swampy tract	Broad swampy floors	Coate	CE
	Units developed on crystalline rocks - Bunbury Basalt		Scarps		Scott	SC
			Plateau elements		Milyeannup	MP

Table 1. Continued

Units of the Scott Coastal Plain	Mixed sediments		Swampy tracts	Swampy plain	Blackwater	BW
				Slightly defined drainage	Cleave	CV
	Sands of coastal dune systems		Mainly parabolic types, some over Tamala Limestone		Meerup	M (Ms, Mf, Mp, Mc, Mu)
Units associated with drainage lines	Units in the Darling Plateau on crystalline rocks		Major valleys (well defined channels)	120 to 150 m deep; to 30° slopes	Bridgetown	BT
				60 to 100 m deep; 10° to 25° slopes	Balingup	BL
				< 5° slopes	Noombling	NB
				100 to 140 m deep; 15° to 20° slopes	Donnelly	DO
				60 to 100 m deep; 10° to 20° slopes	Warren	WA
				40 to 60 m deep; 10° to 20° slopes	Lefroy	LF
				20 to 40 m deep; 5° to 10° slope	Wheatley	WH
				40 to 100 m deep; < 5° to 8° slopes	Wilgarup	WL
				20 to 50 m deep; 5° to 8° slopes	Yerraminup	YE
				< 20 m deep; 3° to 8° slopes	Strachan	ST
			Minor valleys (swampy tracts)	20 m deep: 3° to 8° slopes	Catterick	CC
				< 20 m deep; < 5° slopes	Carbunup	CB
				20 to 40 m deep; 3° to 10° slopes	Pemberton	PM
				< 20 m deep; < 3° slopes	Yanmah	YN

Table 1. Continued

Units associated with drainage lines	Units in the Blackwood Plateau, on Mesozoic sediment		Major valleys	40 to 60 m deep; 8° to 12° slopes	Blackwood	BK
				20 to 40 m deep; 5° to 12° slopes	Jalbaragup	JL
				20 m deep; < 3° slopes	Barlee	BR
			Minor valleys	< 20 m deep; < 3° slopes	Bidella	BD
				< 20 m deep	Layman	LY
	Units on the Scott Coastal Plain; incisions into a swampy coastal plain		Major valleys	< 10 m deep	Jasper	JA

A variety of land uses occur within the study area.

of the older elements of the Meerup dune system, and minor, though significant parts of the soil mantle in the Blackwater, Cormint, Kingia, Coate and Cleave units where deep sands occur in well drained situations.

Sandy soils with a definite but not bleached A2 horizon and a coloured B (Uc4.21) can be referred to as podzolized sands. These are in the Meerup system (Ms, Mp and sometimes Mc). The presence of these soils can sometimes relate to exposure, of the leached surface of the older dune system, (on Tamala Limestone) showing through the discontinuous mantle of the younger Quindalup sands. Morphologically, the soils are similar to the Karakatta series (McArthur and Bettenay 1960) as part of the Spearwood dune system on the Swan Coastal Plain.

Humus podzols (Uc2.20, Uc2.33) have B horizons that are dark brown to black; the boundary between the bleached A2 and B horizons is generally even. Some B horizons are friable (Uc2.20) but more often they form a hardpan, sometimes referred to as 'coffee rock'. These soils occupy parts of the Blackwater, Quagering, Angove, Yornup and Cormint units.

Peaty podzols (Uc3.33) contain moderate to large amounts (usually < 20%) of organic matter in the surface horizons. The A2 horizon is usually grey with sporadic bleaching, and the B horizon consists of a black organic hardpan. These profiles are mainly in the Blackwater, Angove and Quagering units.

Loams

Loamy soils (Um) are not common. There are small areas in poorly drained tracts along valley floors and swampy plains, particularly where iron-rich groundwaters discharge. Reddish yellow loams (Um5.21) are usually characterized by very bright reddish or yellowish colours and the soils are often referred to as orange earths. Textures range from sandy loams to silty clay loams and the profiles, seldom > 40 cm deep, may overlie bog-iron pans which, in turn, overlie a pale grey heavy clay.

These reddish yellow loams occur as scattered pockets in the Yornup, Cormint, Biddela, Coate and Blackwater units, and in the swampy interdune flats of the Meerup unit. They can occupy much of the swampy floor of the Yanmah unit. Other loamy soils are on many of the lower terraces. They range from brown friable sandy loams to sandy clay loams with a pH between 6 and 7 (Um5.52). Such soils are in the Bridgetown, Balingup, Donnelly, Warren, Lefroy, Wheatley, Wilgarup, Yerraminnup and the Strachan units.

Uniform, fine textured soils

Uniform, fine textured soils are not common. Cracking clays (Ug5.13) are on the swampy floors of the Kapalarup, Catterick and Carbunup units, with some non-cracking clays (Uf6.42) also in the Kapalarup unit.

Earths

Soils with gradational increases in clay with depth (Gn) are referred to as earths by Northcote *et al.* (1975). They are mainly on the flanks of prominent hills and on the lower slopes of some major valleys

in the western part of the area. The red earths (Gn2.12, Gn2.14, Gn2.15, Gn4.15) have a brown or reddish brown sandy loam surface, 30 to 60 cm thick, showing much evidence of biological activity. The surface is very friable and may contain up to 50% gravel. Below this the texture gradually becomes finer, sometimes to medium clay, and this material may be structureless or weakly structured while the colour changes to red or brownish red. Deeper layers are generally mottled and fragments of weathered gneiss can be present below a depth of about 150 cm. Red earths, often referred to locally as 'karri loams', make up significant parts of the Crowea, Mattaband, Bridgetown, Balingup, Donnelly, Warren, Lefroy and Pemberton units.

Yellow earths (Gn2.45, Gn2.61, Gn2.64) differ from red earths in having slightly shallower (20 to 40 cm) surface horizons, a firmer consistency throughout and yellow or brownish yellow subsoils. Yellow earths are often closely associated with yellow duplex (Dy) soils, in granitic terrain within the Crowea, Mattaband, Bridgetown, Balingup, Donnelly, Warren and Lefroy units.

Duplex soils

Duplex soils have a sharp texture change and comprise two classes. One class in the study area, the yellow duplex soils, has acidic to neutral profiles and includes various podzols. Others are alkaline at depth, having columnar or prismatic clay subsoils. These are the solodized solonetz and solodic soils which collectively can be referred to as solonetzic soils.

The more common profiles with podzolic character (Dy2.61, Dy2.62, Dy3.61, Dy3.62) have a grey-brown loamy sand to sandy loam surface, on an A2 horizon at 20 to 40 cm and a variously mottled yellow, yellow-brown, brown or yellow-grey clay subsoil. Ferruginous gravel may occur throughout the A horizons but is generally concentrated at the interface of the A and B horizons. Such soils make up major portions of the Bevan, Crowea, Mattaband and Collis units. In this group, where the hue of the B horizon is 10YR*, the map unit symbol is followed by the subscript 'y'. When the hue of the B horizon is 7.5YR the subscript 'b' is used.

Duplex profiles with very sandy surface horizons (Dy5.81, Dy5.82, Dy5.83, Dy5.84, Dy5.85) are the main soils of the Angove, Toponup, Kingia and Bidella units. Minor areas occur in the Bevan, Mattaband, Collis and Crowea units. The profiles are characterized by an A horizon which is bleached, and a yellow mottled clay B horizon. Some ferruginous gravel can be present at the A/B interface. Sometimes there is dark brown staining of the soil material at the interface suggesting the incipient development of a 'podzol B' horizon.

*All colour notations are derived from 'Munsell Soil Color Charts', Munsell (1954).

Mapping units

In all, 48 units are recognized. They are grouped according to parent materials, which include coarse crystalline igneous and metamorphic rocks, quartzites, consolidated sediments (mainly Mesozoic sandstones), unconsolidated quartzose sediments and those units associated with aeolian sands and sediments of mixed origin on a wash plain. In effect, this groups units into those associated with the Darling Plateau (including the unconsolidated sediments), the Blackwood Plateau and the Scott Coastal Plain which are major elements of the area's physiography.

Division within the broad groupings is largely based on topography which means the units are an association of soils, rather than being a single soil type.

Both major and minor valleys have been recognized. Major valleys contain a stream channel and are commonly, but not always, deeper and wider than most minor valleys. The minor valleys usually have swampy floors and are often not as deep. Classification of the major and minor valleys is mainly based on the geological setting through which they pass, their relief, the configuration of their cross-section and the incidence of terraces.

The map units, identified by local names (see Table 1), are described in terms of physiography, geology and soil mantle. Some features of the associated native vegetation are included. Table 2 on page 21 is a proposed correlation between these units and those used by previous workers in this region, while Figure 4 on page 22 shows the relationship of the major units to topographic position, in schematic cross-sections.

The salient features of the mapping units are included in the legends presented with the two map sheets enclosed with this report. The mapping units are listed alphabetically. The four main groupings are:

- Units of the Darling Plateau (other than those of drainage lines)
- Units of the Blackwood Plateau (other than those of drainage lines)
- Units of the Scott Coastal Plain
- Units associated with drainage lines.

Units of the Darling Plateau (other than those of drainage lines)

Units of the Darling Plateau fall into two categories based on parent materials. The units may either have developed mainly on crystalline igneous rocks – the granites and gneisses – or on quartzite and/or unconsolidated quartzose sediments.

Units developed mainly in crystalline igneous rocks – granites and gneisses

The granites and gneisses of the Darling Plateau contribute to two broad unit types:

- units of the western fringe of the plateau, and
- units of the plateau surface.

(1) Units of the western fringe of the plateau

The plateau fringe can be further subdivided into stripped or weathered slopes of the scarp; or the footslopes.

Scarp

Stripped slopes

Unit: Dickson DS

This unit comprises irregular slopes with gradients ranging from 12° to 20°; minor, steeply graded, first order streams are included. The crest of this unit ranges in elevation from 300 m AHD, immediately south of Nannup, to about 100 m further south. It represents

Table 2. Correlation of the units between publications

This publication	McArthur and Clifton (1975)	Churchward and McArthur (1980)	Churchward *et al.* (1988)
Angove	Part of Quagering		Angove
Balingup+			Balingup
Barlee			
Bevan	Part of Balbarup	Dwellingup	Bevan
	Part of Nyanup	Hester	
Bidella	Part of Mungardup		
Blackwater	Blackwater		Blackwater
Blackwood		Darradup	
Bridgetown+			Bridgetown
Carbunup		Yarragil	
Cattaminup			Part of Bevan
			Part of Camballup
			Part of Caldyanup
Catterick		Catterick	
Cleave	Part of Blackwater		Part of Blackwater
Coate		Part of Mungardup	
Collis			Collis
Corbalup		Part of Hester	Part of Bevan
Cormint			
Crowea			Crowea
Dickson		Darling Scarp	
Donnelly		Helena	V_1
Forrard			
Gale		Kingia	
Hawk	Part of Cary		
Jalbaragup		Part of Jarrahwood	
Jangardup			
Jasper			
Kapalarup			Morande
Kingia		Kingia	
Layman		Part of Darradup	
Lefroy		Helena	V_1
Mattaband			Mattaband
Meerup	Meerup	Meerup	
Milyeannup			
Noombling*			
Pemberton			
Quagering	Quagering		Quagering
Quartzite	Part of Quagering		
Quininup			
Scott			
Strachan		Murray	
Telerah		Part of Kingia	
Toponup			
Warren		Helen	V_1
Wheatley		Murray	V_2
Wilgarup		Murray	V_2
Wishart		Kingia	
Yanmah		Yarragil	S_1
Yerraminnup		Murray	
Yornup		Wilga	Part of Caldyanup
			Part of Camballup

\+ Bridgetown and Balingup valley forms in Finkl (1971).

* McArthur *et al.* (1977).

the eroded portion of the Darling Scarp. Fresh rock frequently crops out while shallow colluvial mantles, some with substrates of deeply kaolinized gneissic (and sometimes granitic) rock, are extensive. This is the dominant nature of the Darling Scarp southward to about Stewart Road, beyond which the weathered scarp unit Wishart is more extensive.

The soil pattern is complex and includes yellow duplex, red duplex, gradational red and gradational yellow profiles, all of which have an acidic pH.

The dominant plant community is open forest to tall woodland of *Eucalyptus calophylla* (marri). The shrub layer includes *Xanthorrhoea preissii* (blackboy), *Macrozamia riedlei* (zamia palm), *Acacia pulchella* (western prickly moses), *A. myrtifolia, Bossiaea linophylla, B. ornata, Hovea trisperma, Hardenbergia comptoniana* (native wisteria) and *Andersonia sprengelioides.*

Weathered slopes

Unit: Wishart WS

This unit comprises moderate, smooth slopes (8° to 10°) and represents the less stripped portions of the Darling Scarp. These slopes are mantled by lateritic duricrusts and gravels, usually underlain by deeply kaolinized gneissic (and sometimes granitic) rocks; little fresh rock is exposed. The unit occurs sporadically along the Darling Scarp and is dominant south of Stewart Road where the general surface of the Darling Plateau is < 150 m above the Scott Coastal Plain.

The soils are gravelly, light brownish yellow sands with heavy ferruginous gravel (Ks-Uc5.11). Lateritic duricrust can occur at < 1.5 m below the soil surface. There are some yellow duplex soils with a very gravelly, pale yellow-brown sand A horizon.

Tall, open forests and tall woodlands of *Eucalyptus marginata* (jarrah) are common along with some marri. *Banksia grandis* (bull

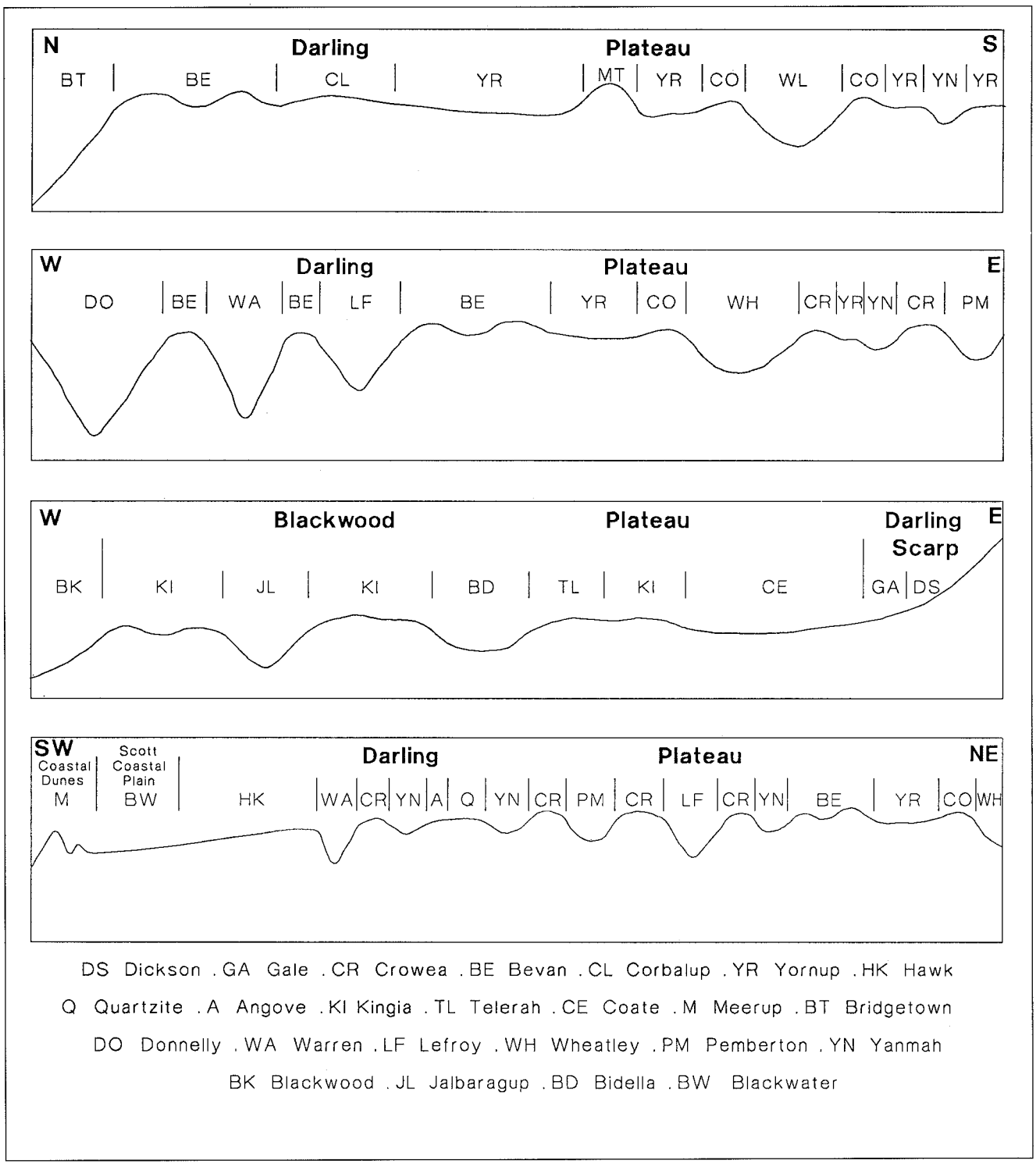


Figure 4. The relationship of some soil and landform mapping units to general topographic position, shown as schematic cross-sections.

banksia), *Persoonia longifolia* (long-leaf persoonia) and *Leucopogon verticillatus* (tassel shrub) form a low tree layer while *Allocasuarina fraseriana* is on some of the deeper sands. *Bossiaea linophylla, B. ornata, Hovea trisperma, Hardenbergia comptoniana, Clematis pubescens* and *Acacia pulchella* are in the shrub layer.

Footslopes

Unit: Gale GA

This unit is a very gently sloping (apparently) depositional apron to the Wishart unit. It is dominated by lateritic duricrusts, gravels and yellow sands but there are scattered incidences of quartzose cobbles. These cobbles have been observed in a pit just south of the Brockman Highway, 3 km south-west of Nannup township, as a discrete stratum about 0.5 m thick beneath unconsolidated lateritic gravels (ref: LH 853365).

The Gale unit extends discontinuously along the foot of the scarp but in places is separated from it by stream incision, such as that of the Carlotta Brook, about 2.5 km south-south-west of Nannup.

The soils are mainly very gravelly light yellow-brown sands.

Tall forests of jarrah, with some marri, occur with an understorey of *Banksia grandis* and *Persoonia longifolia*. The shrub layer is similar to that of the Wishart unit.

(2) Units on the plateau surface

The units on the Darling Plateau's surface are subdivided topographically into distinct hills, more gently undulating terrain and swampy tracts.

Hills

Unit: Mattaband MT

This unit, previously mapped by Churchward *et al.* (1988) to the south of the Manjimup area, comprises the higher hills rising 20 to 40 m above the surrounding plateau.

It has developed on deeply weathered granitic rocks. There may be occasional outcrops of fresh rock and some lateritic duricrust.

This is not a common unit but there are scattered hills on the Darling Plateau north and east of Manjimup. It merges with the Collis and Bevan units. Mattaband usually comprises a single summit and so contrasts with the more complex relief of the Bevan unit.

Yellow duplex soils are dominant, having a clay horizon with a hue of 10YR. Some B horizons with hues of 7.5YR occur but it was not possible to consistently delineate uniform areas of such soils in the manner of Churchward *et al.* (1988). In this study area the dominant yellow duplex profiles have a light grey-brown to yellow-brown A horizon with a pale A2 horizon and a mottled yellow-brown and pale yellowish grey (Dy3.61, Dy3.62), structureless clay B horizon and an acidic pH. Lateritic duricrusts may be present and ferruginous gravels occur in the B horizon. Some Dr and Gn profiles are present on localized steeper slopes.

The vegetation is a tall, open jarrah forest with some marri locally dominant. A small tree layer (6 to 8 m) of *Banksia grandis, Persoonia longifolia* and *Leucopogon verticillatus* is commonly present. The shrub layer includes *Bossiaea linophylla, B. ornata, Xanthosia rotundifolia* (southern cross), *Hovea trisperma, Kennedia coccinea* (coral vine), *K. prostrata* (running postman), *Hardenbergia comptoniana* and *Clematis microphylla* (small-leaf clematis).

Unit: Collis CO

This unit, previously mapped by Churchward *et al.* (1988), comprises low hills, with smooth slopes and broadly convex crests, rising no more than about 20 m above the plateau. Although it is developed on deeply weathered granitic rocks, there may be occasional outcrops of fresh rock and some lateritic duricrust.

Areas of the Collis unit are widely distributed on the Darling Plateau but it is most common north and east of Manjimup. In concept it merges with the Bevan and Corbalup units. However, Collis usually represents a single summit whereas areas of Bevan and Corbalup have a complex of broad summits and shallow vales.

Churchward *et al.* (1988) mapped four classes of Collis south of Pemberton but in the present study it was not possible to consistently delineate these classes. The dominant yellow duplex soils have a mottled yellow-grey and brown, structureless clay B horizon (Dy3.61, Dy3.62). These profiles have a light grey-brown to yellowish brown sandy loam A horizon with a pale A2 horizon. Ferruginous gravels occur in the B horizons but they are usually not a dominant feature. Duplex profiles with a clay B horizon and a hue of 7.5YR are rarely present. There are small areas of yellow-brown sand, sometimes very gravelly, in local concavities.

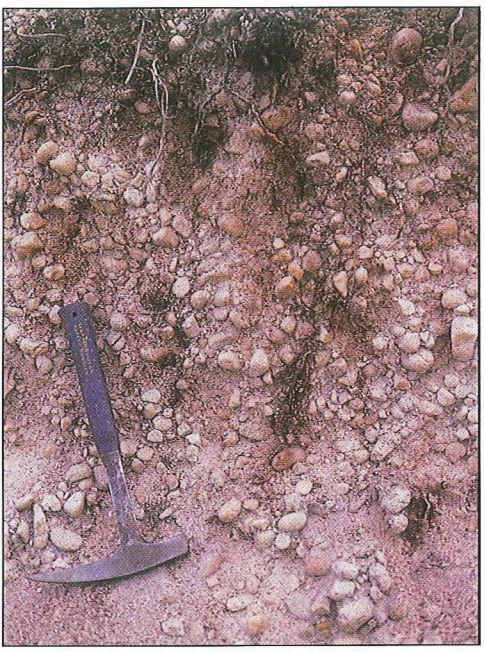
Open jarrah forests and tall woodlands occur with occasional marri; scattered *Banksia grandis, Persoonia longifolia* and *Leucopogon verticillatus* form a low tree layer. The shrub layer includes *Bossiaea ornata, B. linophylla, Hovea trisperma, Xanthorrhoea preissii, Podocarpus drouynianus* (native plum), *Macrozamia riedlei, Agonis parviceps* and *Hardenbergia comptoniana.*

Undulating plateau elements and broad crests

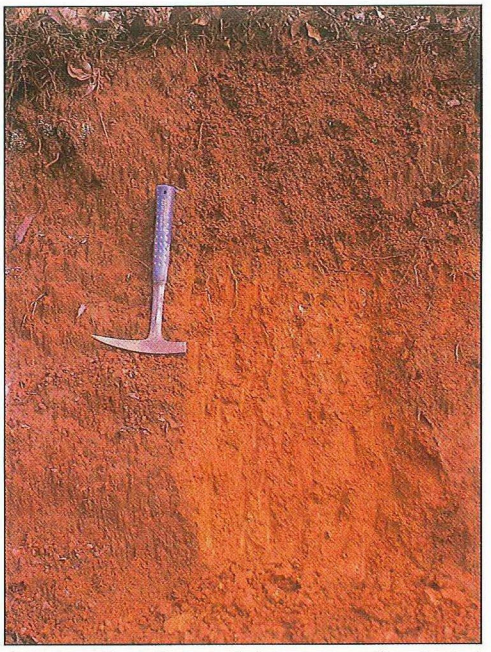
Unit: Bevan BE

This is a gently undulating tract comprising broadly convex crests and shallow minor valleys. It has previously been described by Churchward *et al.* (1988). Slopes in this unit are generally < 5° and the local relief is usually about 20 to 30 m. The crests are about 300 m AHD along the northern border of the map and decrease to about 100 m in the south-west.

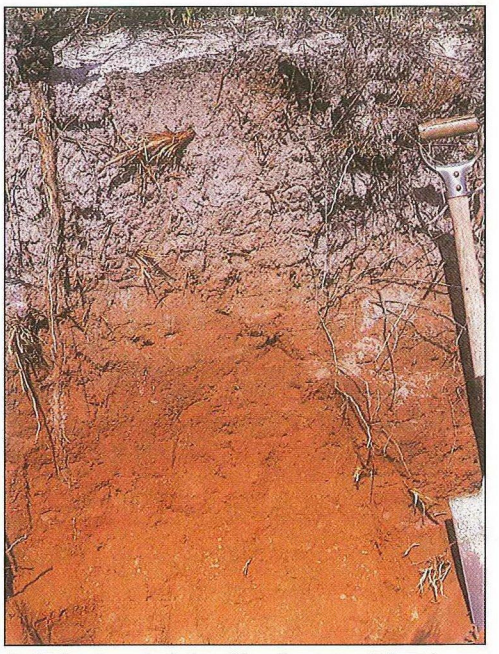
Bevan is most extensive to the north and east of Manjimup. Southward, particularly east and west of Pemberton, it is often replaced by



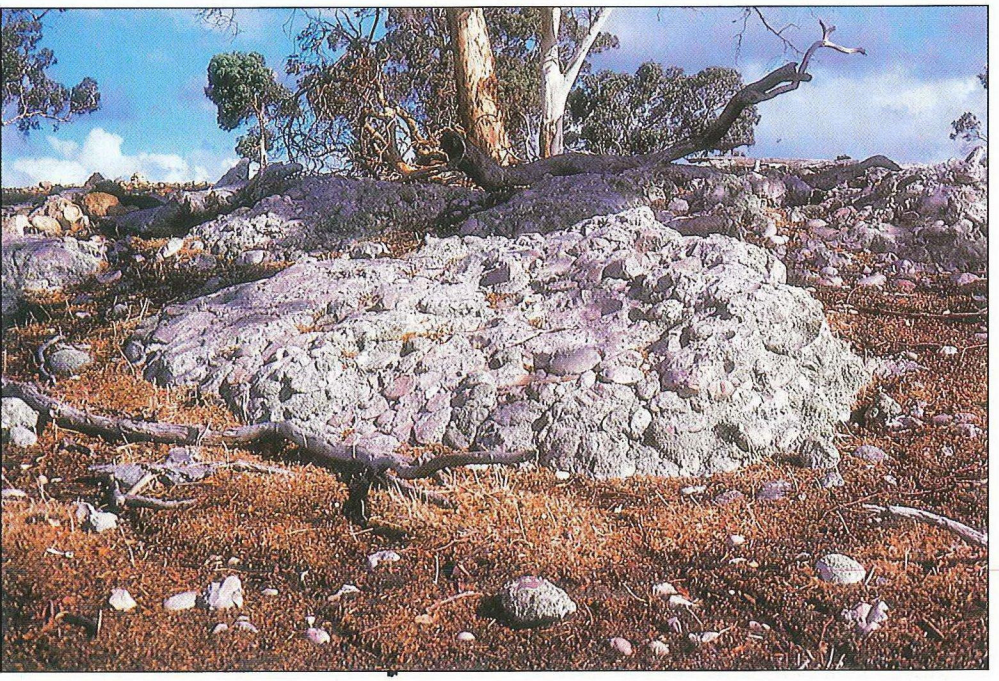
Loose gravels of the Quagering beds, 6 km south-west of Yornup township.



A duplex soil profile typical of the deeper valleys incised into the Darling Plateau.

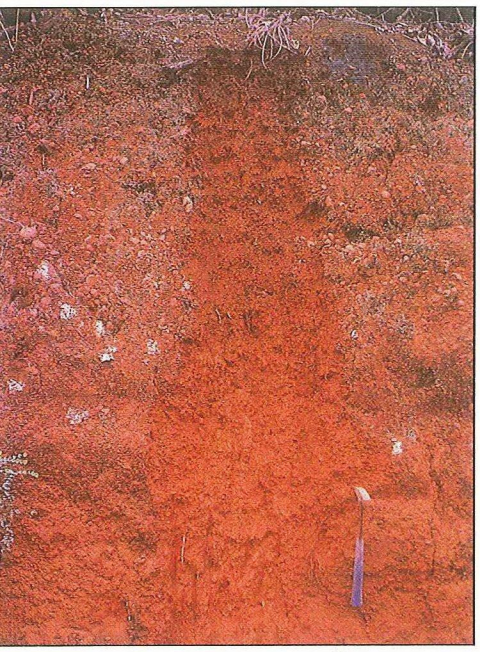


Podzolized sand of the older elements of the Meerup dune system.

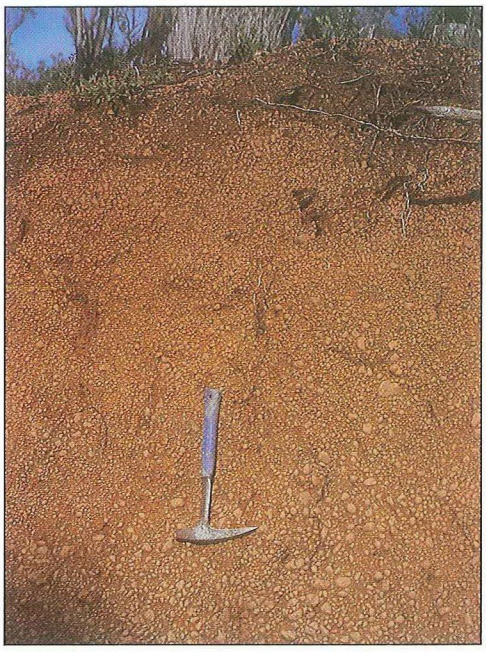


Kirup Conglomerate as a silcrete on a crest of the Darling Plateau near Dwalganup Spring.

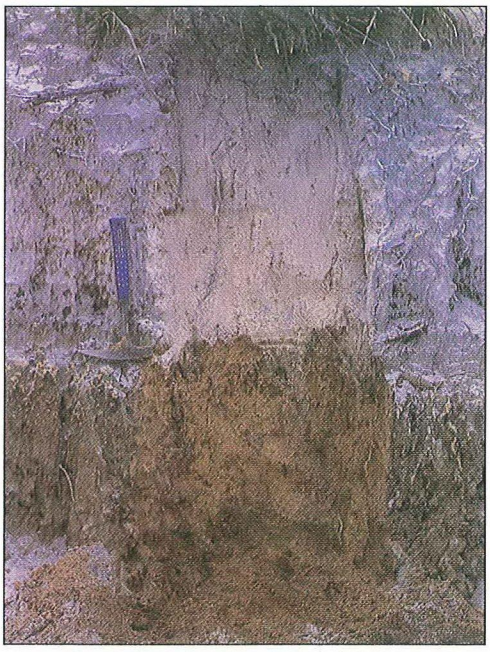
The swampy Scott Coastal Plain, showing the low dunes. The Meerup system forms an elevated mass of dunes in the background.



A red earth profile (karri loam) of the deeper valleys incised into the Darling Plateau.



Deep, gravelly, yellow-brown sands of the Bevan unit.



The profile of a podzol on deep sands of the lower slopes of the Kingia unit.

Elements of the Meerup dune system: the high crests are on Tamala Limestone, the younger dunes form lower ridges.

A deeply incised valley in the Darling Plateau - the Lefroy unit (in the Warren drainage system, south-south-east of Manjimup).

Crowea on the ridge crests. It occupies most local divides immediately east of the Darling Scarp.

A deep kaolinitic mantle, weathered from granitic and gneissic rocks, is extensive and outcrops of fresh rock are rare.

Yellow duplex profiles are dominant and have a light grey-brown loamy sand to sandy loam surface, a pale A2 horizon and a poorly structured clay B horizon, variously mottled yellow-brown; 10YR hues are dominant (Dy3.61, Dy3.62).

Lateritic duricrusts and gravels are important features of the Bevan unit and distinguish it from the Crowea unit. The duricrust occurs on crests and upper slope convexities (see Figure 5), however, as is often the case, when the ridge crest zone is more tabular the duricrust is usually limited to these convexities.

On these broad crests, duplex profiles are the extensive soil. They have very gravelly, pale yellow-brown to grey-brown A horizons and occasional blocks of lateritic duricrust on the B horizon. Down the flanking slopes there are yellow duplex soils or deep, gravelly, yellow-brown sands. These merge to yellow sands as the gravels decrease in amount and size. Podzols and humus podzols are in the minor valley floors and have dark brown to black B horizons at 50 to 150 cm. Here also are areas of orange earths with a bog-iron pan at about 45 to 50 cm, as well as yellow duplex soils having strongly bleached sandy loam A2 horizons and some gley features in the clay B horizon.

Areas dominated by yellow duplex profiles having a clay B horizon with a hue of 7.5YR (Dy3.61, Dy2.62) were recognized during field traversing but were not as clearly expressed on aerial photographs as in areas south of the study. Here, differences in vegetation between classes of the Bevan unit (Churchward *et al.* 1988) affected the tone of the aerial photographs.

Tall, open jarrah and marri forest occurs with an upper tree layer at about 30 m along with a small tree layer (5 to 8 m) of *Banksia grandis, Leucopogon verticillatus* and *Persoonia longifolia*. Small pockets of *Melaleuca preissiana* and *Banksia littoralis* (swamp banksia) mark poorly drained floors. The shrub layer includes such species as *Agonis linearifolia, Bossiaea linophylla, B. ornata, Acacia myrtifolia, A. pulchella, Macrozamia riedlei, Hovea trisperma, Hakea amplexicaulis* (prickly hakea), *Hypocalymma robustum* (Swan River myrtle), *Stirlingia latifolia* (broad-leafed stirlingia), *Hardenbergia comptoniana, Kennedia prostrata* and *K. coccinea.*

Unit: Crowea CR

The unit comprises broadly convex ridge crests and the flanks of gentle upper slopes and ridges. When examples of this unit are wide enough, the terrain may be slightly undulating, about 20 m high. West of Manjimup, Crowea is at 300 m AHD but its elevation declines southward to about 60 m near the Dombakup pine plantation. It is most extensive adjacent to Pemberton and extends south of the mapped area.

The deep kaolinitic mantle developed from gneissic rock is a common substrate to a colluvial surface mantle. Fresh rock outcrops are rare.

The dominant soils have yellow duplex profiles with some ferruginous and lithic gravels at the interface of the A and B horizons. Lateritic duricrust is rare. The three classes of this unit recognized by Churchward *et al.* (1988) have been delineated. Differences in the soil between these classes are mainly related to the hue of the B horizon or the texture of the A horizon.

CRb—the main soils have brown, gravelly A horizons often 50 to 100 cm thick, and mottled clay B horizons with a dominant hue of 7.5YR (Dy2.61, Dy2.62). Red earths or red duplex soils also occur.

A tall, open forest (40 to 80 m high) of *Eucalyptus diversicolor* (karri) and marri is dominant, with *Banksia grandis, Allocasuarina decussata* and

The Pemberton Valley—Pemberton unit.

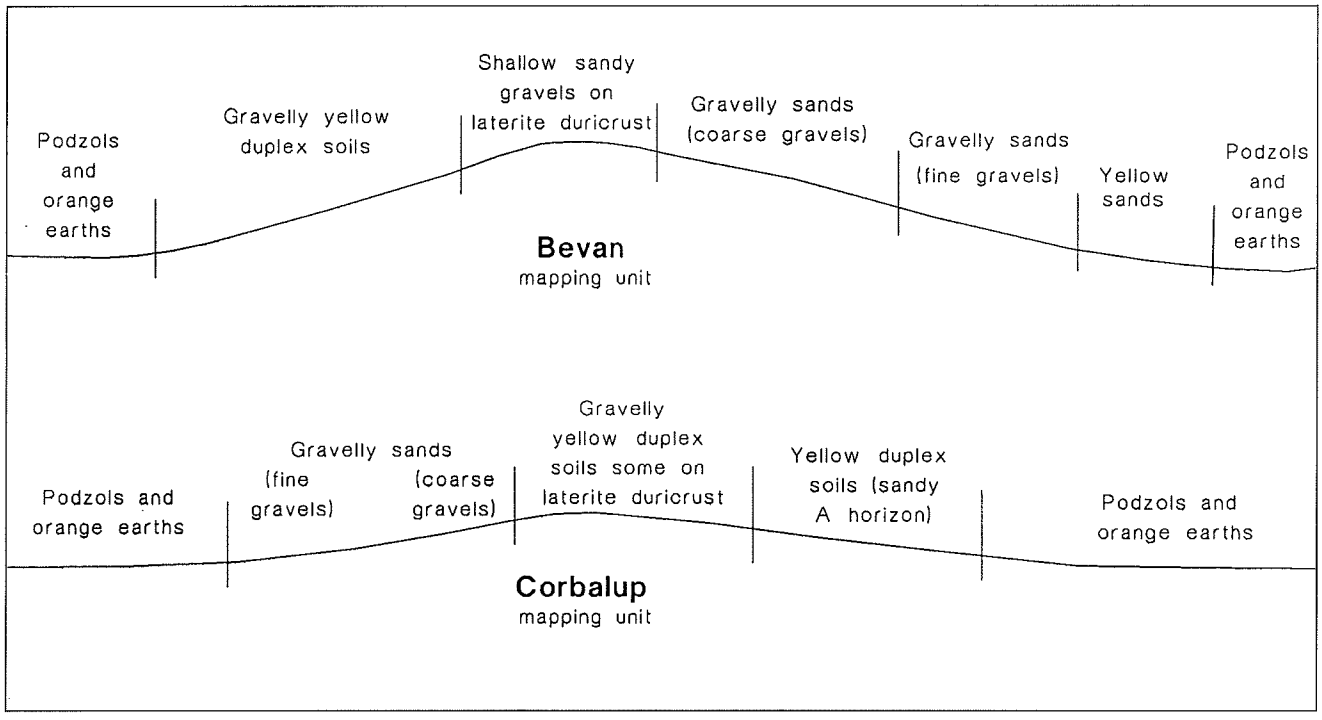


Figure 5. Topographic sequences for the Bevan and Corbalup mapping units showing general position of the main soils.

Persoonia longifolia as a low tree layer. Of significance in the dense shrub layer are *Acacia pentadenia, Trymalium floribundum, Chorilaena quercifolia, Hovea elliptica* (oval-leaved hovea), *Bossiaea linophylla* and *Clematis pubescens.*

CRy—the dominant profiles are duplex yellow soils which have a pale grey-brown loamy sand to sandy loam A horizon that is 20 to 40 cm thick and sometimes bleached slightly. The clay B horizon has a general hue of 10YR that is usually mottled yellow, yellow-brown and grey. It is mildly acidic. There are low to moderate amounts of ferruginous gravels in the A horizon (Dy3.61, Dy3.62) but boulders of this material are rare.

Tall, open marri and jarrah forests (30 to 40 m high) dominate these areas but some karri may be included in the higher rainfall areas. Scattered *Banksia grandis, Persoonia longifolia* and *Xylomelum occidentale* (forest pear) form a small tree layer. A dense shrub layer includes *Bossiaea linophylla, Acacia myrtifolia, A. pulchella, Hovea elliptica, Macrozamia riedlei* and *Xanthorrhoea preissii.* Creepers are mainly *Hardenbergia comptoniana, Kennedia prostrata, K. coccinea* and *Clematis pubescens.*

CRd—these are areas in which duplex yellow soils having grey sand A horizons, are dominant. These A horizons are 20 to 40 cm thick. The A2 horizon is strongly bleached. The B horizons are mottled pale yellow, brown and grey (Dy5.81). At the interface between the A and B horizons, a dark brown organic horizon or a layer of ferruginous gravel is common.

A marri and jarrah tall, open forest (30 to 40 m high) is common and there is a low tree layer (6 to 10 m) of *Banksia grandis* and *Persoonia longifolia,* and a shrub layer containing *Acacia myrtifolia, Agonis parviceps, Macrozamia riedlei, Lepidosperma* spp. (sword sedges), *Kingia australis* (black gin), *Adenanthos obovatus* (basket flower), *Xanthorrhoea preissii* and *Podocarpus drouynianus.*

In the area mapped, CRb tends to be on the flanks of the ridge tops and merges downslope with major valley units such as Donnelly, Warren and Lefroy. In contrast, CRd, with its more sandy A horizons, is on ridge crests and appears to represent the influence of quartzite veins or vestiges of a once more-extensive cover of unconsolidated quartzose sediments.

Unit: Corbalup CL

This very gently undulating terrain usually has broad, almost flat crests flanked by long, gentle slopes (< 3°) that merge with broad sandy, poorly drained concavities. Some areas have occasional convex elements. Relief is usually < 10 m but as it increases slightly, Corbalup tends towards Bevan. On the other hand, the more poorly drained examples of it are akin to Yornup.

The Corbalup unit occupies significant portions of the plateau on deeply weathered granitic rocks north-west and north-east of Manjimup between the valleys of the Blackwood, the Donnelly and the Warren Rivers. There are few exposures of country rock, however, and scattered pockets of ferruginous quartzose sandstone occur as well as some bog-iron pans. There are scattered blocks of lateritic duricrust on low rises.

Yellow duplex soils (Dy5.81) are extensive, particularly on the broad convex elements of this unit (see

Figure 5). Such profiles have a light grey-brown loamy sand A horizon with a pale A2 horizon; the poorly structured clay B horizon is mottled yellow and yellow-brown. The pH is acidic. Some lateritic gravels are present at the interface of the A and B horizons. Down the long gentle slopes flanking the broad convexities, these soils merge with light brownish yellow sands thence with podzols on the swampy floors of the broad concavities. Here also there can be orange earths (Um5.21), with a bog-iron pan at about 40 cm, as well as some yellow duplex profiles with bleached A2 horizons.

Open forests occur with jarrah as the dominant tree species. Some marri can be present. A low tree layer (4 to 8 m high) comprises *Banksia grandis* and *Persoonia longifolia* with *Allocasuarina fraseriana* on pockets of deeper sands. The shrub layer includes *Bossiaea linophylla, B. ornata, Agonis linearifolia, Hovea trisperma, Stirlingia latifolia, Acacia myrtifolia* and *Astartea fascicularis*. Thickets of *Melaleuca preissiana* and *Banksia littoralis* mark the more swampy areas.

Unit: Cattaminup CP

This is a very gently undulating terrain of low relief. Low rises have broad crests alternating with shallow, broadly concave or flat drainage floors. There are a few small ephemeral swamps. Relief from crest to floor is generally < 10 m.

The unit is on the Darling Plateau, occupying a broad divide between the Shannon River and the Tone-Warren drainage system. Granitic rocks, deeply kaolinized, are dominant.

The soil pattern on the broad crests and upper to middle slopes is a complex array of yellow duplex soils, and of red or yellow earths. The yellow duplex soils have a pale yellow-brown A horizon with an A2 horizon which can be bleached. The clay B horizon, at about 40 to 50 cm, is structureless and usually mottled. Yellow hues (10YR) dominate the B horizon but some have brown hues (7.5YR). There may be variable amounts of ferruginous gravels in the A horizon and occasional laterite blocks at the interface between the A and B horizons. Orange earths (Um5.21), often with bog-iron pans and humus podzols, dominate the drainage floors and the ephemeral swamps. Dark brown to black iron/organic pans can occur at about 100 cm.

Marri-karri forest communities are dominant, with *Banksia grandis* and *Persoonia longifolia* as important low (4 to 8 m) tree species. The shrub layer includes *Bossiaea linophylla, B. laidlawiana, Acacia myrtifolia, A. pentadenia, Leucopogon verticillatus, Agonis parviceps* and *Hovea elliptica*. In more swampy pockets *Banksia littoralis* and *Melaleuca preissiana* occur with *Oxylobium lanceolatum* and *Lepidosperma longitudinale* (common sword sedge).

Unit: Hawk HK

This is a very gently sloping to slightly undulating terrain with some minor swampy drainage floors.

The unit occupies a low, broad divide between the dissection of the Warren River to the north and east, and elements of the Scott Plain to the south and west around the southern limits of the Darling Scarp. The unit ranges from 60 to 110 m AHD.

Aeolian sands, as an extensive surface mantle, form hummocks, low dunes and sheets. Quartzose cobbles can be at or near the surface. Saprolite from gneissic rocks is a frequent substrate to these sediments and there are rare, small outcrops of Bunbury Basalt.

The dominant soils are red-brown to yellowish red loamy sands (Uc5.21) with bog-iron, either as a pan or as coarse nodules, from 40 to 80 cm deep. Quartzose cobbles may sometimes be embedded in the pan. Humus podzols, with friable dark brown iron/organic pans at 1 to 1.5 m, occupy the low dunes and hummocks. Red earths are on exposed saprolite, particularly when it is derived from Bunbury Basalt.

Tall open forests are dominant. Karri is important adjacent to the valley of the Warren River but jarrah and marri are more frequent south-west of Fly Brook where the soils are more sandy. There are some thickets of *Banksia littoralis* and *Melaleuca preissiana*, with *Oxylobium lanceolatum*.

Swampy tracts

Unit: Yornup YR

This unit forms swampy plains and includes some broad, low gradient drainage floors and occasional semi-permanent swamps. Scattered, low rises are also present. Local relief is usually not more than 5 m. The Yornup unit is most extensive north, north-east and north-west of Manjimup. It occurs at about 300 m AHD on the Darling Plateau above the valley of the Blackwood River. From here it grades south-west towards the main elements of the Donnelly River drainage system.

Sandy materials dominate the surface and these overlie clays that are mainly kaolinized granitic rocks. The origin of the sands is not clear but some may be unconsolidated quartzose sediments.

Humus podzols (Uc2.33) are the dominant soils. These have dark grey organic sand A horizons with dark brown to black iron/organic B horizons at about 50 to 120 cm.

Yellow duplex profiles are also common and can be dominant. They generally have sandy, bleached A2 horizons and mottled, structureless clay B horizons that have an acidic pH. Some yellow duplex profiles with bleached A2 horizons and coarse-structured clay B horizons are present.

Rarely have calcium carbonate nodules been observed deep in these soils (W.M. McArthur, personal communication). There can be dark brown organic staining at the

interface of the A and B horizons. On the low rises, yellow duplex soils are present, often with some ferruginous gravel, and the A2 horizons can be either conspicuously or sporadically bleached. Lateritic duricrust is rare but there are scattered bog-iron pans usually overlain by shallow, bright reddish yellow or grey-brown loams.

Low open woodlands of *Banksia littoralis* and *Melaleuca cuticularis* occur, along with *Melaleuca preissiana* and *Banksia verticillata* (river banksia), but there are also large areas of heath and sedge communities. Pockets of jarrah woodlands and low forests with some marri and *Banksia grandis* are present especially on the low rises. A dense heath layer often includes *Hakea ambigua, H. varia* (variable-leaved hakea), *Kingia australis* and *Agonis parviceps*. In wetter parts *Anarthria scabra, Leptocarpus scariosus, Mesomelaena* spp., *Gahnia decomposita* (a sedge) and *Evandra aristata* occur.

Unit: Kapalarup KP

This unit comprises semi-permanent swamps and adjacent elements of the swampy plains. These are areas of low relief (< 5 m) but some sand lunettes may rise to 10 m. The Kapalarup unit ranges from 200 to 300 m AHD and is scattered on the Darling Plateau, particularly north-west, north and north-east of Manjimup.

The unit is mantled by locally-derived lacustrine silts and clays as well as some aeolian sands. A deep mantle of kaolinized granite forms a common substrate.

The soil pattern is a complex of non-cracking clays (Uf6.42) and cracking clays. There are occasional pockets of yellow duplex soils with a conspicuously bleached A2 horizon. Podzols are on the deep sands of lunettes and humus podzols are on the deep sands of swampy tracts.

Sedgeland communities are the common vegetation and often include *Evandra aristata, Scirpus nodosus* (knotted club rush), *Leptocarpus scariosus* and *Juncus pallidus* (giant rush). Shrubs such as *Agonis parviceps, Melaleuca acerosa* and *Beaufortia squarrosa* (sand heath bottlebrush) are usually present. Some areas of jarrah woodland with marri, *Banksia grandis* and *Persoonia longifolia* occur on lunettes.

Low open woodlands of *Banksia littoralis* and *Melaleuca preissiana* occur frequently. Tall woodlands of jarrah with *Banksia grandis* and *B. ilicifolia* are found on the lunettes where they are associated with a shrub layer of *Leucopogon verticillatus, Podocarpus drouynianus, Agonis parviceps* and *Adenanthos obovatus.*

Units developed on quartzite and/or unconsolidated quartzose sediments

These units of the Darling Plateau are recognized as low ridges, low hills, undulating plateau and swampy tracts.

Low ridges

Unit: Quartzite QT

This unit comprises ridge crests and low hills. It may also occupy local slopes flanking some of the ridges that form some of the Toponup unit.

The unit is dominated by coarse sands and grits, and angular quartzite gravels. Occasional pockets of cobbles suggest that fluvial processes may have contributed to some areas of this unit.

The soils are mainly podzols, usually with poorly developed iron or iron/organic B horizons at a depth of 1 to 2 m.

Open woodlands of jarrah are dominant along with small trees of *Banksia ilicifolia* (holly-leaf banksia), *Xylomelum occidentale, Nuytsia floribunda* (Christmas tree), *Allocasuarina fraseriana* and a dense shrub layer of *Pultenaea reticulata, Adenanthos obovatus, Dasypogon bromeliifolius* (pineapple-leaved dasypogon), *Macrozamia riedlei, Podocarpus drouynianus* and *Agonis parviceps.*

Low hills

Unit: Quininup QP

This is a complex of low, smoothly convex hills, and vales, associated with ferruginous sandstone, sandy lateritic duricrust and deep, coarse grey sand. The unit is not widespread but is most extensive east and west of Quininup township. A specific example is adjacent to Grays Road (ref: MG283890). Elements of ferruginous sandstone on or near low crests, may be relics of a previous land surface that has been fragmented by stream incision. Much of the quartzose sand and grit which makes up the body of the sandstones could have been derived from quartzite, which occasionally outcrops.

Crests and upper slopes are mantled by pale brownish yellow gravelly sands with ferruginous sandstone and lateritic duricrust at shallow depth. Fragments of this lateritic duricrust are made up of a core of dark reddish brown to reddish black material with some yellowish red and pale yellow mottles. The outer surface is studded with coarse quartzose sand and grit. The deep sands of the flanking slopes and the local concavities are dominated by humus podzols (Uc2.20) with pale grey A horizons and friable dark brown B horizons at 1 to 1.5 m.

This unit is dominated by open jarrah forest communities with a low tree layer of *Banksia grandis* and a dense shrub layer containing such species as *Agonis parviceps, A. linearifolia, Adenanthos obovatus, Macrozamia riedlei, Pultenaea reticulata* and *Podocarpus drouynianus.*

Undulating plateau elements

Unit: Toponup TP

This unit forms a broad ridge crest capped by lateritic duricrust in which there is a scatter of angular quartzite fragments. Some of the laterites are very coarse sandy while there are occasional small

pockets of black ferruginous sandstone. The unit rises gently from 180 to 240 m AHD.

Areas of this unit occur adjacent to Frosty Road, 8 km east of Nyamup township, and a few kilometres east of Quininup township.

The dominant soils are gravelly, pale brown sands. Some of these are deeper than 1 m while others have < 30 cm of sand over lateritic duricrust. There are pockets of light yellow sand and gravelly sand as well as some deep, pale grey sand profiles.

Open jarrah forests and woodlands with some marri are the dominant communities. *Banksia grandis* and *Persoonia longifolia* are important low tree species. The shrub layer usually contains *Bossiaea linophylla, Leucopogon verticillatus, Xanthorrhoea preissii, Macrozamia riedlei* and *Podocarpus drouynianus.*

Unit: Forrard FR

This unit forms crests and flanking upper slopes capped by Kirup Conglomerate. The capping often comprises a silcrete which encases coarse (to 35 cm diameter) quartzose cobbles. The steep erosional slopes flanking these crests are strewn thickly with loose cobbles.

A small area of this unit is on the plateau surface, above the dissection of the Blackwood River, at the northern limit of the map (ref: MH472374).

The soils of the crests are stony, grey to pale yellow coarse sands. On the flanking slopes are duplex yellow profiles with a stony, light brown sandy loam A horizon over a yellow-brown to brownish yellow, poorly structured clay B horizon. The A2 horizon has sporadic bleaching. A stone line in the A horizon comprises fragments of diverse origin suggesting a colluvial nature.

Open forests to tall woodlands of jarrah, with some marri, dominate these areas. Low tree species include *Persoonia longifolia, Dryandra sessilis* and *Banksia grandis. Macrozamia riedlei, Xanthorrhoea preissii, Bossiaea linophylla* and *Leucopogon verticillatus* are important elements of the shrub layer.

Swampy tracts

Unit: Cormint CT

This is a complex of swampy tracts and low rises adjacent to the Toponup, Quininup and Quartzite units. It shows coarse quartzose sand, angular quartzite gravel and scattered, small outcrops of quartzite. A kaolinized granitic substrate to the soil mantle is common.

The Cormint unit is of limited extent; there are several examples east and west of Quininup township, generally arrayed close to latitude 34°27'S.

The soil mantle comprises a complex pattern of humus, iron and peaty podzols while low rises have yellow duplex soils with pale grey, sandy A horizons.

Heath communities are dominant but there is a scatter of low trees including jarrah, *Nuytsia floribunda, Banksia littoralis* and *Melaleuca cuticularis.* A dense shrub layer includes species such as *Agonis parviceps, Pultenaea reticulata* and *Lepidosperma longitudinale.*

Unit: Quagering Q

The Quagering unit has flat to very gently sloping, poorly drained, sandy terrain, sometimes with a complex of low rises. It often occurs on broad valley divides and ridge crests some 20 to 60 m above the present stream channels (Churchward *et al.* 1988).

The surface is dominated by deep, unconsolidated quartzose sediment but there are some zones of quartzite. Frequently this sediment comprises coarse gritty sand containing varying amounts of coarse cobbles and is referred to as the Quagering beds. Crude stratification of sands and clays, sometimes cross-bedded, may be evident. Deeply kaolinized granitic rocks form substrates for these unconsolidated sediments.

Several large areas of this unit are at 120 to 160 m AHD south-west of Pemberton (e.g. near the junction of Benghazi and Fly Brook Roads, ref: MG966867). An area west of Yornup (ref: MH177292) on the Darling Plateau above the valley of the Blackwood River, is at 280 m AHD . Another, 13 km south of Nannup, is immediately east of the Darling Scarp, at 220 m AHD (the corner of Wishart and Davidson roads, ref: LH900247).

The dominant soils are humus podzols but some peaty podzols are present. The iron/organic B horizons sometimes form pans and the water table is usually at < 1 m for much of the year.

Low open woodlands of depauperate jarrah, *Nuytsia floribunda* and *Banksia ilicifolia* are present. There are extensive heath communities either as a dense substratum to the low tree layer or by themselves. This heath includes *Agonis parviceps, Pultenaea reticulata, Kingia australis, Beaufortia sparsa* (gravel bottlebrush), *Evandra aristata, Lepidosperma gladiatum* (coast sword sedge) and *Leptospermum firmum.*

Unit: Angove A

This unit, previously described by Churchward *et al.* (1988), comprises very gentle slopes and some broad drainage divides. It is sometimes identified on the edges of the Quagering unit where it appears to represent a slight erosional modification of the Quagering unit. Local relief is < 20 m and it ranges from 60 to 250 m AHD.

The surface of this unit is dominated by quartzose sands and grits. The presence of cobbles indicates that some of the quartzose materials are of sedimentary origin. Others appear to have been derived from local quartzite. The substrate to the sands is often kaolinitic clay, the result of weathering of gneissic rocks.

The dominant soils are yellow duplex profiles with a light grey-brown sand A horizon, having a

bleached A2 horizon over a mottled, structureless clay B horizon. The profiles are acidic (Dy5.81). Dark organic staining is common at the interface of the A and B horizons. These soils merge with humus podzols developed on deep sand.

Low open woodlands of depauperate jarrah and *Banksia ilicifolia, Xylomelum occidentale* and *Nuytsia floribunda* are usually present. A dense heath layer is dominated by *Agonis parviceps, Pultenaea reticulata, Kingia australis, Adenanthos obovatus, Leucopogon australis, Leptospermum firmum,* and *Dasypogon bromeliifolius.*

Units of the Blackwood Plateau (other than those of drainage lines)

Geology divides the units on the Blackwood Plateau into those developed on either Mesozoic sediments or crystalline rocks.

Units developed on Mesozoic sediments

All units developed on Mesozoic sediments are located on the plateau surface. There are two topographical categories: undulating local divides and swampy tracts.

Undulating local divides

Unit: Kingia KI

This unit was mapped by Churchward and McArthur (1980). It comprises gently to slightly undulating ridge crests which form many of the local drainage divides of the Blackwood Plateau including the upper ends of minor valleys. At the foot of the Darling Scarp, crests of these units are about 140 m AHD but decline to about 50 m south and south-westwards adjacent to the Scott Coastal Plain.

The unit has developed on deeply weathered, sandy Mesozoic sediments; there are few fresh rocks exposed.

Both yellow duplex profiles and humus podzols occur extensively. The duplex profiles have a pale brownish grey sand A horizon, often with a bleached A2 horizon. The mottled clay B horizon is usually structureless, and some ferruginous gravels are common in the A2 horizon along with blocks of laterite. Humus podzols have developed on deep sand and have a dark brown to black iron/organic B horizon, sometimes as a pan, at about 1 m. Water tables at a depth of < 1 m are common in these profiles for about six months each year.

On the crests there are pale yellow-brown gravelly sands with much lateritic duricrust at a shallow depth. Down the gentle slopes, pale yellow sands with some ferruginous gravels become more common. On the lower slopes, the yellow sands merge to podzols and humus podzols in broad shallow concavities. Where the crests are broad and tabular, lateritic duricrust is not common. In this situation the crests are mantled by humus podzols with black iron/organic B horizons over mottled clays having gley features. However, there is a narrow zone of lateritic duricrust associated with the convexity flanking the crest.

Woodlands occur most frequently but the wetter parts are dominated by heath and sedge communities. The woodlands are mainly jarrah, with some marri, while a low tree layer contains *Banksia grandis, Xylomelum occidentale* and *Allocasuarina fraseriana.* The dense shrub layer comprises a wide range of species such as *Podocarpus drouynianus, Agonis parviceps, Kingia australis, Pultenaea reticulata, Adenanthos obovatus, Dasypogon hookeri* and *Lepidosperma angustatum.*

Unit: Telerah TL

The Telerah unit has slightly undulating ridge crest zones which form portions of local drainage divides of the Blackwood Plateau. It has a general elevation range of 100 to 130 m AHD while internal relief is < 5 m.

This unit is closely associated with the Kingia unit and has developed on deeply weathered, sandy Mesozoic sediments.

The soil pattern is complex. Lateritic duricrust occurs most frequently on the broadly convex summits of low rises. Here also are gravelly, pale yellow-brown to pale yellowish grey-brown sands, ranging in thickness from < 30 cm to 100 cm. Some areas of deep, pale yellow-brown to brownish yellow sands occur downslope and these grade laterally into deep, light grey sands which can be classified as humus podzols. Some of the long, very gentle slopes of the crests have sandy, yellow duplex profiles but there are significant areas of soils with gradational profiles. These are yellowish grey-brown sandy loams merging to pale yellowish brown sandy clay loams at a depth of 15 cm. Ferruginous gravels sometimes appear at 30 to 40 cm, set in a mottled pale brownish yellow and light yellow sandy clay. The coarse gravels increase with depth, but then decrease to about 1 m where the profile is mottled light brownish yellow to pale yellow-brown and orange sandy clay.

Areas of this unit are dominated by depauperate, low, open woodlands of jarrah and marri. *Allocasuarina fraseriana* and *Xylomelum occidentale* are on some of the deeper sands. A dense shrub layer is common and this includes *Agonis parviceps, Kingia australis, Hypocalymma angustifolium, Adenanthos obovatus, Dasypogon hookeri* and *Lepidosperma angustatum.* A low heath dominates some areas, particularly those of gradational profiles. Epacrids are common and include *Andersonia sprengelioides* and *Leucopogon capitellatus.*

Unit: Jangardup JN

This is a slightly undulating terrain of < 10 m relief. Broadly convex rises are flanked by long, very gentle slopes which merge with floors that are either concave or flat and swampy.

Jangardup occurs along the flanks of the Blackwood Plateau as it merges with the Scott Coastal Plain to the south. Geologically

these areas are dominated by deeply weathered sandstone but there are small areas of weathered granitic rocks and Bunbury Basalt. There are rare surface pockets of quartzose cobbles.

Yellow duplex profiles are on the convex rises and usually have a pale grey-brown sand A horizon to 50 cm thick and a pale brownish grey A2 horizon. The B horizon is a structureless, mottled gritty clay and there can be dark brown to black staining at the interface of the A and B horizons. Lateritic gravels can be scattered throughout the A horizon and occasional blocks of lateritic duricrust can be present.

Several large pockets of soils with browner hues appear to be related to pockets of Bunbury Basalt. These profiles have a light brown to light greyish brown, sandy loam A horizon on a yellowish brown to brown clay B horizon at 40 cm. An A2 horizon is generally present but not bleached. The clay B horizon is poorly structured and has a pH of 6.5 at depth.

Humus podzols are common on the broad, poorly drained interridge floors. These have a thick, pale grey sand A2 horizon with a black iron/organic horizon, often as a pan at 90 to 120 cm. Pale grey gritty clays form an extensive substrate to these profiles. Orange earths with bog-iron pans and nodules are also common on these swampy tracts.

The crests and upper slopes have jarrah-marri tall woodland to open forest communities with *Banksia grandis* and *Persoonia longifolia* as a low tree understorey. A heath understorey contains an array of species such as *Adenanthos cuneatus, Agonis parviceps, A. linearifolia, Bossiaea linophylla, Stirlingia latifolia* and *Dasypogon bromeliifolius*. The more swampy tracts are dominated by a depauperate jarrah community and there can be thickets of *Melaleuca preissiana* and *Banksia littoralis*. These areas contain a dense heath of *Agonis parviceps, Beaufortia sparsa, Evandra aristata* and *Lepidosperma longitudinale*.

Swampy tracts

Unit: Coate CE

This unit comprises broad swampy floors 0.5 to 1.5 km wide. There are some low, broad rises with crests < 5 m above the floor of the unit.

Coate usually comprises the upper tracts of the drainage system for the Blackwood Plateau. It is set some 10 to 20 m below the crest of the adjoining Kingia and Telerah units. The elevational range is from 140 m AHD at the foot of the Darling Scarp to 80 m adjacent to the Scott Coastal Plain in the southwest.

Humus podzols are widespread and have a dark brown to black iron/organic B horizon at about 1 m, often as a pan. Water tables occur at < 1 m for at least eight months.

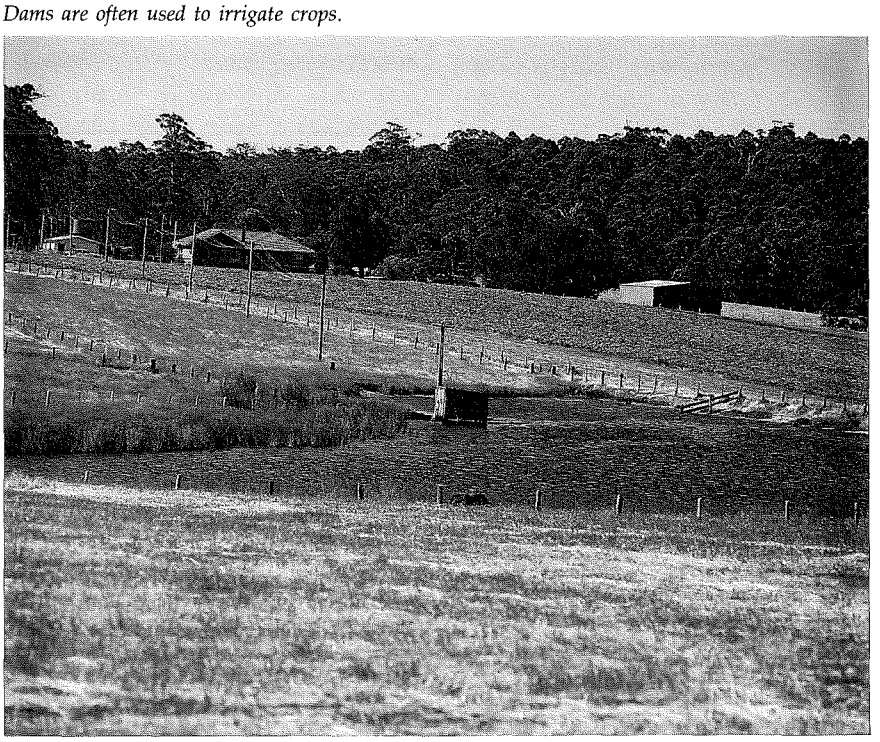
Scattered pockets of orange earths are present with bog-iron pans. These earths sometimes cap low rises. Some duplex profiles have a pale yellowish brown, silty clay loam A horizon on a light yellowish brown B horizon at about 35 to 45 cm. Yellow duplex soils occur on some of the low rises, along with light yellowish grey, sand A horizons which often have a bleached A2 horizon with some ferruginous gravels. A structureless, mottled clay B horizon is at 40 to 60 cm.

Sedgelands and heaths are common, sometimes beneath a low, open woodland of depauperate jarrah, marri and *Allocasuarina fraseriana*. There are a few scattered pockets of low trees, mainly *Melaleuca preissiana, Banksia littoralis* and *B. ilicifolia*. Shrub communities include *Agonis parviceps, Pultenaea reticulata, Andersonia sprengelioides, Lepidosperma* spp., *Evandra aristata, Scirpus nodosus, Beaufortia sparsa, Leptocarpus scariosus, Kingia australis* and *Mesomelaena* spp.

Units developed on crystalline rocks – Bunbury Basalt

Two units are associated with Bunbury Basalt: one occupies portions of scarps and valley slopes, and the other forms undulating plateau elements.

Dams are often used to irrigate crops.



Scarps

Unit: Scott SC

The Scott unit comprises crests and slopes associated with outcrops of Bunbury Basalt. Such slopes flank parts of the Blackwood River valley and the McAtee Brook, a northern tributary of the Blackwood River. There are also some narrow outcrops of Bunbury Basalt along the Darling Scarp.

Deep saprolite, usually as a red clay derived from Bunbury Basalt, is common. The soils are generally red earths with red, friable sandy loam to sandy clay loam surfaces merging gradually to a friable red clay loam by about 30 cm deep. There can be some fragments of weathered basalt in these horizons. Red and reddish yellow clay is found at about 45 cm.

Marri forest communities are present, with *Banksia grandis* and *Persoonia longifolia* forming a low tree layer (4 to 8 m). The shrub layer includes *Bossiaea laidlawiana, Macrozamia riedlei, Hovea elliptica, Kennedia prostrata, K. coccinea* and *Hakea amplexicaulis.*

Undulating plateau elements

Unit: Milyeannup MP

The Milyeannup unit is a gently undulating upland surface forming part of the skyline of the Blackwood Plateau. Undulations often have a relief of about 10 m, however, a greater relief range (up to 100 m) occurs on crests of the unit, where it is adjacent to the incision of the Blackwood River.

Areas of this unit together present a general north-south zone towards the western limit of the map. This has general concordance with the inferred occurrence at depth of Bunbury Basalt as presented in Figure 3 of Wilde and Walker (1984) as well as being adjacent to outcrops of this rock along valleys.

Lateritic duricrusts and the associated shallow, gravelly, light brown to yellow-brown sands are extensive on the ridge crests. Downslope, these sands increase in thickness while the gravels become finer until deep sands are dominant. These soils range through reddish yellow, light brown, yellow-brown to light brownish yellow and commonly have a clayey sand texture.

Open forests of jarrah and marri dominate this unit. There is a lower tree layer (4 to 8 m) of *Allocasuarina fraseriana, Banksia grandis* and *Persoonia longifolia.* The shrub layer includes such species as *Leucopogon verticillatus, Macrozamia riedlei, Bossiaea linophylla, B. laidlawiana, Kennedia prostrata, Hardenbergia comptoniana, Hovea trisperma, Clematis pubescens* and *Acacia pulchella.*

Units of the Scott Coastal Plain

The geology of the Scott Coastal Plain basically separates the mapping units into two classes. Units are developed either on mixed sediments or aeolian sands.

Units developed on mixed sediments

All units on the mixed sediments of the Scott Coastal Plain are swampy. Two topographical classes are recognized; swampy plains and zones of slightly more defined drainage.

Swampy plain

Unit: Blackwater BW

This is a major part of the Scott Coastal Plain. The unit was described by Churchward *et al.* (1988) as 'a flat, poorly drained plain, often with very diffuse drainage patterns; both seasonal or permanent swamps are included'. Some low, generally linear dunes occur, often with an east-south-east orientation. Within the area of this map, elevation ranges from 70 m AHD inland to about 40 m adjacent to the coastal dunes.

Unconsolidated sands and clays are extensive, some being derived from the weathering of Mesozoic sediments and Archaean crystalline rocks. There are also traces of quartzose cobbles.

Humus and peaty podzols are dominant and have dark brown to black iron/organic pans. Orange earths with bog-iron pans and nodules form a significant, though minor, component of this soil mantle. Podzols occur on the dunes and have A2 horizons to 2 m thick over a light yellow-brown to brown friable sand B horizon which often has a convolute form.

Heath and some sedgeland communities are extensive. The heath species include *Beaufortia sparsa, Kunzea recurva, Astartea fascicularis, Kingia australis* and *Pultenaea reticulata.* The sedges include *Evandra aristata, Scirpus nodosus, Gahnia decomposita* and *Anarthria scabra.* There are scattered low trees, mainly *Nuytsia floribunda* and *Melaleuca preissiana.* Dunes have a woodland of *Banksia ilicifolia, B. attenuata* and *Allocasuarina fraseriana.*

Slightly defined drainage

Unit: Cleave CV

This swampy terrain reflects the slight incision of the Blackwater unit by a system of minor streams some 2 m deep which are flanked by long, very gentle slopes that extend up to the Blackwater unit < 10 m above. Minor low rises occur, often representing the bevelled nose of spurs resulting from the stream incision.

Elements of both Archaean crystalline rocks and Mesozoic sediments may occur and are usually deeply weathered. Quartzose cobbles are sometimes found, strewn sparsely on the surface and there may be occasional low hummocks of aeolian sand.

Humus podzols are dominant with a dark brown to black iron/organic pan at about 1 m. These usually have a light grey sandy clay substrate. Some of the A1 horizons appear to have sufficient organic matter to classify the profiles as peaty podzols. Yellow duplex profiles are present on the low rises and have a pale grey-brown sand A horizon with a bleached A2 horizon. The light brownish yellow

and yellow mottled sandy clay B horizon is structureless. There is usually some dark brown staining between the A and B horizons. Occasional blocks of lateritic duricrust can be present.

Heath and sedge communities dominate this unit and there are some pockets of depauperate jarrah woodlands, particularly on the low rises. The heath communities include *Beaufortia sparsa, Homalospermum firmum, Astartea fascicularis, Agonis parviceps, A. linearifolia, Kingia australis* and *Leucopogon propinquus*; scattered low trees of *Melaleuca preissiana* occur. Sedges include *Gahnia decomposita* and *Evandra aristata.*

Units developed on aeolian sands

All units on aeolian sands of the Scott Coastal Plain can be classified as variations of the one dune system. Five variations are recognized.

Unit: Meerup M

This is an array of parabolic dunes forming part of the coastal dune system. They have their equivalents in the parabolic dunes along the west coast of south-western Australia where they are referred to as the Quindalup dunes system by McArthur and Bettenay (1960). In the area mapped, the dunes of the Meerup unit have a general east to east-north-east orientation and transgress a broad ridge of Tamala Limestone, extending some distance inland over the swampy plain represented by the Blackwater unit. Their seaward flank is marked by steep slopes and local cliffs developed in the underlying Tamala Limestone and ferruginous facies of Mesozoic sandstones.

The dune complex was first referred to as the Meerup soil association by McArthur and Clifton (1975) and further details of this unit have been presented by Churchward *et al.* (1988). They recognized six subdivisions but only five are delineated on the present map. Beach ridges (My) do not occur along this section of the coast.

Ms—the oldest dune phase; has smooth, rounded crests and gentle slopes. Most of the areas mapped as Ms have swampy interdune tracts, delineated as Mf.

The soils are often podzols usually with a bleached A2 horizon from 1.5 to 2.5 m thick and a friable brown to yellow-brown B horizon (Uc2.21). Calcium carbonate is usually not present within 4 m of the surface, in the mottled light yellow, deep subsoil. In some of the well drained swales there are profiles that have a grey-brown surface horizon (10 cm thick) over light brown, neutral to mildly acidic sand. By about 1 to 1.2 m, this profile merges to a light yellow-brown and pale brown, non-calcareous sand.

Woodlands of marri are dominant with jarrah, *Eucalyptus megacarpa* (bullich) and *E. cornuta* (yate). *Agonis flexuosa* (Western Australian peppermint), *Allocasuarina fraseriana, Banksia grandis, Leucopogon verticillatus* and *Persoonia longifolia* are important low tree species. A dense shrub layer includes *Macrozamia riedlei, Leucopogon australis, L. propinquus, Bossiaea linophylla, Hovea elliptica, Hibbertia stellaris* (star guinea flower), *Hardenbergia comptoniana, Acacia pulchella, Xylomelum occidentale, Hakea oleifolia* and *Hybanthus* spp.

Mf—interdune flats which, as mapped, are often dominated by swampy tracts. The soils are podzols with a dark brown to black B horizon at about 0.75 to 1.25 m beneath a bleached sand A2 horizon.

There are woodlands and thickets of *Melaleuca preissiana, Banksia littoralis* and *Agonis juniperina* (native cedar). Some pockets of *Eucalyptus cornuta, E. megacarpa* and *Eucalyptus calophylla* occur. A dense shrub layer includes *Pultenaea reticulata* and *Leucopogon australis.*

Mp—dunes with crests that are often higher and sharper than Ms. In the area mapped the soils are podzolized sands that have a grey A1 horizon and a pale grey-brown A2 horizon which merges to a light brown to light yellow-brown, friable B horizon from 0.5 to 1.5 m. With depth, the B horizon merges to a diffusely mottled light yellow, pale yellow and pale grey-brown sand (Uc4.21). Calcium carbonate, if present, is rare within the upper 5 m which contrasts with the profiles of the unit described by Churchward *et al.* (1988) further east. However, many of these profiles are comparable with the Karakatta series, described by McArthur and Bettenay (1960) on the Swan Coastal Plain.

Agonis flexuosa woodlands are dominant and can be associated with *Hakea oleifolia, Allocasuarina fraseriana, Banksia grandis* and *B. ilicifolia.* The shrub layer include *Acacia cyclops, A. cuneata, Hibbertia* spp., *Melaleuca thymoides, Jacksonia furcellata* and *Xanthorrhoea preissii.* Some portions of Mp can have marri woodlands comparable with Ms.

Mc—areas having a high frequency of steep, sharply peaked dunes. The sands appear to be variable; some are much less calcareous than described for this unit in Churchward *et al.* (1988). Some profiles have a pale grey-brown A2 horizon and a light yellow to yellow-brown B horizon at 0.5 to 1.0 m. Low amounts of carbonate can be present at about 2 m. In this profile there is organic enrichment of the surface 10 cm. Other profiles have light brownish grey sand to 10 cm, merging to pale brown or light yellowish brown sands by 30 cm. Slight to light calcium carbonate, sometimes as sand

grains and general effervescence to acid, appears at about 40 to 50 cm.

The vegetation comprises a dense shrub layer and coastal heaths. The dwarf form of *Agonis flexuosa* is common along with *Olearia axillaris, Jacksonia furcellata, Hemiandra pungens* (snake bush), *Spyridium globulosum* and *Scaevola* spp.

Mu—mobile sands that are pale yellow to light yellow-brown and are often low to very low in calcium carbonate.

Units associated with drainage lines

Drainage lines form three broad groups of units. There are those on the Darling Plateau (crystalline rocks), the Blackwood Plateau (mainly on Mesozoic sediments) and the Scott Coastal Plain.

Units associated with drainage lines in the Darling Plateau, on crystalline rocks

This broad group of units can be subdivided into major and minor valleys. Major valleys have floors with well defined drainage channels, minor valleys have swampy tracts.

Major valleys

Unit: Bridgetown BT

This unit, defined by Finkl (1971) represents the southern parts of the trunk valley of the Blackwood River incised into the Darling Plateau. Elements of it extend westward from about 15 km east of Bridgetown to where the river flows through the Darling Scarp. In the area mapped, the unit has a relief of 120 to 150 m. Slopes are steep (to 30°) and are irregular because of outcrops of gneiss, migmatite and granite. Colluvium occurs extensively, sometimes as slumps.

The soil mantle is a complex array of gradational and duplex profiles. Red hues are dominant, suggesting the greater overall influence of rocks with mafic (i.e. basic) composition. Stone lines in the A horizon of the duplex soils are common, suggesting that it has developed in a transported medium. The upper terrace has brown to yellow-brown clayey sands while the lower terrace comprises greyish brown to brownish grey silty loams to silty clay loams.

Vegetation is mainly open marri forest, with *Banksia grandis* as an important element of the low tree layer. *Eucalyptus rudis* (flooded gum) dominates the terraces of the valley floors.

Unit: Balingup BL

This unit, defined by Finkl (1971), represents tributary valleys of the Blackwood River system. These valleys are 2 km wide and from 60 to 100 m deep; their flanking slopes are commonly between 10° and 25° but can be as low as 6°. The surface of this unit appears to be smoother than the Bridgetown unit. The floors are broadly concave to flat. There can be local swamps and a shallow stream channel can be flanked by a narrow terrace. There are occasional outcrops of gneiss, migmatite and granite but these rocks have generally been deeply kaolinized to form a widespread substrate to the soil mantle.

Gradational profiles are more common than duplex profiles and red hues are more common than yellow. Yellow duplex profiles with a bleached A2 horizon and a mottled structureless B horizon are on the valley floor; yellow-brown sandy loams are on the narrow terraces.

Open forests and tall woodlands of marri, with some jarrah, are common. *Banksia grandis* and *Persoonia longifolia* are prominent in the low tree layer. There may also be some *Acacia acuminata* (jam) and *Eucalyptus loxophleba* (york gum) but *E. rudis* woodlands dominate the valley floor, with some *Allocasuarina huegeliana.*

Unit: Noombling NB

This terrain, described by McArthur *et al.* (1977) for the Murray-Hotham catchment, is dominated by long, gentle slopes (< 5°) that extend down from low, often flat-crested hills towards narrow alluvial valley floors. Erosional scarps (breakaways) as narrow zones flanking some of these mesas are the steepest parts of the terrain. Unlike the other valley units, the Noombling unit, as an erosional tract, can in places extend across divides from one valley to the next.

Although there are scattered outcrops of granitic rocks and dolerite dykes, kaolinitic clay derived from these rocks forms a frequent substrate to the soils. Lateritic duricrusts, and associated gravels and sands, cap the mesas and are seen as remnants of a once, more extensive, deeply weathered land surface that has been stripped from slopes and local divides.

The Noombling unit is drained by the Blackwood River and is limited to the extreme north-eastern corner of the area. It ranges from 180 to 280 m AHD and local relief is about 50 m.

The soil mantle is dominated by duplex profiles. The presence of stone lines of mixed composition at the interface of the A and B horizons, indicate the colluvial origin of many of the surface horizons.

Yellow duplex profiles dominate areas on granite. These have a pale grey-brown to light yellowish brown, hard-setting sandy loam to loamy sand A horizon and can have A2 horizons with a spotty bleach (Dy3.61). The clay B horizon can be whole-coloured or slightly mottled. Sometimes it is not structured. The deep subsoil usually has a neutral pH.

Red duplex profiles (Dr2.21) are much less common and generally relate to the presence of a dolerite dyke. The sandy loam to sandy clay loam A horizon is usually light reddish brown with a pale reddish brown A2 horizon. The clay B horizon is usually moderately structured but not mottled and the pH is neutral.

The crests of mesas are dominated by gravelly pale brown to yellow-brown sands usually with lateritic duricrust at < 30 cm. There may be some areas of deeper sands with much pisolitic lateritic gravel.

The vegetation is dominated by tall marri woodlands with *Eucalyptus wandoo* (wandoo) and some jarrah. Small pockets of woodland comprising low trees of *Allocasuarina huegeliana, Eucalyptus loxophleba* and *Acacia acuminata* may be found by rock outcrops. *Eucalyptus rudis* woodlands dominate the valley floors along with some *Melaleuca rhaphiophylla*. The laterite capped crests have tall jarrah woodlands with a dense understorey which includes *Dryandra sessilis, Macrozamia riedlei* and *Xanthorrhoea preissii.*

Unit: Donnelly DO

This unit comprises valleys 100 to 140 m deep and 1 to 2 km wide, and which have slopes of 15° to 20° but can be as low as 6°. The floor can be occupied by a narrow terrace. Although there are scattered outcrops of gneissic or migmatitic rocks, the slopes are generally smoother than those of the Bridgetown unit. They are mantled by colluvium which overlies kaolinitic clay derived from the weathering of gneissic rocks.

The unit occupies the lower course of the Donnelly River and neighbouring streams associated with the Darling Plateau, just before they pass through the Darling Scarp.

Red earths (Gn2.12) are the dominant profiles but there are some yellow earths as well as red and yellow duplex soils (Dr2.2, Dy3.6). Brown sandy loams occupy the narrow terraces.

Tall, open karri forests are dominant but marri becomes important as rainfall decreases towards the northern limit of the unit. A low tree layer is mainly represented by *Allocasuarina decussata, Agonis flexuosa* and *Banksia grandis*. There is a dense shrub layer of *Acacia pentadenia, Bossiaea linophylla, Trymalium spathulatum, Chorizema ilicifolium* (holly flame pea), *Hovea elliptica* and *Hardenbergia comptoniana.*

Unit: Warren WA

This unit comprises valleys that are from 60 to 100 m deep and from 0.75 to 1 km wide. Slopes range from 10° to 20° but can be as low as 5°. The floors can be occupied by a narrow terrace. The few outcrops are usually of gneissic rocks and the slopes are usually smooth and partially mantled by colluvium arising from the kaolinitic clay derived from the underlying rocks.

This unit occupies parts of the Donnelly River system and valleys of adjacent streams. It is upstream of the Donnelly unit and downstream from the Lefroy unit.

Red earths (Gn2.12) are the dominant soils. There are some yellow earths and red and yellow duplex soils, also brown sandy loams are to be found on the narrow terrace.

Tall, open karri forests are dominant but marri is more important as rainfall decreases northward. The low tree layer is mainly *Banksia grandis, Agonis flexuosa* and *Allocasuarina decussata*. The shrub layer is dense and important species include *Acacia pentadenia, Bossiaea linophylla, Hovea elliptica, Clematis pubescens* and *Chorizema ilicifolium.*

Unit: Lefroy LF

This unit consists of major valleys from 40 to 60 m deep. The smooth flanking slopes range from 10° to 20°; some (to 30°) are more irregular and occur in local erosional alcoves. The floor is occupied by a narrow terrace and there is a clearly defined stream channel. Deep kaolinitic clays form an extensive substrate to the soils so that outcrops of the underlying gneissic rock are infrequent.

This unit occurs along valleys west of Manjimup and south to south-west of Pemberton. It merges downstream with the Warren unit and upstream with the Wheatley unit.

Red earths (Gn2.12) are dominant and often have a gravelly sandy loam A horizon. There are significant areas of red duplex profiles and gravelly duplex soils that have brownish hues (7.5YR).

Tall, open karri forests are dominant but marri becomes more important to the north-west of Manjimup probably due to the lower rainfall. The low tree layer includes *Banksia grandis, Agonis flexuosa* and *Allocasuarina decussata.* There is a dense shrub layer of *Trymalium floribundum, Acacia pentadenia, Bossiaea laidlawiana, Chorilaena quercifolia* and *Hovea elliptica. Agonis juniperina* and *Oxylobium lanceolatum* are on the narrow terraced valley floors.

Unit: Wheatley WH

This unit comprises valleys that are from 20 to 40 m deep and flanked by smooth slopes of 5° to 10°; there are local steeper facets to 15°. The valleys have swampy floors terraced by stream channels incised from 1 to 2 m.

The associated gneissic and migmatitic rocks have been extensively kaolinized at depth. There are few outcrops of fresh rocks.

The Wheatley unit is upstream of the Lefroy unit in valleys situated west, south, and south-east of Manjimup and Pemberton.

The soils of the flanking slopes have gradational profiles. Red hues (Gn2.12) are common but there are some that are yellow. The surface horizon is a greyish brown, gravelly sandy loam which merges at 40 to 50 cm to a brownish red or brown light clay. Some duplex profiles, both red or yellow types, can also occur. The swampy terraces generally have grey-brown to yellow-brown sands to sandy loams. There are some areas with profiles having a pale yellow-brown sandy loam A horizon on a mottled brownish yellow clay B horizon.

Tall, open forests of karri and marri are dominant. There are scattered low trees of *Allocasuarina decussata, Banksia grandis, Persoonia longifolia* and *Agonis flexuosa*, and a dense shrub layer of *Acacia pentadenia, Bossiaea laidlawiana, Trymalium floribundum, Chorilaena quercifolia* and *Hovea elliptica. Eucalyptus megacarpa, E. patens* (Swan River blackbutt), *Agonis juniperina, Oxylobium lanceolatum* and *Melaleuca preissiana* grow on swampy terraces.

Unit: Wilgarup WL

These valleys have considerable morphological variation. They range in depth from 40 to 100 m but are commonly from 50 to 70 m. This considerable range is generally related to broad but localized undulations of the adjacent plateau surface. The short flanking slopes of the Wilgarup valleys are generally smooth and gentle (from 5° to 8°) but may be steeper (to 20°), when associated with deeper valley tracts. Here, slopes are irregular and much country rock is exposed. The upper limits of the unit are marked by exposures of lateritic duricrust. Terraces occupy the valley floor.

The geology of this unit is dominated by granitic rocks which are occasionally intruded by dolerite dykes.

The Wilgarup unit can be present upstream of the Warren unit and is best represented along the lower courses of the Wilgarup, Perup and Warren Rivers.

Red and yellow duplex soils are common. The A2 horizon usually has a spotty bleach and stone lines at the interface of the A and B horizons indicate the colluvial origin of materials forming the A horizon. The B horizon often has a moderate grade of coarse blocky structure, is either whole-coloured or diffusely mottled and the subsoil is usually mildly acidic to neutral. The terraces have yellow-brown sand to grey-brown silty loams.

Tall woodlands and open forests, dominated by marri, are the most extensive plant communities. Low tree species include *Banksia grandis, Leucopogon verticillatus* and *Persoonia longifolia*. Some tall woodlands dominated by wandoo appear as the rainfall declines eastwards. The shrub layer includes *Bossiaea linophylla, B. ornata, Podocarpus drouynianus, Hovea trisperma* and *Xanthorrhoea preissii*. Thickets of *Gastrolobium bilobum* (heart-leaf poison) occur in the valley of the Perup River. *Eucalyptus rudis* woodlands dominate the terraces and there are thickets of *Melaleuca incana* (grey honey-myrtle), *M. viminea* and *Banksia littoralis*.

Unit: Yerraminnup YE

This unit comprises valleys in the Darling Plateau with a depth of 20 to 40 m, but occasionally to 50 m. The slopes are 5° to 8°; occasionally to 25°. Broad valley floors have a sinuate stream channel set some 3 m into a terrace.

The Yerraminnup unit merges downstream to the Catterick unit and upstream to the Wilgarup unit. The unit is more common in the drier parts of the mapped area, appearing some 15 km east of Manjimup along such streams as the Yerraminnup and Perup rivers.

Granite is the dominant country rock while dolerite occurs as scattered dykes. These rocks are exposed locally on steep slopes; more usually they are covered by a thick kaolinitic mantle.

Yellow duplex profiles are common. These have a pale brown to grey-brown loamy sand to sandy loam A horizon and an A2 horizon that is sometimes bleached. The mottled, weakly-structured clay B horizon is acidic to neutral at depth (Dy3.61, D3.62). Red duplex profiles and red earths are associated with mafic rock outcrops or subcrops. Variable amounts of ferruginous gravels are present in the A horizon. Sometimes there is a stone line in the A2 horizon that comprises clasts of country rock and vein quartz. Yellow duplex profiles with a bleached sandy loam A2 horizon and a mottled, coarsely structured clay B horizon are on the valley floor and have an acidic to neutral pH.

Marri woodlands to open forest communities are dominant, particularly on the slopes, while *Eucalyptus rudis* woodlands occupy the floors. *Melaleuca preissiana* and *Banksia littoralis* thickets occur in swampy areas.

Unit: Strachan ST

This unit consists of valleys < 20 m deep, with smooth, gentle slopes (3° to 8°) and terraced floors. Country rock is mainly granite. The unit is represented by the valley of the Tone River, east and west of the Strachan mill site (ref: MG 503930); and a short length of the Wilgarup River valley near Morallup (ref: MH422023), where there are some low elevations on the plateau surface bordering the valley.

Yellow duplex profiles are dominant and have a very gravelly, light grey-brown loamy sand A horizon with a spotty bleach. The yellow-brown clay B horizon is poorly structured and the soil reaction is mildly acidic at depth.

Tall woodlands and often forests of jarrah and marri are dominant. Associated species include *Banksia grandis, Persoonia longifolia, Podocarpus drouynianus, Leucopogon verticillatus, Bossiaea linophylla* and *Agonis parviceps. Eucalyptus rudis, Astartea fascicularis, Melaleuca incana* and *M. viminea* are important on the terraced floors.

Minor valleys

Unit: Catterick CC

This unit represents minor valleys on the Darling Plateau (Churchward and McArthur 1980) downstream from the Carbunup unit. Such valleys are generally about 20 m deep but are occasionally 30 m and are flanked by 3° to 8° slopes, although some slopes may be up to 15°. The flat and swampy floors are more clearly defined than the valley floors of the Carbunup unit. Occasionally the drainage is defined in shallow channels.

Granite rocks dominate in these areas and are usually weathered to a deep kaolinitic saprolite. A few outcrops of granite and dolerite (as dykes) can occur in the rare steeper slopes.

The smooth flanking slopes generally have yellow duplex soils with a very gravelly, pale grey-brown loamy sand A2 horizon which is sometimes bleached. Red gradational and red duplex profiles indicate an outcrop or subcrop of dolerite dykes on the few steeper slopes.

Light yellow-brown sands, sometimes very gravelly, may also mantle the valley slopes blending with podzols in the valley floor. Most of the floors are, however, dominated by yellow duplex soils having a bleached A2 horizon. Grey-brown to orange earths with bog-iron pans are often present along the swampy drainage axis.

Open forests of jarrah and marri communities are dominant on the slopes. Woodlands on the floors include *Eucalyptus rudis* and pockets of *Melaleuca preissiana* and *Banksia littoralis*.

Unit: Carbunup CB

The Carbunup unit consists of minor valleys on the Darling Plateau that are < 20 m deep and flanked by long gentle slopes of < 5°. They have broad swampy floors. Shallow stream channels are not common.

These valleys occur in areas of granite but exposure of fresh rock is rare. There is a general thick substrate of kaolinized country rock.

The slopes are usually mantled by deep, gravelly, light yellow-brown sands, sometimes with lateritic duricrust at 1 to 2 m. The lateritic gravels become finer downslope, giving way to deep, light yellow-brown sands on the lower slopes and portions of the floor. Podzols are dominant on the floors with some humus podzols as well as some pockets of sandy orange earths with bog-iron pans at < 1 m.

Tall woodlands and open forests of jarrah are dominant. *Banksia grandis* and *Persoonia longifolia* are the common low tree species along with *Allocasuarina fraseriana* and *Xylomelum occidentale* on some of the deep sands. *Melaleuca preissiana* and *Banksia littoralis* are associated with swampy parts. Shrub species include *Podocarpus drouynianus, Agonis parviceps, A. linearifolia, Pultenaea reticulata* and *Hypocalymma angustifolium.*

Unit: Pemberton PM

These valleys are 20 to 40 m deep and generally have flat or very gently sloping floors. There is little or no channel development. Flanking slopes have gradients of 3° to 10°. Some slopes are steeper (to 15°), usually in erosional alcoves.

This unit occupies the upper reaches of many valleys west and south of Manjimup, mainly upstream of the Wheatley unit. Many of these valleys terminate through relatively steep slopes to the upland units, Bevan or Crowea. Occasionally they merge upstream to broad swampy tracts such as the Yornup unit.

The country rocks rarely outcrop. They are generally covered by a deep kaolinitic mantle.

Red, and some yellow earths with a gravelly sandy loam to sandy clay loam surface horizon, are most extensive. There are areas of red duplex profiles which also have a light brown, gravelly sandy loam A horizon. Some of these profiles have an A2 horizon. Humus podzols and orange and grey-brown earths occur on the valley floor.

Tall, open karri forests with some marri are usual for this unit; sometimes marri is dominant. A low tree layer of *Allocasuarina decussata, Agonis flexuosa, Banksia grandis* and *Persoonia longifolia* occurs. The shrub layer includes *Hovea elliptica, Hardenbergia comptoniana, Bossiaea laidlawiana, B. linophylla* and *Clematis pubescens.* Thickets of *Agonis juniperina, Banksia verticillata* and *Oxylobium lanceolatum,* with some *Eucalyptus rudis* are on the swampy valley floors where there is also a dense shrub layer of *Agonis parviceps* and *Lepidosperma longitudinale.*

Unit: Yanmah YN

This unit comprises minor valleys of about 20 m depth, with flat to broadly concave, poorly drained valley floors. The smooth flanking slopes are usually 3° or less. Granitic and gneissic rocks, deeply kaolinized, form a common substrate but exposures of fresh rock are not common.

Yellow duplex soils are dominant. These have a pale grey-brown gravelly sand to loamy sand A horizon, sometimes with a bleached A2 horizon. The clay B horizon is mottled and structureless. Occasional blocks of laterite may occur at the interface of the A and B horizons. The duplex profiles dominate the valley slopes and there may be some areas of deep, very gravelly, light yellow sands. These soils merge into light yellow sands downslope, on the fringes of the valley floor, and then to podzols and humus podzols in the valley floor. Some yellow duplex soils may occur on the floors as well as pockets of orange-brown or grey-brown earths with bog-iron pans.

Tall woodlands and open forests of marri, with some jarrah, are dominant. Karri is an important associated species and increases with rainfall to the south and west of Manjimup. The low tree layer is often *Banksia grandis, Persoonia longifolia* and sometimes *Agonis flexuosa* and *Acacia pentadenia.* A dense shrub layer can include *Bossiaea linophylla, B. laidlawiana, B. ornata, Acacia myrtifolia, A. pulchella* and *Trymalium floribundum.* The swampy valley floor may have a low woodland of *Banksia littoralis* and *B. verticillata, Agonis juniperina* and *Oxylobium lanceolatum* in higher rainfall areas, along with many sedges and reeds.

Units associated with drainage lines in the Blackwood Plateau, mainly on Mesozoic sediments

As with the Darling Plateau, units of the drainage elements on the Blackwood Plateau can be categorized as occurring in major (well defined) or minor (swampy) valleys.

Major valleys

Unit: Blackwood BK

This unit comprises major valleys 40 to 60 m deep with flanking slopes ranging from 8° to 12°; occasionally as steep as 20°. A system of two terraces of variable width occupies the floors and this system is trenched (to 4 m deep) by the sinuous channels of major trunk streams.

The Blackwood unit represents the valley of the Blackwood River incised into the undulating surface of the Blackwood Plateau. Sandstones are exposed along the steeper slopes but on most of the gentler grades the country rock is mantled by lateritic detritus including both sand and gravel with scattered blocks of duricrust and kaolinitic sandy clay saprolite.

The dominant soils of the slopes are yellow duplex profiles with a pale brownish grey A horizon and sometimes a bleached A2 horizon over a pale yellow, sandy clay B horizon, which is usually mottled and structureless. There can also be pale yellow sands on some of the more gentle slopes which merge to podzols downslope. The upper terraces have light yellow-brown to brown clayey sand to sand and the lower terraces are usually grey-brown silty loams.

On the slopes there are marri woodlands with closed woodlands of *Eucalyptus rudis* on the terraces. Low trees include *Banksia grandis, Persoonia longifolia* and *Allocasuarina fraseriana* on the slopes and *Agonis flexuosa* and *Banksia verticillata* on the terraces.

Unit: Jalbaragup JL

This unit comprises valleys incised 20 to 40 m into the Blackwood Plateau. Stream channels are generally about 1 m deep and are flanked by a narrow terrace. The slopes are 5° to 12°.

The sedimentary rocks forming the Blackwood Plateau are not usually exposed and the slopes are mantled by kaolinitic saprolite, lateritic gravels and sand.

Yellow duplex profiles are common on the slopes. These have a dark grey-brown loamy sand A horizon which merges at depth to a pale brownish grey A2 horizon overlying a mottled structureless sandy clay B horizon. There may be some lateritic gravels in the A horizon. The narrow valley floor has grey-brown silty loams, with some orange earths and yellow-brown clayey sands.

Marri forest communities dominate these areas but there is some jarrah. Low trees of *Banksia grandis* and *Persoonia longifolia* are on the slopes. Along the narrow floors and lower slopes, *Eucalyptus rudis* is associated with *Banksia verticillata* and *Agonis flexuosa*. A dense shrub layer includes *Bossiaea linophylla, B. laidlawiana, Agonis parviceps* and *Hovea elliptica*.

Unit: Barlee BR

This unit comprises valleys to 20 m deep with flanking slopes of about 3°. The broad valley floors usually have two terraces, and the stream channel is about 2 m deep.

These valleys are incised into the Blackwood Plateau. Flanking slopes are kaolinized Mesozoic sedimentary rocks and are mantled by lateritic detritus.

Yellow duplex profiles dominate the slopes. These have a pale grey-brown loam A horizon with a well developed A2 horizon. Ferruginous gravels occur frequently. The B horizon is a mottled, structureless, gritty clay at about 35 to 45 cm. The soils on the upper terraces are yellow-brown sands to clayey sands. Humus podzols are found in local swampy tracts. Grey-brown silty loam to silty clay loams occupy the lower terrace.

Open marri forests are common, particularly on the slopes, with *Banksia grandis* and *Persoonia longifolia*. *Eucalyptus rudis* appears on the terraces along with *Melaleuca preissiana, Banksia verticillata, B. littoralis* and *Agonis flexuosa*. A dense heath layer includes *Agonis parviceps, Kingia australis, Bossiaea linophylla* and *Hovea elliptica*.

Minor valleys

Unit: Bidella BD

This unit comprises minor valleys on the Blackwood Plateau upstream from the more deeply incised valleys of the Jalbaragup unit. The valleys are usually < 20 m deep and have broadly concave, swampy floors. The flanking slopes are generally < 3° and are cut into kaolinized Mesozoic sediments of the Blackwood Plateau. They are mantled by lateritic gravels and sands.

A frequent soil toposequence in this unit begins upslope with yellow duplex profiles having a very gravelly, pale grey-brown sand A1 horizon and a very gravelly pale brown-grey to grey A2 horizon on a mottled sandy clay B horizon at about 35 to 50 cm. Further downslope the A horizons deepen and humus podzols are the dominant soils with dark organic sand A1 horizons merging at depth to light pale grey sand A2 horizons and compact black iron/organic sand B horizons at 70 to 100 cm. Beneath this are light grey sandy clays.

On the upper slopes of some toposequences, pale yellow sands have a slightly developed A2 horizon containing ferruginous gravel. These give way to podzols on mid to lower slopes and thence to humus podzols on the valley floors. Some yellow duplex profiles with a pale brown silty loam to brown silty clay loam A horizon over pale to light yellow-brown sandy clay B horizon, occur on the valley floors as well.

Open forests to tall woodlands of jarrah and marri dominate the slopes, with *Banksia grandis, Persoonia longifolia* and *Allocasuarina fraseriana* as the lower tree species. *Banksia littoralis* and *B. verticillata* appear on the valley floors along with *Melaleuca preissiana*. A dense shrub layer includes *Agonis parviceps, Pultenaea reticulata, Podocarpus drouynianus* and *Dasypogon hookeri*.

Unit: Layman LY

This unit includes valleys that are < 20 m deep and also have broadly concave, flat and occasionally swampy, gently sloping tracts. Such areas are dominated by colluvial sands but there can be alluvial elements. The Layman unit often lies next to the Blackwood River where its roughly curvate shape suggests that some portions of the unit, at least, represent an early phase of the Blackwood River system before it was incised. The unit ranges from 60 to 80 m AHD.

The unit is dominated by deep sand profiles. There are light brownish yellow sands on the better drained parts. These merge downslope with podzols and eventually humus podzols in the more swampy portions.

Tall woodlands and low, open forests are common. Jarrah is the dominant tree, but there is some marri. *Banksia grandis, Allocasuarina fraseriana* and *Nuytsia floribunda* form a low tree layer. *Banksia littoralis* and *Melaleuca preissiana* are in the more swampy parts. A dense shrub layer with a large range of species is present.

Units associated with drainage lines on the Scott Coastal Plain

There is only one major valley unit on the Scott Coastal Plain. It has a well defined channel.

Unit: Jasper JA

The unit comprises a trench < 10 m deep. There are two terraces; some portions of the upper terrace can be swampy.

Jasper largely represents the entrenchment of the lower Barlee Brook and the Donnelly River, and associated minor tributaries, as they traverse the swampy plain (the Blackwater unit). Included is that stretch of the Donnelly River which passes through the belt of coastal dunes.

The lower terrace has grey-brown to light yellow-brown silty loams to silty clay loams. The upper terrace is mainly light yellow-brown clayey sands but some podzols are present. Humus podzols occur on the more swampy parts.

Marri forests occur, with a low tree layer of *Banksia grandis, B. verticillata, Persoonia longifolia* and *Agonis flexuosa*. A dense shrub layer of *Podocarpus drouynianus, Bossiaea linophylla, Kingia australis* and *Adenanthos obovatus* is present.

Acknowledgements

The author wishes to thank those colleagues whose many comments and criticisms were of assistance in the preparation of this manuscript, in particular Geoff Dimmock, Jim Dixon, Brian Purdie and Peter Tille.

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Appendix 1

Two map sheets accompany this publication

MANJIMUP AREA
DAWA LAND RESOURCE MAP No. 13/1

SOILS AND LANDFORMS OF THE MANJIMUP AREA WESTERN AUSTRALIA

SHEET 1

H.M. Churchward
Land Resources Series No. 10

N

2000m 0 2 4 6 8 10km

Scale 1:100 000

Areal scale

800 ha in units of 100 ha

Legend of mapping units: symbols arranged in alphabetical order

(See also detailed legend on separate sheet, included)

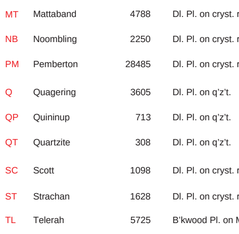
Mapping unit		Area (ha)	Major physiographic and geological setting. Main soils.
A	Angove	1623	Dl. Pl. on q'tz. Smp. Pod., some Dy's (sy).
BD	Bidella	15370	B'kwood Pl. on Mez. sed. Min. drainage. Dy's (sy); some pod.
BE	Bevan	95666	Dl. Pl. on cryst. rocks. Pl. el. Dy's, some Y/S, some gvly.
BK	Blackwood	2475	B'kwood Pl. on Mez. sed. Maj. drainage. Dy's.
BL	Balingup	9331	Dl. Pl. on cryst. rocks. Maj. drainage. Dr's, Dy's, Gn's.
BR	Barlee	1394	B'kwood Pl. on Mez. sed. Maj. drainage. Dy's (sy); some pod.
BT	Bridgetown	1083	Dl. Pl. on cryst. rocks. Maj. drainage. Dr's, Dy's, Gn's.
BW	Blackwater	27657	Sc. C. P. on mixed sed. Smp. Pod.
CB	Carbunup	4781	Dl. Pl. on cryst. rocks. Min. drainage. Y/S, some gvl; some pod.
CC	Catterick	8462	Dl. Pl. on cryst. rocks. Min. drainage. Dy's.
CE	Coate	9596	B'kwood Pl. on Mez sed. Smp. Pod; some Dy's.
CL	Corbalup	29186	Dl. Pl. on cryst. rocks. Pl. el. Dy's.
CO	Collis	8005	Dl. Pl. on cryst. rocks. Hills. Dy's.
CP	Cattaminup	3377	Dl. Pl. on cryst. rocks. Pl. el. Dy's.
CR	Crowea	31554	Dl. Pl. on cryst. rocks. Pl. el. Dy's, some sy. Note three subdivisions.
CT	Cormint	3206	Dl. Pl. on q'z't. Smp. Pod. G/S; pod.
CV	Cleave	1553	Sc. C. P. on mixed sed. Smp. Pod.
DO	Donnelly	3271	Dl. Pl. on cryst. rocks. Maj. drainage. Red Gn's; some Dy's and Dr's.
DS	Dickson	1198	Dl. Pl. on cryst. rocks. Scarp. Dy's and Gn's.
FR	Forrard	52	Dl. Pl. on q'z't. Pl. el. G/S; pod.
GA	Gale	761	Dl. Pl. on cryst. rocks. Footslopes. Y/S; gvl.
HK	Hawk	3492	Dl. Pl. on cryst. rocks; some sed. Pl. el. Gn's; pod.
JA	Jasper	1431	Sc. C. P. on Mez. sed. Maj. drainage. Gn's; pod.
JL	Jalbragup	3475	B'kwood Pl. on Mez. sed. Maj. drainage. Dy's (sy); some pod.
JN	Jangardup	6754	B'kwood Pl. on Mez. sed. Pl. el. Dy's (sy); some pod.
KI	Kingia	34105	B'kwood Pl. on Mez. sed. Pl. el. Dy's (sy); some pod.
KP	Kapalarup	1110	Dl. Pl. on cryst. rocks. Smp. Pod.; some cracking clays.
LF	Lefroy	19996	Dl. Pl. on cryst. rocks. Maj. drainage. Red Gn's; some Dy's.
LY	Layman	900	B'kwood Pl. on Mez. sed. Min. drainage. Y/S and pod.
Ms	Meerup	14282	Sc. C. P. on aeolian sand. Tam. l. subs. rare. Oldest dunes. Pod.
Mp	Meerup	11541	Sc. C. P. on aeolian sand. Tam. l. subs. common. Younger than Ms. Pod.
Mc	Meerup	1987	Sc. C. P. on aeolian sand. Tam. l. subs. common. Youngest dunes. Pale B/s.
Mf	Meerup	2386	Sc. C. P. on aeolian sand. Interdune flats; smp. Pod.
Mu	Meerup	8497	Sc. C. P. on aeolian sand. Unstable dunes. Pale B/S.
MP	Milyeannup	3963	B'kwood Pl. on cryst. rocks. Pl. el. B/S; gvl.
MT	Mattaband	4788	Dl. Pl. on cryst. rocks. Hills. Dy's; some Dr's and Gn's.
NB	Noombling	2250	Dl. Pl. on cryst. rocks. Maj. drainage. Dy's; some Dr's.
PM	Pemberton	28485	Dl. Pl. on cryst. rocks. Min. drainage. Red or yellow Gn's; some Dr's.
Q	Quagering	3605	Dl. Pl. on q'z't. Smp. Pod.
QP	Quininup	713	Dl. Pl. on q'z't. Hills. Pod.
QT	Quartzite	308	Dl. Pl. on q'z't. Hills. Pod.
SC	Scott	1098	Dl. Pl. on cryst. rocks. Scarp. Red Gn's.
ST	Strachan	1628	Dl. Pl. on cryst. rocks. Maj. drainage. Dy's.
TL	Telerah	5725	B'kwood Pl. on Mez. sed. Pl. el. Pod; Dy's (sy).
TP	Toponup	997	Dl. Pl. on q'z't. Pl. el. B/S; some gvly.
WA	Warren	9667	Dl. Pl. on cryst. rocks. Maj. drainage. Red Gn's; some Dr's and Dy's.
WH	Wheatley	29309	Dl. Pl. on cryst. rocks. Maj. drainage. Red Gn's; Dr's, some Gn's.
WL	Wilgarup	5230	Dl. Pl. on cryst. rocks. Maj. drainage. Dy's and Dr's.
WS	Wishart	1820	Dl. Pl. on cryst. rocks. Scarp. Dy's; gvl.
YE	Yerraminup	3492	Dl. Pl. on cryst. rocks. Maj. drainage. Dy's.
YN	Yanmah	26104	Dl. Pl. on cryst. rocks. Min. drainage. Dy's; some pod.
YR	Yornup	17712	Dl. Pl. on cryst. rocks. Smp. Dy's; some pod.

Abbreviations-

Dl. Pl.	Darling Plateau.
B'kwood Pl.	Blackwood Plateau.
cryst.	crystalline.
q'tz.	quartzite and unconsolidated sediments.
Mez. sed.	Mesozoic sediments.
Tam. l.	Tamala limestone.
Subs.	Substrate.
Maj.	Major.
Min.	Minor.
Smp.	Swampy tracts.
Pl. el.	Plateau elements.
Dy	yellow duplex soils.
Dr	red duplex soils.
Gn	gradational, non-calcareous soils.
G/S, B/S, Y/S	grey, brown and yellow sands.
pod.	podzols.
gvly	gravelly.
gvl	gravel.
sy	sandy.

Soil/landform boundary
Surveyed boundary
Unsurveyed boundary
Grouped location boundary
Named, unsurveyed and undedicated constructed road

Location diagram



Index to map sheets

Bibliographic reference

Churchward, H.M. "Soils and landforms of the Manjimup area Western Australia." (Scale 1:100 000 2 map sheets) DAWA Land Resource Map No. 13/1. To accompany "Soils and landforms of the Manjimup area Western Australia", Land Resources Series, No. 10.

Acknowledgements

Soil survey by H.M. Churchward. Digital cadastre base supplied by the Department of Land Administration. Map prepared by P.M. Goulding and A.F. MacDonagh, Resource Management Division, Department of Agriculture Western Australia.

Reference

Projection:	Universal Transverse Mercator
Grid:	A.M.G. Zone 50
Source data:	Field survey and interpretation of aerial photography.

Use of map
This map is designed for use at the published scale. Technical queries should be directed to the Land Management Branch, Department of Agriculture, Western Australia.

MANJIMUP AREA, W.A.
DAWA LAND RESOURCE MAP No. 13/2

SOILS AND LANDFORMS OF THE MANJIMUP AREA WESTERN AUSTRALIA

SHEET 2

H.M. Churchward
Land Resources Series No. 10

Legend of mapping units: symbols arranged in alphabetical order

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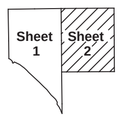
Soil/landform boundary
Surveyed boundary
Unsurveyed boundary
Grouped location boundary
Named, unsurveyed and undedicated constructed road

Areal scale

800 ha in units of 100 ha

Location diagram

Index to map sheets



Scale 1:100 000

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