Tambellup-Borden land resources survey

Angela Stuart-Street

Rohan Marold

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LAND RESOURCES SERIES

No. 21

TAMBELLUP-BORDEN AREA
LAND RESOURCES SURVEY

Department of Agriculture and Food
GOVERNMENT OF WESTERN AUSTRALIA
TAMBELLUP–BORDEN
LAND RESOURCES SURVEY

by Angela Stuart-Street and Rohan Marold

Land Resources Series No. 21

Department of Agriculture and Food
3 Baron-Hay Court
South Perth 6151
WESTERN AUSTRALIA

Funded by the National Landcare Program, Department of Agriculture and Food
Western Australia and National Heritage Trust
Disclaimer
This survey report is designed for use at the publication scale (1:100,000). The scale influences:

- the homogeneity of the map unit
- the accuracy of the lines
- the accuracy of the descriptions and attributions.

Descriptions of map units apply to the whole survey and to any occurrences in adjacent surveys. Individual map units may differ considerably from this description in terms of the proportion of different soils and landforms that occur within them. Thus, the map provides a guide to what soils may occur at a particular point or in a selected area, not a definitive statement.

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‘Koikyennuruff’, the Aboriginal name for the Stirling Range, has been interpreted as referring to the way the mist moves about on the range (Department of Conservation & Land Management 1999).

Cover photo: View of the Stirling Range
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Summary

This report presents results from soil-landscape mapping at a scale of 1:100,000 in the Tambellup–Borden area of Western Australia. It is accompanied by a soil-landscape map covering almost 511,000 hectares.

Most of the survey occurs within the upper Frankland-Gordon, Kent, North Stirlings Basin and upper reaches of the Pallinup and Kalgan River catchments. The survey falls within the Katanning and Albany Department of Agriculture and Food advisory districts.

Seventeen soil-landscape systems have been identified and are represented on the map on the accompanying CD-ROM. These systems have been further divided into subsystems. The main soils, landforms, geology, land use and native vegetation in each system are described. Within each subsystem, the main WA Soil groups are indicated.

A summary is provided of the main soils and the major land degradation hazards identified during the survey. This is designed to give a broad overview of the limitations and opportunities of the soils. Information on the land use history, geology and physiology, climate, native vegetation and previous soil surveys are also included in the report.

This land resource information has been collected for the survey to help improve the decisions made by planners, researchers and land managers. The information can be used at the regional scale, catchment scale and farm level. By improving knowledge of our land resources, more sustainable land uses can be developed within the region.
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CD ROM Containing print ready map and digital copy of report ................................................................. Inside Back Cover
Introduction

The lack of good soil information for the area has up to now hindered communication about the soils and their management requirements. Prior to this land resources survey, the only information on soils and landforms at a regional scale was available in the *Atlas of Australian Soils* (Northcote et al. 1967) at a scale of 1:2,000,000. Soil scientists from the Council for Scientific and Industrial Research (CSIR) did some detailed soil mapping in the 1940s and 50s in the North and South Stirlings areas prior to closer settlement. In the early 1990s, the Department of Agriculture and Food, in conjunction with the local Land Conservation District Committee, described and mapped the soil landscapes of the North Stirlings area (Hardy & Tille 1993).

The objectives of the survey were:

- to provide a mapped inventory of soil-landscapes at a regional scale (1:100,000) for the Frankland-Gordon, Kent, North Stirlings Basin, Pallinup and upper Kalgan catchments, including areas within the shires of Tambellup, Cranbrook, Gnowangerup, Plantagenet and the City of Albany

- to collate and disseminate information on the nature and extent of soils in the survey area for research and land management purposes

- to provide soils information and assist in soil mapping workshops for landcare groups working on farm and catchment planning, thereby providing information to farmers on the variability and properties of soils and the different management strategies for different soil types

- to contribute to the development of more sustainable land uses within the region.

The survey was undertaken by the Western Australian Department of Agriculture and Food and was funded by the Commonwealth and Western Australian governments under the National Land Conservation and National Landcare programs. It is part of a program to map the land resources of the agricultural regions of Western Australia.

At regional level, the information in this report can be used for land use and land management planning, and in the development of conservation policies and strategies to overcome land degradation. It can also be used for planning and targeting research funding and to help communicate research results.
How to use this report

The report and map provide the summarised collation of information about the soils and land resources of the region. The report provides an overview of past and present uses of land and the geology and native vegetation associations in order to develop an appreciation of the components of the landscape and its developmental characteristics.

The process used to identify the soil or a soil property at a point or area of interest is outlined below.

1. Locate the point or area of interest on the map on the attached CD-ROM.

2. From the map, identify the map symbol and note its colour (e.g. Nt1).

3. Go to the map legend and locate the map symbol. The map units are arranged by soil-landscape system and the map unit colour is useful in identifying the system.

4. The map legend provides:
   i. the full map unit name
   ii. a brief landscape description
   iii. a list of the main WA Soil Groups within the map unit.

5. Using the report, turn to the relevant map unit. These are listed alphabetically by system (e.g. North Stirlings 1 or Nt1 will be under the North Stirlings System). A table presenting information on each subsystem is included for each system. A brief description of the landform for each map unit is included. Several soils are usually present in each area. Only the most common ones are listed in the report for each subsystem. For each system, a map of the occurrence in the current survey and a schematic cross-section diagram of the conceptual relation of subsystems and phases is provided.

6. For more detailed information about specific soils, refer to the soil series section. The most common soil series encountered during the survey are listed alphabetically and information is presented under headings including definition, related soil series, reference profiles, characteristic soil properties, land management characteristics and associated native vegetation. (This section may also refer to reference profiles from other surveys.)

7. To access a detailed list of all the soils for each zone, system and subsystem, follow the link to the NRM Info Website by visiting: http://spatial.agric.wa.gov.au/slip. By clicking on the map window, a report of the active map unit and soil data can be generated. Additionally, thematic maps have been created from the database, to provide land degradation hazard maps and land capability maps for a range of land uses. See the Appendix for guidance regarding the soil-landscape information on the website.

8. The print-ready soil-landscape map and a digital copy of this report are presented on the accompanying CD-ROM. (A copy of the soil-landscape map, or a portion thereof, can be purchased from the Department of Agriculture and Food. It is also possible to purchase a portion of this map together with a portion of an adjoining survey.)
Location

The Tambellup–Borden survey covers nearly 511,000 hectares in the Great Southern region of Western Australia (Figure 1). It corresponds to two 1:100,000 map sheets from the national topographic map series: Tambellup (2429) covers the western half and Borden (2529) covers the east.

The northern boundary of the survey runs just to the north of Tambellup and eastward to just beyond the locality of Toompup. The survey extends southward to incorporate the Stirling Range and beyond, to the lakes and sandplains. The southern boundary dissect Two Mile Lake and continues eastward to include Kendenup and the Albany Highway. The western boundary extends just beyond the junction of the Albany and Great Southern highways.

The towns of Cranbrook, Tambellup, Borden, Tenterden and Kendenup are located within the survey. Gnowangerup, Ongerup and South Stirling are just outside the boundaries. The Albany and Great Southern highways, and Chester Pass Road are the major traffic routes. The Great Southern railway passes through the area. Most of the survey falls within the Frankland–Gordon, Kent, Pallinup and Kalgan River catchment areas and the internally drained basins to the north and south of the Stirling Range.

The eastern half of Cranbrook Shire, the major portion of Tambellup Shire, the western region of Gnowangerup Shire, and small northern sections of the Shire of Plantagenet and the City of Albany are in the survey (Figure 1).

Figure 1 Location of the survey in relation to the region and to the rest of Western Australia
History of land use

Aborigines have occupied this region for thousands of years and constituted at least two groups, the Qaaniyan to the west and the Koreng to the east. The area, especially Koikyennuruff (the Aboriginal name for the Stirling Range), appears to have been a highly significant place.

In 1827 a European settlement was established at King George Sound (now known as Albany), and early pioneers in search of new land and resources made expeditions inland and to the distant mountains. In January 1832 Ensign Robert Dale climbed Mt Toolbrunup and looked inland over a vast plain that was ‘diversified with open downs and extensive forests and with a great number of bare spots which were supposed to be salt lakes …’ (Dale 1832, cited in Parnell 1982). The string of prominent peaks was renamed the Stirling Range by the Surveyor General John Septimus Roe, after Governor Stirling, during their 1835 Great Southern Expedition.

Europeans explored the area more extensively in the 1835 expedition, the main purpose of which was to determine a route to link the Albany and Perth colonies. Part of the area they travelled through went along the Pallinup River, not far from where Tambellup is today, and even then they noted that the water there was very brackish and barely drinkable. Roe also encountered a waterway named Pakeerup, made up of a series of fresh pools surrounded by areas of broad grassy plains with few trees, judged to be ideal for grazing. He named this the Gordon River in honour of the Earl of Aberdeen.

The Perth to Albany road was established by 1838, passing through Round Swamp (later Tenterden). Settlers began to arrive by 1839 in the south-western area, and by the early 1850s they had established themselves in what was later known as the Cranbrook region. Between 1840 and 1850, Captain John Hassell explored a great deal of the area, and by 1842 he had land at Kendenup, where he established a wool growing enterprise with many sheep and numerous shepherds in his employ. These shepherds drove his flocks from his holdings in the north and east to Kendenup for shearing.

The region was more fully examined during a further expedition by JS Roe in 1848. By then, the whole area was much traversed by sandalwood cutters who had been exploring and working in the area since 1845. One of the early cutters’ tracks became Chester Pass Road, and another became Salt River Road. Sandalwood cutting was widespread across the region. Collecting possum skins for the fur trade, and the cutting and export of mallet bark for tannin production became common activities for supplementary incomes for many early settlers and Aborigines.

In 1872 Joseph Norrish settled just east of the current townsite of Tambellup, where he was involved in sandalwood cutting and then wool production. Tambellup, one of the sidings on the Albany to Beverley railway which opened in 1889, was declared a town in 1898.

By the turn of the century, agricultural enterprise in the area consisted largely of sheep grazing for wool production, as well as cropping, dairying and fruit growing. The pioneering farmers initially concentrated on sheep rather than crops as they were cheaper and easier to run and the land did not require complete clearing. Some early settlers were hindered, however, by sheep deaths from poisonous plants, which later were revealed to be
Gastrolobium species. Dingoes also became a serious problem and a widespread baiting program was established which continued well into the next century.

Land settlement began in the east near Amelup in the late 1800s and in the vicinity of Borden by 1905. Borden developed rapidly as the main siding on the Gnowangerup–Ongerup line after it was opened in 1913.

By the early 20th century, the area was well established and expanding rapidly. Near Tenterden, fruit growing (featuring stone fruit, pears and apples, with associated canned and dried fruit and fruit juice) was successfully developed, and commercial potato growing flourished. This diversification was encouraged by an expanding local market associated with the influx of people to the goldfields around Coolgardie and Kalgoorlie. Fruit and potatoes, however, would not prove successful in the long term. Mixed wool and cereal production was becoming more common, especially with the introduction of mechanisation to ease the clearing of land, and superphosphate to increase yields. Barley and oats were still more widely grown in the western area, with wheat the dominant grain elsewhere. Cattle also became more numerous.

Land to the north of the Stirling Range was cleared only gradually at first, but this increased considerably in the period after the Second World War. The remaining uncleared land was surveyed in the mid 1960s, when many blocks were taken up and clearing then progressed rapidly, up to the early 1970s.

The attractions of the rugged beauty and unique flora of the Stirling Range have long been popular with tourists. It was gazetted as a National Park in 1913, and by the 1920s a dedicated Tourist Association had already developed to manage access into the area.
Current land use

Land use in the survey area is currently based mainly on dryland agricultural production using annual, winter growing pastures and crops.

Wool production is still widespread, with many top merino studs located in the north. Grazing mainly occurs on clover-dominant pastures in rotation with cropping programs. More recently the incorporation of perennial pastures, particularly lucerne, into phase cropping rotations is becoming more widespread. Beef cattle enterprises also occur, particularly in southern areas, as well as a few piggeries.

Throughout the region cereals (wheat, barley and oats) remain the dominant crops within the rotation, with significant areas under canola. Pulse crops, mainly faba beans and field peas and to a lesser extent chickpeas and lentils, are also part of many crop rotations, particularly in the east. Lupins are also grown in rotation, often as a break crop and to increase soil fertility. More recently, opportunistic plantings of warm season crops have been explored in the south, particularly sunflowers, millet and sorghum. Minimum tillage and lower stocking rates have proven to be important, especially to protect the fine sandy soils that occur in many areas.

Adoption of high water use farming systems has seen perennial pastures (mainly lucerne and kikuyu) become more widespread. Commercial timber plantations have been established, including pine plantations (Pinus pinaster and P. radiata) in areas which are often deep sand, and Tasmanian blue gum (Eucalyptus. globulus). Alley farming techniques using oil mallees and sandalwood plantations are also being adopted.

Landcare activities have been strongly supported across the survey area, particularly in the vicinity of the Pallinup–North Stirlings region. Large portions of the land there are subject to widespread effects of secondary salinisation and waterlogging. Detailed investigations into the causes of these problems, particularly the hydrology, have been undertaken over several decades. Landcare groups work together to identify land management practices to prevent or reduce land degradation. Many landholders in this area have become innovators in alternative farming methods through necessity. Currently, options for saltland pastures are being explored.

As the Stirling Range area offers one of the richest areas for flora in the world, nature conservation is a very significant land use in the survey area. The flora and its unique topography continue to attract many tourists to the region.
Climate

The survey has a Mediterranean climate with hot, dry summers and mild, wet winters. Average annual rainfall varies across the agricultural region of the survey area from almost 600 mm in the south-west to just below 400 mm in the north-east. Rainfall in the Stirling Range National Park is generally higher and varies from 500 to 1000 mm. Average monthly minimum and maximum temperatures are about 6 °C and 17 °C in winter and 12 °C and 29 °C in summer respectively. There is a slight trend of increasing temperature from south to north across the survey area. The following summary of climatic data is presented from Lennard et al. (1991), Department of Conservation and Land Management (1999), the Australian Rainman program (Clewett et al. 1994) and Silo Data Drill database (Queensland Department of Natural Resources).

Rainfall

The monthly mean and median rainfall data for six stations in and near the survey are presented in Table 1. Rainfall is concentrated in the winter months with more than half the annual average annual rainfall falling from May to August. More than 70 per cent of annual rainfall occurs between May and October. Figure 2 shows the rainfall isohyets (100 mm intervals) for the survey. Rainfall is highest in the south-west at 592 mm and decreases to 385 mm in the north-east. This trend reflects the effect of cold fronts from the Indian and Southern oceans, which bring more rain into the western and southern parts of the survey area. The area extending eastward from Cranbrook is, however, drier than would otherwise be expected due to the rain shadow effect of the Stirling Range.

The annual rainfall across the Stirling Range is significantly higher than the surrounding land, due to the orographic effect. In the south-west it receives approximately 600 mm, in the north-west less than 500 mm, and in the central region near Coyanarup Peak and Bluff Knoll, the annual rainfall is estimated to be approximately 1000 mm. The higher peaks may experience extended periods of drizzle and cloud cover when winds are on-shore, even during summer months. Heavy rainfall can cause rapid run-off on steep slopes and flash flooding of adjacent low-lying areas. Occasionally light snow may fall on the higher peaks during winter and spring.

Table 1 Mean and median monthly and yearly rainfall for six recording stations (1900-1994) (Clewett et al. 1994 and Queensland Department of Natural Resources)

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<th>Location</th>
<th>Jan</th>
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</tbody>
</table>
The average minimum and maximum temperatures for each month at various locations around the survey area are presented in Table 2. The table also includes the highest and lowest recorded temperatures. Summer temperatures increase from south to north across the survey area, in part reflecting the earlier arrival of the sea breeze from the Southern Ocean (the ‘Albany Doctor’) in the south.

Summer temperatures (December to February) range from a minimum of 12 °C to a maximum of 29 °C. Winter temperatures (June to August) range from a minimum of 6 °C to a maximum of 17 °C. Temperatures below zero have been recorded from May and into October. The risk of frost is an important consideration when growing crops on low-lying valley flats and alluvial plains.
Table 2 **Mean minimum and maximum monthly temperatures (1900-1994); highest and lowest recorded temperatures** (Clewett et al. 1994 and Queensland Department of Natural Resources).

<table>
<thead>
<tr>
<th>Location</th>
<th>Jan</th>
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<td>3</td>
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**Evaporation**

Estimates of Class A pan evaporation for Borden, Cranbrook, Jam Vale, Kendenup and Tambellup are presented in Table 3. Evaporation increases about 10 per cent across the survey area from just over 1400 mm/year in the south-west to almost 1600 mm in the north-east. The monthly estimates show evaporation is highest in December and January and lowest in June and July, following temperature trends.

Table 3 **Monthly and annual estimates of Class A pan evaporation and evaporation losses (mm) from dams** (Queensland Department of Natural Resources)

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<th>Location</th>
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<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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Geology and physiography

A brief description of the geology and physiography of the survey area is provided below. For a detailed analysis of the region, the Albany–Mt Barker edition of the 1:250,000 Geological Series (Muhling & Brakel 1985) is available. The Geology and Mineral Resources of Western Australia (Myers 1990a, 1990b; Hocking 1990) also provides a good coverage. Many other useful texts regarding the geology, hydrogeology and physiography of this region are available, including Smith (1997), Thompson et al. (1993), Churchward et al. (1988), Newbey (1985), Beard (1979) and Moncreiff (1977).

Figure 3 Major geological structural units within the survey area

The major geological influences within the Borden–Tambellup survey are from the Precambrian and Cainozoic eras.

**Precambrian geology**

**Yilgarn Craton**

The northern and central sections of the survey fall within the Western Gneiss Terrane (Myers 1990) province which forms the western margin of the Yilgarn Craton. Here gneisses predominate over granites and greenstones.
In this area, the Craton consists of repeatedly deformed and metamorphosed banded gneiss, with quartz-rich meta-sedimentary rocks and banded iron formations. Large areas of slightly recrystallised granitoid are also predominant, featuring migmatite and gneiss (Muhling & Brakel 1985).

The southern and south-eastern part of the Craton occurring in this area are intruded by a dense swarm of dolerite dykes (the Gnowangerup Dyke Swarm) lying subparallel to the southern boundary margin of the Western Gneiss Terrane. South-east of Tenterden, the granitoid has also been cut by numerous quartz-epidote veins and minor shear zones trending north-west and north-east. Several minor faults occur south-east of Cranbrook.

Albany–Fraser Orogen

The gently undulating to level plain of the south coast is underlain by the Proterozoic Albany–Fraser Orogen. This area of high grade metamorphism and granite intrusion is characterised by an easterly trend of the structural grain. This contrasts with the NNW–SSE trend of the gneiss in the Yilgarn Craton to the north, implying the presence of a structural break (Myers 1990b). In the survey area, the boundary between the Albany–Fraser Orogen and the Yilgarn Craton is covered by Cainozoic sedimentary rocks and Proterozoic low-grade meta-sedimentary rocks of the Stirling Range Formation, discussed in further detail below.

Stirling Range Formation

The Stirling Range Formation is a Middle Proterozoic sequence of metamorphosed sandstone and shale which straddles the boundary between the Yilgarn Craton and the Albany–Fraser Orogen. The central and eastern part of this boundary is not exposed but is likely a shear zone that lies along the southern edge of the Stirling Range Formation.

The resultant Stirling Range is a chain of isolated peaks that begin west of Cranbrook and continue eastward to terminate abruptly at Ellen Peak, south-east of Borden. From the west to the east, the Stirling Range progressively increases in height, angularity and jaggedness, with exposed cliffs and rock faces replacing the rounded outlines of more westerly eminences. Bluff Knoll (1074 m) is the highest point in the southern half of the state.

The rocks of the range show an overall southerly dip which reflects long, asymmetric folds that were refolded by large-scale, open, easterly-trending folds (Myers 1990). The sediments were originally laid down in shallow water and consist of quartzite, slate and phyllite. Detailed descriptions of the Stirling Range geology are available in Thompson et al. (1993) and Newbey (1985).

Cainozoic geology

There are two important Cainozoic units in the survey, collectively known as the Late Eocene Plantagenet Group: the Pallinup Siltstone and the Werillup Formation (Muhling & Brakel 1985). The group forms the onshore portion of the Bremer Basin where it consists of numerous small sediment-filled depressions and paleo-drainage valleys incised into the Albany–Fraser Orogen and the southern part of the Yilgarn Craton (Hocking 1990).

The Werillup Formation is a dark-coloured clay, grey siltstone, sandstone and lignite. It occurs mainly to the north of the Stirling Range, reaching to the west of Borden and east of Tambellup, with other isolated areas east of Borden. It was deposited in fluvial and back-
swamp environments and today many of the lakes north-north-east of the range, such as Racecourse Lake, Anderson Lake and Balicup Lake, are underlain by this formation.

To the south of the Stirlings, the Werillup Formation is overlain by Pallinup Siltstone. This consists of a light coloured siltstone and white spongolite, deposited in several broad topographic depressions and shallow seaways.

Other Cainozoic units occurring in the region includes widespread laterisation and pre-Quaternary deposits of alluvium and colluvium, sand and silcrete. The deposition of sheets of windblown sand in the interior is a feature here, occurring presumably during an acutely arid and windy climatic phase. The sandsheets can be seen in the vicinity of Tambellup, where sand was blown out of the bed of the Gordon River. Along the Pallinup River the sandsheets appear near Kebaringup and also to the south and south-east of Borden.

Outcroppings of shallow doleritic, granitic or gneissic bedrock are common in areas of the Dedatup, Upper Pallinup and Jaffa systems.
Native vegetation

The Tambellup–Borden area straddles four botanical districts of the South-western Botanical Province, as defined by Beard (1979). These include the Darling Botanical District (Menzies Subdistrict), the Eyre Botanical District, the Avon Botanical District and the Roe Botanical District. These are further subdivided into seven vegetation systems, as illustrated in Figure 4 and described below. Beard (1979) mapped the vegetation units of this area at 1:250,000 scale. These units are the basis of the interpreted vegetation systems. In 1981 he defined botanical regions, provinces and districts at 1:1,000,000 scale.

![Vegetation systems within the survey](image)

**Darling Botanical District (Menzies Subdistrict)**

**Kendenup System**
A mixed woodland vegetation system occurs across this plain, featuring jarrah (*Eucalyptus marginata*) combined equally with marri (*Corymbia calophylla*) and wandoo (*E. wandoo*) on upper slopes. Lower slopes have flat-topped yate (*E. occidentalis*) and wandoo, with redheart (*E. decipiens*) appearing in depressions with some tea-tree along creeks.

**Kwornicup System**
The vegetation of the poorly drained area of plain at the south-west corner of the survey is a mosaic with jarrah-marri forest as the dominant member, enclosing numerous patches of jarrah low-forest, paperbark low-forest and reed swamps. Jarrah-marri is often mixed with yate (*Eucalyptus cornuta*), flat-topped yate (*E. occidentalis*) and wandoo (*E. wandoo*). Redheart (*E. decipiens*) forms mallee communities with *Xanthorrhoea* and *Hakea varia* on lunettes, and *Banksia verticillata* is common in swampy depressions. Clay swamps are typified by flat-topped yate with a paperbark understorey (*Melaleuca cuticularis* and *M. violacea*), and sandy swamps typically have dense paperbark low-forest grading to reeds.
Eyre Botanical District

Stirling Range System
Owing to the diversity of the habitats, the flora of the Stirling Range has long been recognised for its richness and high proportion of endemism. Vegetation communities covering the range are arranged in a catena that consists of a mixed thicket on the summits, without clear dominance, but featuring Dryandra formosa, Isopogon latifolius and Oxylobium atropurpureum as the most conspicuous species. On lower slopes, a mallee-form jarrah (Eucalyptus marginata) is common in the mallee-heath formation, merging into jarrah low woodland on footslopes, and this, in combination with marri (Corymbia calophylla), is seen in valleys, occasionally with wandoo (E. wandoo). Mallee-heath surrounds the range with blue mallee (E. tetragona) being predominant.

Qualup System
This is a widespread area of mallee-heath over sandy plains, with the conspicuous blue mallee (E. tetragona) dominating the system. Areas of deep sands support a scrub-heath formation with chittick (Lambertia inermis) generally replacing the mallee. The common salt lakes, pans or swampy depressions across the system have redheart (E. decipiens) associations if the area is predominantly sandy, and flat-topped yate (E. occidentalis) if loamy. Mallee is seen on the lunettes fringing the lake areas.

Jerramungup System
This system is transitional between the Qualup and Chidnup vegetation systems, with mallee-heath a more significant part of the mosaic of vegetation types seen in the small region of its occurrence within the study area. Mallee species includes tall sand mallee (Eucalyptus eremophila) and giant mallee (E. oleosa) with black marlock (E. redunca) and hook-leaved mallee (E. uncinata) being predominant in areas with less gravel. Allocasuarina heath and moort (E. platypus) are seen on patches of clay. Flat-topped yate (E. occidentalis) woodland occurs on creeks and lower valleys.
Cape Riche System
The mallee-heath becomes dominated by jarrah (*Eucalyptus marginata*) here instead of blue mallee (*E. tetragona*). On areas of deep sand, the mallee-heath merges into a scrub-heath similar to that found in the Qualup System. Small depressions are dominated by redheart (*E. decipiens*) or flat-topped yate (*E. occidentalis*), depending on the degree of swampiness, or in some cases, with sedges and *Hakea varia*.

**Avon Botanical District**

Tambellup System
This vegetation system occurs on a dissected landscape of low relief. It features a few laterite-capped hills or breakaways that carry woodlands of blue and brown mallet (*Eucalyptus gardneri* and *E. astringens*). Otherwise, the system is dominated mainly by wandoo (*E. wandoo*), which associates with flat-topped yate (*E. occidentalis*) in various landscape positions, with flat-topped yate being more common on heavier soils. Flooded gum (*E. rudis*) occurs more commonly around drainage lines to the west.

Roe Botanical District

Chidnup System
This area of the Roe Botanical District is very subdued with a flat to gently undulating landscape. Mallee is the dominant association here, with patches of heath with blue mallee (*Eucalyptus tetragona*) dominant on rises. The major valleys and small lakes and pans see patches of eucalypt woodland. The general mallee association is black marlock and hook-leaved mallee (*E. redunca* and *E. uncinata*) with mallee-forms of merrit (*E. flocktonia*), blue mallet (*E. gardneri*) and flat-topped yate (*E. occidentalis*) also occurring. Moort (*E. platypus*) and open-fruited mallee (*E. annulata*) are seen on heavy winter-wet soil. Tea-tree is common in the understorey. Depressions in this area feature flat-topped yate woodland with wandoo (*E. wandoo*) further west, and paperbark (*Melaleuca* spp.) if the depressions are swamppy. In the larger valleys such as the Pallinup, continuous woodland is seen with flat-topped yate and York gum (*E. loxophleba*) common, with some wandoo and marri (*Corymbia calophylla*) closer to the Stirling Range, and red morrel (*E. longicornis*) closer to Borden. Swamp sheoak (*Casuarina obesa*) grows in the Pallinup River bed.

Pallinup System
Dominating the central northern region of the survey, this system has a low forest of merrit (*Eucalyptus flocktonia*) and blue mallet (*E. gardneri*) on gravelly hillcrests and mallee on upland plains, including black marlock (*E. redunca*) and hook-leaved mallee (*E. uncinata*). On hillslopes of valleys, woodlands of York gum (*E. loxophleba*) and flat-topped yate (*E. occidentalis*) are common with red morrell (*E. longicornis*), wandoo (*E. wandoo*) and marri (*Corymbia calophylla*), with moort (*E. platypus*) and flat-topped yate on clays. The levees and banks of drainage lines and valley floors feature flooded gum (*E. rudis*) and flat-topped yate, with swamp sheoak (*Casuarina obesa*) along stream channels and York gum and *Acacia huegeliana* on sandy deposits.
Previous surveys

CSIR Division of Soils conducted several large-scale surveys in the late 1940s to improve knowledge of the soils and provide information on properties nominated for the War Service Settlement program. Each survey included sections on climate, physiography and geology, vegetation and soils. They also included a small section on the suitability of soils for agriculture and any land degradation hazards likely to be encountered. Surveys conducted in the area include *Reconnaissance Soil Surveys in the South and South-east Stirling Areas* (Smith 1950) and *Preliminary Report on the Soils of the North Stirling Area* (Hare, cited in Poutsma 1953). Following the reconnaissance survey, the salt status of the soils was further investigated and reported by Burvill (1949), *Soil Reconnaissance in the North Stirling Range Area*. Doubts still existed, however, regarding the development of this area as the soils were considered unsuitable for the establishment of subclover, and there was a suggested high risk of large areas of land becoming saline after clearing. A further, more detailed, report was undertaken by Poutsma (1953), the *North Stirling Soil and Salinity Survey*, to investigate these concerns.

The most widely used soil information for the area to date has been Sheet 5 of the *Atlas of Australian Soils* (Northcote et al. 1967) and the associated Factual Key (Northcote 1979). It is published at a scale of 1:2,000,000 and provides a broad indication of the major soil and landform associations.

The *Atlas of Australian Soils* also provided background for two publications concerned with the study area: *An introduction to the soils of the Albany advisory district* (Stoneman 1990) and *An introduction to the soils of the Katanning advisory district* (Stoneman 1991). More recently, Hardy and Tille (1993) mapped the soil-landscape units of the North Stirlings Land Conservation District to help farmers identify soil types and as a tool for farm planning.

To the north, the Katanning Area Land Resources Survey (Percy 2000) has been undertaken, and to the south is the South Coast and Hinterland Area Report (Churchward et al. 1988). The survey adjoining the western boundary is the Tonebridge–Frankland Land Resources Survey (Stuart-Street 2005) and the Nyabing–Kukerin Land Resources Survey abuts the north-eastern perimeter (Percy 2003). The Jerramungup Land Resource Survey (Overheu, in prep) to the east is in preparation (Figure 5).
Minimum and zero tillage and stubble retention are widespread practices to protect the sandy surface of many soils in the area, such as here in the Upper Pallinup system.
Survey methods

The following procedures were used in the Tambellup–Borden survey.

- Previous work on the land resources (soils, vegetation and geology) of the survey area and adjacent areas was reviewed.

- A field reconnaissance survey was conducted to identify major subdivisions of mapping units to soil-landscape province, zone and system level.

- Preliminary map unit boundaries were identified by stereo air photo interpretation using 1:25,000 colour photos (Job No. 920405, March 1993).

- Sites were chosen using the free survey technique (Gunn et al. 1988) to describe soil profiles and identify their relationship to the landscape. They were also used to test and improve the conceptual models for mapping. The preliminary mapping and ease of access influenced site selection.

- Fieldwork was undertaken between April 1994 and May 1999 over approximately 511,000 hectares. The Borden 1:100,000 map sheet survey was undertaken initially by Timothy Overheu who described 102 sites, and the remainder was completed by Rohan Marold.

- The Tambellup 1:100,000 map sheet was surveyed by Melanie Roberts. Angela Stuart-Street finalised the survey, selecting and collecting samples from pits for chemical analysis.

- Peter Tille and Justin Hardy surveyed the North Stirlings area in 1988. Their descriptions from 110 sites were included in the soil profile database and were used to develop map unit descriptions for this area.

- Data was collected at 1394 sites (about one site per 370 ha). The distribution of sites is shown in Figure 6. At most sites soil profiles and their environment were described using the Australian Soil and Land Survey Field Handbook (McDonald et al. 1990) and coded to Department of Agriculture and Food standards. Soil profiles were described from pits, exposures and/or hand auger borings to a depth of 1 m, where possible. The amount of detail varies from comprehensive descriptions of soil pits (data point) to abbreviated description from auger borings (observation point). Many of the soil profiles were classified in the field using the Australian Soil Classification (Isbell 2002) and Soil Groups of Western Australia (Schoknecht 2002).

- Sites were concentrated on privately owned land and only very few sites in the Stirling Range National Park were described. There were two reasons for this: firstly, the focus of the survey was on agricultural land use; and secondly, there were concerns by surveyors regarding the spread of the soil-borne fungal pathogen dieback (Phytophthera cinnamomi) within the park. Surveyors’ movements were therefore restricted.

- Data was recorded manually on site cards and later entered onto the computerised WARIS database (Purdie 1993a), later upgraded to the Department of Agriculture and Food’s Soil Profile database where this information is now stored.
• Soil profiles at 30 soil pits were described and sampled for chemical and physical analysis.

• The Chemistry Centre of Western Australia carried out laboratory analyses.

• Conceptual models were developed which relate the various sources of evidence (field data, previous resource data, photo interpretation, published soil process and development models) to soil variation. A synthesis of this material was used to adjust the map boundaries and predict which soils occur within them.

• Colour aerial photographs at 1:25,000 scale were used as the mapping base. The map unit boundaries and labels were captured by Angela Stuart-Street, John Wagnon and Kus Kuswardiyanto from these photographs using a computer aided mapping system operated on MicroStation software. The site locations were also digitised from aerial photographs. The map unit at each site was identified from the digitised maps and has been added to the Soil Profile database.

• The map units were described in a standard format and this information has been added to the Map Unit database. The description includes the expected proportion of WA Soil groups (Schoknecht 2002) within each map unit.

• Land qualities were assessed for each soil group and for the soil group in each land unit within each map unit following the methodology outlined in van Gool, Tille and Moore (2005).

Figure 6 Location of field sites
Mapping units

A map unit identifies areas with similar characteristics and properties. In the Tambellup–Borden survey, soil-landscape units identify areas that have similar soil and landforms. Soil-landscape map units were used in this survey because large areas can be covered rapidly. The broad mapping scale and low intensity of sampling do not allow individual soil units to be mapped. Soil-landscape units (e.g. soil-landscape systems) are delineated with the aid of remote sensing techniques such as aerial photographs. They are defined on the basis of landform and the pattern of geology, soil and vegetation within the landform.

The Department of Agriculture and Food has established a hierarchy of soil-landscape map units. The hierarchy aims to maintain a consistent approach with different scales of mapping and varying levels of complexity of soils and landscapes (Schoknecht et al. 2004). Moving down the hierarchy, the map units cover smaller areas and the complexity within each unit decreases. Each soil-landscape map unit in Western Australia has a unique symbol indicating its place in the mapping unit hierarchy. The following examples show how the hierarchy is established for each unit. An example of a map unit from the survey is illustrated in Figure 7.

Example 1: 242Ch2g indicates the map unit is in the Western Region (2), Stirling Province (24), Albany Sandplain Zone (242), Chillinup System (242Ch), Chillinup 2 Subsystem (242Ch_2), Chillinup 2 Subsystem gilgai phase (242Ch_2g). On the accompanying map the map unit is labelled Ch2g.

Example 2: 254KeCMp indicates the map unit is in the Western Region (2), Avon Province (25), Warren Denmark Southland Zone (254), Kent System (254Ke), Camballup Subsystem (254KeCM), Camballup Subsystem plains phase (254KeCMp). On the accompanying map the map unit is labelled CMp.

Some subsystems are expressed by numbers (Example 1) and others by letters (Example 2). This conforms to mapping standards previously established in adjoining soil surveys. The leading numerals are omitted from the accompanying maps for clarity. The full symbols are attached to the digital maps and are used in the Soil Profile and Map Unit databases.

WA Christmas trees (Nuytsia floribunda) on Pale deep sand in the Hydenup System (241Hd)
1. Regions
Broad subdivisions of the Australian continent (Bettenay 1983).
e.g. Western Region (2)

2. Provinces
Provides a broad overview of the whole state suitable for maps at scales of about 1:5,000,000 (Bettenay 1983).
e.g. Stirling Province (24)

3. Zones
Areas defined on geomorphologic or geological criteria, suitable for regional perspectives.
e.g. Pallinup Zone (241)

4. Systems
Areas with recurring patterns of landforms, soils and vegetation, suitable for regional mapping at scales of 1:250,000.
e.g. Hydenup System (241Hd)

5. Subsystems
Areas of characteristic landform features containing a definite suites of soils, suitable for mapping at regional scales of 1:100,000.
e.g. Hydenup 2 Subsystem (241Hd_2)

6. Subsystem phases
Division of subsystems based on land use interpretation requirements.
e.g. Hydenup 2 sandy phase (241Hd_2s)

7. Land units
Describe areas of land with similar soils, slopes and landforms. Land units are unmapped at regional scale mapping.

Figure 7 Hierarchy of soil-landscape map units used in this report
Soil-landscape regions, provinces and zones

The Tambellup–Borden survey is located within the Western Soil-landscape Region of Australia which covers most of the agricultural and pastoral areas of Western Australia excluding the Kimberley, the Sandy Desert and the Nullarbor Plain (Bettenay 1983). Soil-landscape Regions are divided into Provinces. Two soil-landscape Provinces, Avon and Stirling, are represented in the survey.

The Avon Province is a lateritised plateau on Precambrian granites and gneisses, dissected at the margins by rivers, including the Swan-Avon and the Blackwood (Bettenay 1983). The northern area and the south-western corner of the survey are within the Avon Province. Two soil-landscape zones in the survey which fall into this province are the Warren Denmark Southland Zone and the Southern Zone of Rejuvenated Drainage.

The Stirling Province is a narrow strip along the Southern Ocean with mainly ‘Proterozoic gneisses and migmatites which are overlain sporadically by Tertiary marine and continental sediments’ (Bettenay 1983). It includes the Pallinup Zone, the Stirling Range Zone, and the Albany Sandplain Zone.

The boundaries of the soil-landscape provinces and zones are shown in Figure 8.

Figure 8 Soil-landscape provinces and zones in the survey
**Warren–Denmark Southland Zone**

The Warren–Denmark Southland Zone (Tille 1996) occurs in a small region in the south-west corner of the survey. It forms a series of gentle steps or broad benches rising gradually in elevation from the Southern Ocean northward. The Stirling Range Zone and Albany Sandplain Zone define its eastern limits.

The zone has mainly formed on crystalline rocks of the Albany–Fraser Orogen. In many areas this bedrock is overlain by a deeply weathered lateritic mantle or sedimentary deposits dating from the Quaternary and Tertiary periods.

The rainfall in this zone is 550–600mm. Clearing for agriculture is widespread and jarrah-marri (*Eucalyptus marginata-Corymbia calophylla*) forest and woodland remnants are dominant. These are interspersed with areas of sedge lands, heath lands and paperbark woodlands.

The Warren–Denmark Southland Zone makes up just over three per cent of the survey area and includes the Yaraleena and Kent soil-landscape systems. Its mapping hierarchy code is 254.

**Southern Zone of Rejuvenated Drainage**

The Southern Zone of Rejuvenated Drainage is an erosional surface of gently undulating rises to low hills. It has continuous stream channels that flow in most years. Colluvial processes have been active with most soils formed in colluvium or weathered crystalline rock (mainly derived from the Yilgarn Craton). Laterite capping is believed to have once covered much of this area. It has been stripped away in many places, leaving the landscape as it appears today, with only small gravelly remnants of the laterite profile remaining on hillcrests and are often flanked by steep breakaways.

The zone extends from Brookton to south of Tambellup (Percy 2000). The Eastern Darling Range Zone bounds it to the west. The Southern Zone of Ancient Drainage forms its major eastern boundary. The boundary between the zones of Rejuvenated and Ancient Drainage is known as the Meckering Line. This imaginary line was defined by Mulcahy (1967) as marking the downstream limit of broad valley flats with salt lake chains.

Within the survey area, the zone is vegetated mainly by woodlands of wandoo (*E. wando*), rock sheoak (*Allocasuarina huegeliana*) and jam (*Acacia acuminata*). Flat-topped yate (*E. occidentalis*), brown mallet (*E. astringens*), blue mallet (*E. gardneri*) and flooded gum (*E. rudis*) are also common.

The Southern Zone of Rejuvenated Drainage covers almost nine per cent of the survey area and consists of the Carrolup, Mooliup and Gordon Flats soil-landscape systems. Its mapping hierarchy code is 257.

**Stirling Range Zone**

The Stirling Range Zone dominates the southern half of the survey area. It consists of the steep mountains of the Stirling Range (Proterozoic meta-sediments) and associated areas of
undulating rises on crystalline rocks and poorly drained flats on Eocene sediments. The Stirling Range Zone is bounded to the north and east by the Pallinup Zone and to the west and south by the Warren–Denmark Southland Zone and the Albany Sandplain Zone respectively. To the north-west it is flanked by the Southern Zone of Rejuvenated Drainage. It stretches approximately 100 km from east to west and almost 50 km from north to south at its widest point. It is largely contained within the survey area.

Stony soil, bare rock and gravels are common features of the peaks and slopes of the steep hills and mountains. These smooth down to a level to gently undulating internally drained plain to the north, which is dominated by sandy duplex and saline wet soils. Subsoils of the plain are generally sodic. Granitic outcrops, sandy duplex and loamy duplex soils dominate the gently undulating rises that border the western flanks of the range.

The zone is dominated by its namesake. The abrupt mountains of the Stirling Range reach a pinnacle height of 1073 m at Bluff Knoll, the highest point of the southern half of the state (Beard 1981). In the west, the hills become more rounded and subdued. Sukey Hill at Cranbrook, just 373 m, and Geekabee Hill, north-east of Frankland (to the west of the survey), reaching 400 m, are the outlying westernmost prominences of the range. Immediately north of the main range is the North Stirlings basin. This area of broad plains is formed on Eocene sediments with poorly defined drainage lines and many salt lakes (Hardy & Tille 1993).

The rainfall across the zone generally varies from 600 mm in the west to 400 mm in the east, but can be highly variable, ranging from up to 1000 mm on the highest peaks to the rainshadow effect felt in the North Stirlings area. The peaks of the range can create localised weather conditions, often as extended periods of cloud cover and drizzle, and occasional snow on the highest peaks during winter and spring.

Salt lakes are a common feature in the north of the Stirling Range Zone.
The native vegetation across the Stirling Range forms a unique catena (Beard 1979), ranging from mixed thicket associations on the upper slopes and peaks to mallee-heath on mid-slopes, and woodland of jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*) and wandoo (*E. wandoo*) on protected lower slopes and drainages. On the plains to the north, mallee-heath formation is dominant with blue mallee (*E. tetragona*) being the conspicuous species, interspersed with scrub heath dominated by chittick (*Lambertia inermis*). Flat-topped yates (*E. occidentalis*) are seen in many swampy areas, together with paperbark woodlands (*Melaleuca cuticularis*) and tea-trees (*Melaleuca* species). The undulating rises and plains to the west of the main range feature woodland remnants of wandoo, jarrah and marri, with yate.

The Stirling Range Zone is the largest in the survey, covering 39.1 per cent of the area. It features the Stirling Range, North Stirlings and Jaffa soil-landscape systems. Its mapping hierarchy code is 248. (Note: The Stirling Range Zone previously described by Percy (2000) has been split to accommodate the new Pallinup Soil-landscape Zone. Consequently, the description for this unit has been amended.)

**Albany Sandplain Zone**

The Albany Sandplain Zone is a broad, level sandplain with numerous scattered small lakes and seasonally inundated depressions that makes up 10.4 per cent of the survey area. Linear sand dunes and lunettes adjacent to small swamps are common features across the landscape. Its margin to the south is defined by the Southern Ocean. It extends west to meet the Warren–Denmark Southland Zone, and it abuts the Ravensthorpe Zone at its eastern extent. To the north, the Stirling Range Zone, the Pallinup Zone and the Jerramungup Plain Zone meet its borders.

The basement geology (comprising granites and gneiss of the Albany–Fraser Orogen) rarely outcrops on the land surface. More prominent are the aeolian sand deposits and deeply weathered mantles of laterite overlying thick Eocene and Tertiary sediments of the Pallinup and Werillup formations. The sediments have been incised by rivers that in places have revealed the basement rock.

Texture contrast soils are dominant. They mainly comprise Duplex sandy gravels, Grey deep and shallow sandy duplexes (often gravelly with a fine sandy surface texture and alkaline and sodic subsoils). These are seen together with Pale deep sands, Wet and Semi-wet soils and Shallow gravels. These soils are developing on weathered Tertiary marine sediments. Pale deep sands occur as deep (deflation) sandsheets or on the south-eastern side of swamps and drainage lines across the sandplain.

Mallee-heath and jarrah-marri-sheoak-yate-banksia woodland dominate the vegetation patterns.

Within the survey area, the Chillinup, Lower Pallinup and Upper Kalgan soil-landscape systems represent the Albany Sandplain Zone, and the mapping hierarchy code is 242.

**Pallinup Zone**

The Pallinup Zone (previously described as part of the Stirling Range Zone in Percy 2000) consists of broad upland plains dissected by the Pallinup River to form gently undulating rises with narrow alluvial plains. The zone extends from north-west of Gnowangerup to the North
Stirlings basin in the south and east to Ongerup. It is bounded in the west by the Southern Zone of Rejuvenated Drainage (Avon Province). The Stirling Range Zone forms its southern boundary. Its northern boundary is formed by the South-western and South-eastern Zones of Ancient Drainage (Avon Province). In the survey this boundary corresponds to the catchment divide between the Pallinup River and the Gordon-Frankland River. Its eastern perimeter is formed by the Jerramungup Zone (Stirling Province).

This zone is similar to the Southern Zone of Rejuvenated Drainage in that most of the laterite profile has been stripped to expose the fresh crystalline rock of the Yilgarn Craton or mottled and pallid zone clays. The soils of the Pallinup Zone are mainly shallow duplex soils with hardsetting sandy or loamy topsoils. Their subsoils are sodic and range from neutral to alkaline and are often calcareous. A large number of dolerite and gabbro dykes occur in this zone, close to Gnowangerup. Alkaline reddish brown shallow sandy and loamy duplex soils are found on these dykes.

The native vegetation within the Pallinup Zone is mainly woodland, with York gum (*E. loxophleba*), flat-topped yate (*E. occidentalis*), and some salmon gum (*E. salmonophloia*), wandoo (*E. wandoo*) and moort (*E. platypus*).

The Pallinup Zone covers over 38 per cent of the survey area and consists of the Upper Pallinup, Toompup, Hydenup, Kokarinup, Dedatup and Mabinup soil-landscape systems. The mapping hierarchy code is 241.

**Accompanying maps**

Soil maps are an attempt to represent the complex reality of the landscape in a simplified form. Soils form a continuum in the landscape, therefore unit boundaries are determined by surveyor judgment on the basis of evidence available at the scale of mapping. They do not indicate sharp changes, but a position where the rate of soil and landscape variation is greatest.

The survey was mapped at a scale of 1:100,000 and is presented as one map which covers two map sheets. The map legend briefly describes the landscape and major Western Australian soil groups for each map unit (usually the subsystem). Descriptions of map units apply to the whole survey and to any occurrences in adjacent surveys. Individual map units may differ considerably from this description in terms of the proportion of different soils and landforms that occur within them. Thus the map provides a guide, not a definitive statement, as to what may occur at a particular point or selected area. All map units within each soil-landscape system have the same colour and the map legend is arranged alphabetically by soil-landscape system.

The map of the survey area is provided on the accompanying CD-ROM and can be viewed or printed as desired. Additionally, soil-landscape maps and further soil information for this survey and for the entire south-west of Western Australia are available to be viewed at [http://spatial.agric.wa.gov.au/slip](http://spatial.agric.wa.gov.au/slip).

The distribution of soil-landscape systems is provided in Figure 9.
Soil-landscape systems

Seventeen soil-landscape systems have been identified in the Tambellup–Borden survey. They are defined on criteria including geology, landform and soil. Table 4 lists the systems according to how they fit into the mapping hierarchy and the area covered in the survey. The boundaries of the soil-landscape systems and their relation to towns and localities are presented in Figure 9. These soil-landscape systems are described in alphabetical order in the following section.

Most of the systems are further subdivided into subsystems and in some cases into phases. For each system the main landforms are briefly described and the regional geology is listed. An indication of present land use and land management issues associated with each system is also included. A table describing the subsystems and their phases in terms of landforms, the dominant Western Australian Soil Groups and associated Soil Series, has been included for all of the systems. The descriptions also include a cross-sectional diagram that indicates the relative heights of the landforms and the underlying regolith.
Table 4  **Soil-landscape systems within the survey and their place in the mapping hierarchy**

<table>
<thead>
<tr>
<th>Province and Zone</th>
<th>System</th>
<th>Hierarchy Code</th>
<th>Area (ha)</th>
<th>% of survey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avon Province</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warren–Denmark Southland Zone</td>
<td>Kent</td>
<td>254Ke</td>
<td>16,010</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Yaraleena</td>
<td>254Ya</td>
<td>1,383</td>
<td>0.3</td>
</tr>
<tr>
<td>Southern Zone of Rejuvenated Drainage</td>
<td>Carrolup</td>
<td>257Ca</td>
<td>23,906</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>Gordon Flats</td>
<td>257Gd</td>
<td>7,982</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Moolup</td>
<td>257Mp</td>
<td>13,056</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Stirling Province</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pallinup Zone</strong></td>
<td>Dedatup</td>
<td>241Dd</td>
<td>24,633</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Hydenup</td>
<td>241Hd</td>
<td>13,581</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Kokarinup</td>
<td>241Kb</td>
<td>11,165</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Mabinup</td>
<td>241Mb</td>
<td>6,589</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Toompup</td>
<td>241Tm</td>
<td>31,882</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>Upper Pallinup</td>
<td>241Up</td>
<td>107,765</td>
<td>21.1</td>
</tr>
<tr>
<td><strong>Albany Sandplain Zone</strong></td>
<td>Chillup</td>
<td>242Ch</td>
<td>38,890</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Lower Pallinup</td>
<td>242Lp</td>
<td>1,330</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Upper Kalgan</td>
<td>242Uk</td>
<td>12,771</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Stirling Range Zone</strong></td>
<td>Jaffa</td>
<td>248Jf</td>
<td>19,476</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>North Stirlings</td>
<td>248Nt</td>
<td>59,440</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>Stirling Range</td>
<td>248St</td>
<td>120,746</td>
<td>23.7</td>
</tr>
</tbody>
</table>

**Legend to symbols used in system cross-section diagrams**

- Aerial deposits, mainly deep sands
- Eocene sediments
- Granite, gneiss and/or adamellite with dolerite dykes, colluvial deposits also occur
- Metasediments - sandstone and shale
- Wet or waterlogged soils, including salines wet soils
- Colluvium and/or Tertiary laterite profile
- Tertiary laterite profile with duricrust
- Alluvial deposits
Carrolup System

23,906 ha 4.7% of the survey area

Gently undulating to undulating rises, undulating low hills and narrow alluvial plains surround the headwaters of the Gordon River in the north-east of the survey.

**Parent materials:** Colluvium is most common with minor areas of alluvium. Significant areas of granite, adamellite, granodiorite and gneiss occur, with intrusive dolerite and gabbro dykes. Alluvial deposits cover the valley flats and alluvial plains. Small areas are mapped as laterite and reworked sandplain.

**Native vegetation:** Tambellup Vegetation System (Beard 1981). Woodlands dominated by wandoo (*Eucalyptus wandoo*) associated with flat-topped yate (*E. occidentalis*). Gravelly crests feature blue and brown mallet (*E. gardneri* and *E. astringens*).

**Land use:** Rotational cropping is dominant with a relatively long annual pasture phase (3–8 years) in rotation with cereal crops (oats, barley or wheat), canola or less often lupins and field peas. Minor valley floors are not cropped and often remain vegetated while the major valley floors are occasionally cropped with oats; saline areas are grazed or fenced and revegetated with trees and/or salt tolerant perennials.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrolup 1 Subsystem (Ca_1)</td>
<td>Upper slopes, crests and breakaways</td>
<td>Deep sandy gravel</td>
<td>18</td>
</tr>
<tr>
<td>(1,868 ha)</td>
<td></td>
<td>Shallow gravel</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex sandy gravel</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Ironstone gravelly soils, Deep and Shallow sands)</td>
<td>34</td>
</tr>
<tr>
<td>Carrolup 2 Subsystem (Ca_2)</td>
<td>Lower to upper slopes</td>
<td>Grey deep sandy duplex</td>
<td>44</td>
</tr>
<tr>
<td>(16,576 ha)</td>
<td></td>
<td>Grey shallow sandy duplex</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Loamy and Sandy duplex soils and Ironstone gravelly soils)</td>
<td>46</td>
</tr>
<tr>
<td>Carrolup 2 sandy phase (Ca_2s)</td>
<td>Sandsheets</td>
<td>Brown deep sand</td>
<td>90</td>
</tr>
<tr>
<td>(28 ha)</td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>10</td>
</tr>
</tbody>
</table>
| Carrolup 3 Subsystem (Ca_3) (63 ha) | Slopes of gently undulating rises | Grey deep sandy duplex  
Brown deep sand  
Grey shallow sandy duplex  
Yellow/brown deep sandy duplex  
Other soils (mainly Bare rock and Loamy duplex soils) | 22  
20  
15  
13  
30 |
| Carrolup 4 Subsystem (Ca_4) (1,545 ha) | Drainage lines and upper tributaries of the Pallinup River | Grey shallow sandy duplex  
Grey deep sandy duplex  
Duplex sandy gravel  
Other soils (mainly Shallow loamy duplex and Saline wet soils) | 30  
25  
15  
30 |
| Carrolup 5 Subsystem (Ca_5) (1,293 ha) | Valley flats (100–300 m wide stream channels and lower slopes 0–2% gradient) | Saline wet soil  
Grey deep sandy duplex  
Brown deep sand | 65  
30  
5 |
| Carrolup 6 Subsystem (Ca_6) (2,082 ha) | Valley flats and narrow plains (300–1500 m wide) with some low dunes along stream channels | Grey deep sandy duplex  
Grey shallow sandy duplex  
Alkaline grey shallow sandy duplex  
Brown deep sand  
Other soils (mainly Saline wet soil) | 49  
17  
12  
11  
11 |
| Carrolup 7 Subsystem (Ca_7) (480 ha) | Dunes derived from windblown river deposits | Brown deep sand  
Grey deep sandy duplex  
Other soils (mainly Deep sand and Saline wet soils) | 80  
14  
6 |
Chillinup System 242Ch

38,890 ha  7.6% of the survey area

Level to gently undulating plain on the south-eastern side of the Stirling Range. Drainage is confined to the scattered lakes, swamps and depressions.

Parent materials: The dominant geology is Eocene sediments of the Plantagenet Group underlain by Granitoid gneiss of the Albany–Fraser Orogen. There has been deep weathering and most of the plain is covered in a mantle of sand and sandy lateritic gravel. Some of the sand has been reworked by wind into linear dunes and lunettes.

Native vegetation: Qualup and Cape Riche Vegetation Systems (Beard 1981). Mallee-heath vegetation dominated by blue mallee (Eucalyptus tetragona) with chittick (Lambertia inermis) prominent in understorey and in areas of scrub heath on deep sands. Sandy wet depressions and lakes feature redheart (E. decipiens) and, if loamy, flat-topped yate (E. occidentalis).

Land use: Clover-dominant pastures and lupins are rotated with cereals (mostly barley). Canola has recently grown in importance as a profitable rotation. Minimum tillage and lower stocking rates have proven to be important in protecting the fine sandy soils that dominate this land system. Overclearing of the low mallee scrub, the large open plains and the proximity to the south coast lead to a high frequency of erosive wind events. Sheep are the dominant grazing animal with cattle becoming more common in areas closer to the coast. Increased adoption of high water use farming systems has seen perennial pastures (mainly lucerne and kikuyu) becoming more widespread. Commercial timber plantations are established in areas here including Tasmanian blue gum (E. globulus), and pine plantations (Pinus pinaster and P. radiata), which are often located on areas of deep sand.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chillinup 1 Subsystem (Ch_1) (8,923 ha)</td>
<td>Level sandy and gravelly sandplain</td>
<td>Grey deep sandy duplex</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey shallow sandy duplex</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex sandy gravel</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils and Deep sands)</td>
<td>45</td>
</tr>
<tr>
<td>Chillinup 2 Subsystem (Ch_2) (12,937 ha)</td>
<td>Level to gently undulating sandy gravelly plain</td>
<td>Duplex sandy gravel</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pale deep sand</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deep sandy gravel</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplex and Wet soils)</td>
<td>44</td>
</tr>
<tr>
<td>Chillinup 2 gilgai phase</td>
<td>Poorly drained, level, low-lying plains with large areas represented by shallow</td>
<td>Alkaline grey shallow sandy duplex</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alkaline grey deep sandy duplex</td>
<td>20</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Landform</td>
<td>Soils</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Chillinup 3</td>
<td>Crabhole gilgai</td>
<td>Hard cracking clay, Wet soil, Other soils (mainly Cracking and Non-cracking clays, Loamy and Sandy duplex soils)</td>
<td></td>
</tr>
<tr>
<td>(Ch _2g)</td>
<td>(1,508 ha)</td>
<td>10 10 32</td>
<td></td>
</tr>
<tr>
<td>Chillinup 4</td>
<td>Linear dunes (oriented in NW–SE direction) and associated interdunal swales</td>
<td>Pale deep sand, Grey deep sandy duplex, Other soils (mainly Ironstone gravelly soils and Deep sands)</td>
<td></td>
</tr>
<tr>
<td>(Ch _3)</td>
<td>(6,672 ha)</td>
<td>63 17 20</td>
<td></td>
</tr>
<tr>
<td>Chillinup 5</td>
<td>Salt lakes with minor lunettes</td>
<td>Salt-lake soil, Calcareous loamy earth, Pale deep sand, Other soils (mainly Sandy and Loamy duplex and Sandy earth soils)</td>
<td></td>
</tr>
<tr>
<td>(Ch _4)</td>
<td>(3,963 ha)</td>
<td>33 16 15 36</td>
<td></td>
</tr>
<tr>
<td>Chillinup 6</td>
<td>Gentle gravelly rises with areas of sandsheet deposits</td>
<td>Duplex sandy gravel, Pale deep sand, Deep sandy gravel, Other soils (mainly Sandy duplex and Ironstone gravelly soils)</td>
<td></td>
</tr>
<tr>
<td>(Ch _5)</td>
<td>(2,480 ha)</td>
<td>22 18 16 44</td>
<td></td>
</tr>
<tr>
<td>Chillinup 6</td>
<td>Large lunettes adjacent to swamps and salt lakes</td>
<td>Pale deep sand, Alkaline grey deep sandy duplex, Calcareous loamy earth, Other soils (mainly Sandy and Loamy duplex soils and Wet soils)</td>
<td></td>
</tr>
<tr>
<td>(Ch _6)</td>
<td>(3,915 ha)</td>
<td>50 18 10 22</td>
<td></td>
</tr>
</tbody>
</table>
**Dedatup System**

24,633 ha 4.8% of the survey area

Undulating rises and undulating low hills of the Pallinup River valley which cuts deeply into the landscape as it passes to the north-east of the Stirling Range.

**Parent materials:** The dominant geology is gniess of the Yilgarn Craton. Most of the laterite profile has been stripped, allowing fresh soils to develop on the underlying rock.

**Vegetation:** Jerramungup System (Beard 1981). A mosaic of vegetation featuring mallee and mallee-heath, dominantly tall sand mallee and black marlock (*Eucalyptus eremophila*; *E. oleosa*) association, sometimes with patches of yate (*E. occidentalis*) woodland in valleys.

**Land use:** Cereal cropping is an important land use with yields higher than surrounding areas due to the more fertile soils. The land along the Pallinup River valley was some of the earliest cleared for this reason. Rotations included in recent years are faba beans and canola which seem to be well suited to these soil types. Sheep grazing occurs on clover-dominant pastures in rotation with the cropping programs. Water erosion is significant here due to the relatively steep slopes.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedatup 1 Subsystem (Dd _1) (1,626 ha)</td>
<td>Residual gravelly plains bordered by upper valley slopes and some breakaways</td>
<td>Duplex sandy gravel, Grey deep sandy duplex, Alkaline grey shallow sandy duplex, Shallow gravel, Other soils (mainly Sandy and Loamy duplexes)</td>
<td>18, 18, 16, 12, 36</td>
</tr>
<tr>
<td>Dedatup 2 Subsystem (Dd _2) (3,399 ha)</td>
<td>Mid to upper valley slopes</td>
<td>Grey shallow sandy duplex, Grey deep sandy duplex, Grey shallow loamy duplex, Other soils (mainly Loamy and Sandy duplex, and Ironstone gravelly soils)</td>
<td>44, 17, 10, 29</td>
</tr>
<tr>
<td>Dedatup 3 Subsystem (Dd _3) (18,734 ha)</td>
<td>Areas of shallow basement rock of dolerite and gneiss</td>
<td>Grey deep sandy duplex, Red/brown non-cracking clay, Alkaline red shallow loamy duplex, Other soils (mainly Sandy and Loamy duplex, Loamy earths and Bare rock)</td>
<td>11, 11, 10, 68</td>
</tr>
<tr>
<td>Dedatup 4 Subsystem (Dd _4)</td>
<td>Narrow valley floors</td>
<td>Alkaline grey shallow sandy duplex, Alkaline red shallow loamy duplex, Red deep loamy duplex</td>
<td>13, 13, 13</td>
</tr>
<tr>
<td>(293 ha)</td>
<td>Other soils (mainly Wet soils and Sandy and Loamy duplexes)</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------------------</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>Dedatup 5 Subsystem (Dd_5) (581 ha)</td>
<td>Major valley floors and flanking valley slopes</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Saline wet soil</td>
<td>Brown loamy earth</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Yellow/brown shallow loamy duplex</td>
<td>Other soils (mainly Bare rock and Loamy and Sandy duplex soils)</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>

Undulating rises in the Dedatup System, looking toward the Stirling Range
Gordon Flats System 257Gd

7982 ha  1.6% of the survey area

Broad valley floor (0.5–3 km wide) incorporating the floodplains of the upper part of the Gordon River. The plain is interspersed with low dunes, swampy depressions and low gravelly rises.

Parent materials: Alluvial deposits which cover the valley flats and alluvial plains are most common, with minor areas of colluvium.

Native vegetation: Tambellup Vegetation System (Beard 1981). Woodlands dominated by wandoo (Eucalyptus wandoo) associated with flat-topped yate (E. occidentalis). Some wet areas may feature flooded gum (E. rudis) or tea-tree (Melaleuca viminea) in the drier upper reaches of the Gordon River.

Land use: Rotational cropping is dominant with a relatively long annual pasture phase (3–8 years) in rotation with cereal crops (oats, barley or wheat), canola or less often lupins and field peas. Minor valley floors are not cropped and often remain vegetated while the major valley floors are occasionally cropped with oats; saline areas are grazed or fenced and revegetated with trees and/or salt tolerant perennials.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gordon Flats 1 Subsystem (Gd_1) (3,671 ha)</td>
<td>Broad valley plains (0.5–3 km wide)</td>
<td>Semi-wet soil, Duplex sandy gravel, Saline wet soil, Grey deep sandy duplex, Other soils (mainly Deep sands and Sandy duplexes)</td>
<td>15, 14, 12, 10, 49</td>
</tr>
<tr>
<td>Gordon Flats 2 Subsystem (Gd _2) (1,442 ha)</td>
<td>Low sandy rises and dunes on alluvial plains</td>
<td>Pale deep sand, Grey deep sandy duplex, Grey shallow sandy duplex, Other soils (mainly Deep sands and Sandy duplexes)</td>
<td>25, 25, 12, 38</td>
</tr>
<tr>
<td>Gordon Flats 3 Subsystem (Gd _3) (65 ha)</td>
<td>Low gravelly rises</td>
<td>Duplex sandy gravel, Grey deep sandy duplex, Pale deep sand, Other soils (mainly Ironstone gravelly soils)</td>
<td>36, 18, 14, 32</td>
</tr>
<tr>
<td>Gordon Flats 4 Subsystem (Gd _4) (1,038 ha)</td>
<td>Swampy terrain with minor areas of dunes</td>
<td>Pale deep sand</td>
<td>26</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>------------------------------------------</td>
<td>----------------</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Semi wet soil</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline wet soil</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Deep sand and Sandy duplexes)</td>
<td>36</td>
</tr>
<tr>
<td>Gordon Flats 5 Subsystem (Gd _5) (702 ha)</td>
<td>Saline drainage lines and flats (100–500 m wide)</td>
<td>Saline wet soil</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils and Deep sands)</td>
<td>36</td>
</tr>
<tr>
<td>Gordon Flats 6 Subsystem (Gd _6) (1,063 ha)</td>
<td>Broad drainage lines of main river channels (0.5–2.5 km wide)</td>
<td>Saline wet soil</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pale deep sand</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils and Deep sands)</td>
<td>35</td>
</tr>
</tbody>
</table>

Gordon River in the Gordon Flats System at Tambellup
Hydenup System

13,581 ha  2.7% of the survey area

Known locally as the Kybelup Sandplain, this system consists of a large level to gently undulating plain with a few very sluggish drainage areas that include numerous shallow depressions. The system is a mosaic of level gravely plains, yate (*Eucalyptus occidentalis*) swamps, salt lakes, sand dune systems, sandsheets and shallow gravelly rises.

**Parent materials:** The geology in this system is dominated by sand (commonly with iron pisoliths), alluvium and colluvium, interspersed with lake and swamp deposits. These overlie siltstone of the Plantagenet Group and granitoid and gneiss bedrock.

**Native vegetation:** Pallinup Vegetation System (Beard 1981). Mallee vegetation is dominant, featuring a black marlock and hook-leaved mallee (*Eucalyptus redunca* and *E. uncinata*) association. Patches of merrit and blue mallet low forest (*E. flocktoniae* and *E. gardneri*) are common on gravelly uplands; around winter wet depressions and swamps are low forests of moort, open-fruited mallee and flat-topped yate (*E. platypus, E. annulata* and *E. occidentalis*). Areas of woodland occur in larger valleys featuring flat-topped yate and York gum (*E. loxophleba*) with some wandoo (*E. wandoo*)

**Land use:** Clover-dominant pastures and lupins are rotated with cereals. Canola is a crop that has recently grown in importance as a profitable inclusion in the rotation. Minimum tillage and lower stocking rates have proven to be important in protecting the fine sandy soils that dominate this land system. On the farm that takes up most of this system the only land use is zero tillage cropping, which seems to be well suited to the soils. There is a high risk of wind erosion due to the very low relief, extensive clearing and sandy surfaced topsoils. Rising saline groundwater tables are also an important issue due to the low relief. Many of the once fresh swamps are becoming saline.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydenup 1 Subsystem (Hd_1) (1,353 ha)</td>
<td>Gravelly rises above the level sandplain</td>
<td>Duplex sandy gravel</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deep sandy gravel</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alkaline grey deep sandy duplex</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplexes and Ironstone gravelly soils)</td>
<td>40</td>
</tr>
<tr>
<td>Hydenup 2 Subsystem (Hd_2) (9,708 ha)</td>
<td>Level to gently undulating plain mainly covered in thin sandsheet</td>
<td>Grey deep sandy duplex</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex sandy gravel</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deep sandy gravel</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplexes and Deep sands)</td>
<td>30</td>
</tr>
</tbody>
</table>
Hydenup 2s
Sandy Phase
(Hd _2s)
(491 ha)
Sandsheets and low dunes
Pale deep sand 61
Grey deep sandy duplex 23
Duplex sandy gravel 10
Brown deep sand 6

Hydenup 3
Subsystem
(Hd _3)
(2,521 ha)
Level plain with swamps and salt lakes
Grey deep sandy duplex 29
Pale deep sand 21
Salt-lake soil 15
Semi-wet soil 15
Other soils (mainly Wet soils) 20

Thick cereal stubble on Grey deep sandy duplex soil in the Hydenup 2 Subsystem
**Jaffa System**

19,476 ha 3.8% of the survey area

The Jaffa system features undulating topography on adamellite and granitoid geology which sets it apart from the sandstone and shale of the Stirling Range system it flanks to the west. Rock outcrops are common on hillslopes.

**Parent materials:** The dominant geology is colluvium over adamellite and granitoid rock. In many areas the surface has been stripped, allowing fresh soils to develop on the underlying rock.

**Native vegetation:** Kendenup and Tambellup Vegetation Systems (Beard 1981). Dominantly a mixed woodland featuring jarrah (*Eucalyptus marginata*) with marri (*Corymbia calophylla*) and wandoo (*E. wandoo*). Lower slopes and depressions feature flat-topped yate (*E. occidentalis*) and wandoo woodland.

**Land use:** Rotational cropping is common with a relatively long annual pasture phase (3–8 years) in rotation with cereal crops. Minor valley floors and rockier areas are not cropped and often remain vegetated or improved for pasture. The main limitation here is waterlogging.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
</table>
| Jaffa 1 Subsystem (Jf_1) (221 ha) | Lower to upper slopes and hillcrests | Duplex sandy gravel  
Grey deep sandy duplex  
Grey shallow sandy duplex  
Other soils (mainly Ironstone gravelly soils and Loamy earths) | 31  
28  
15  
26 |
| Jaffa 2 Subsystem (Jf_2) (13,119 ha) | Footslopes, gently undulating rises and undulating plains | Grey deep sandy duplex  
Grey shallow sandy duplex  
Semi-wet soil  
Other soils (mainly Ironstone gravelly soils and Loamy duplexes) | 29  
18  
15  
38 |
| Jaffa 3 Subsystem (Jf_3) (5,020 ha) | Mid to upper slope and hillcrest areas characterised by rock outcrop | Grey deep sandy duplex  
Grey shallow loamy duplex  
Bare rock  
Other soils (mainly Ironstone gravelly soils and Loamy and Sandy duplexes) | 26  
22  
15  
37 |
| Jaffa 4 Subsystem | Footslopes and drainage lines | Grey deep sandy duplex | 25 |
Rock outcrops are common on slopes and crests of the Jaffa 3 Subsystem
**Kent System**

16,010 ha  
3.1% of the survey area

In the south-western corner of the survey, the Kent system covers the alluvial plains and gentle gravelly rises surrounding the headwaters of the Kent River. Small lakes and swamps are also scattered across the area.

**Parent materials:** The area is dominated by alluvium and colluvium with areas of sand which commonly contains iron pisoliths and overlying laterite. These are interspersed with laterite, mainly featured on low rises and plains.

**Native vegetation:** Kwornicup Vegetation System (Beard 1981). A mosaic with jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) low forest being dominant, mixed with yate (*E. cornuta*), flat-topped yate (*E. occidentalis*) and wandoo (*E. wandoo*). Paperbark (*Melaleuca cuticularis*) low forest and flat-topped yate are more prominent in wet areas with reed swamps.

**Land use:** The main land use of the area is wool and sheep production and, to a lesser extent, the breeding of beef cattle. Pastures generally have a relatively long annual phase (3–8 years) rotationally grazed with cereal crops, mainly oats, barley, wheat, canola, lupins and field peas. There are small areas of horticulture and viticulture as well, and more recently bluegum plantations have been established. Waterlogging can be severe in lower parts of the landscape in this system and salinity is a common sight, often associated with waterlogged valley floors and depressions in the landscape.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camballup Subsystem</td>
<td>Swampy plain with lunettes and low rises</td>
<td>Semi-wet soil, Pale deep sand, Wet soil, Saline wet soil, Other soils</td>
<td>14, 12, 12, 12, 50</td>
</tr>
<tr>
<td>Plains phase (Ke_CMp)</td>
<td></td>
<td>(mainly Ironstone gravelly soils and Sandy duplexes)</td>
<td></td>
</tr>
<tr>
<td>(94 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camballup Subsystem</td>
<td>Lakes and swamps with lunettes</td>
<td>Wet soil, Semi wet soil, Saline wet soil, Other soils (mainly Ironstone</td>
<td>27, 25, 10, 38</td>
</tr>
<tr>
<td>Wet Phase (Ke_CMw)</td>
<td></td>
<td>gravelly soils and Deep sands)</td>
<td></td>
</tr>
<tr>
<td>(2,814 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mallawillup Subsystem</td>
<td>Broadly undulating low gravelly rises</td>
<td>Duplex sandy gravel</td>
<td>20</td>
</tr>
</tbody>
</table>
### TAMBELLUP-BORDEN LAND RESOURCES SURVEY

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform Description</th>
<th>Soils</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naypundup Subsystem downstream phase</td>
<td>Minor valleys of low relief</td>
<td>Grey deep sandy duplex</td>
<td>33</td>
</tr>
<tr>
<td>(Ke_NYd) (1,216 ha)</td>
<td></td>
<td>Duplex sandy gravel</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline wet soil</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (Wet soils and Ironstone gravelly soils)</td>
<td>30</td>
</tr>
<tr>
<td>Perillup Plain Subsystem</td>
<td>Very gently undulating plain</td>
<td>Duplex sandy gravel</td>
<td>14</td>
</tr>
<tr>
<td>(Ke_PP) (4,185 ha)</td>
<td></td>
<td>Wet soil</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils, Sandy duplexes and Ironstone gravelly soils)</td>
<td>65</td>
</tr>
</tbody>
</table>

*Perillup Plain Subsystem of the Kent System*
**Kokarinup System**

11,165 ha  
2.2% of the survey area

Gently undulating rises and gently undulating plains that are associated with the Pallinup river. Parts of the land system have been covered dunes and sandsheets that seem to have come from the main channel of the Pallinup River. The dune system is orientated in an east-west direction.

**Parent materials:** The dominant geology is colluvium with areas of alluvium and a significant proportion of this land system has been overlain with sandsheets and dunes. These areas of sand commonly contain iron pisoliths. This overlies gneiss bedrock of the Yilgarn Craton and isolated pockets of Eocene sediments.

**Native vegetation:** Pallinup Vegetation System (Beard 1981). Mallee vegetation is dominant, featuring a black marlock and hook-leaved mallee (*Eucalyptus redunca* and *E. uncinata*) association. Patches of low forest around winter wet depressions and swamps feature low forests of moort, open-fruited mallee and flat-topped yate (*E. platypus*, *E. annullata* and *E. occidentalis*). Areas of woodland occur in larger valleys featuring flat-topped yate and York gum (*E. loxophleba*) with some wandoo (*E. wandoo*). The sandy aeolian deposits are covered by York gum and swamp sheoak (*Casuarina obesa*).

**Land use:** Cereal cropping in rotation with sheep grazing clover-dominant pastures is the main land use. Some of the sand dune areas have been left as remnant vegetation or planted to tagasaste. The dunes that are high in the landscape are particularly prone to wind erosion and are difficult to manage because they only occupy small areas.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kokarinup 1</td>
<td>Gently undulating rises</td>
<td>Alkaline grey shallow sandy duplex, Alkaline grey deep sandy duplex, Grey deep sandy duplex, Other soils (mainly Deep sands and Sandy duplexes)</td>
<td>29, 21, 17, 33</td>
</tr>
<tr>
<td>Subsystem (Kb_1)</td>
<td>(550 ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kokarinup 2</td>
<td>Gently undulating valley slopes</td>
<td>Alkaline grey deep sandy duplex, Alkaline grey shallow sandy duplex, Grey deep sandy duplex, Other soils (mainly Loamy duplexes and Deep sands)</td>
<td>38, 17, 10, 35</td>
</tr>
<tr>
<td>Subsystem (Kb_2)</td>
<td>(6,090 ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kokarinup 3</td>
<td>Longitudinal dunes oriented mainly in an east–west direction, associated with the Pallinup River</td>
<td>Pale deep sand, Alkaline grey deep sandy duplex, Grey deep sandy duplex, Other soils (mainly Sandy duplexes)</td>
<td>41, 22, 14, 23</td>
</tr>
<tr>
<td>Subsystem (Kb_3)</td>
<td>(3,525 ha)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Alkaline grey deep sandy duplex soil in a patchy stubble paddock on a gentle rise in the Kokarinup System
Lower Pallinup System

1330 ha  0.3% of the survey area

Valley slopes of the lower Pallinup River where it dissects the siltstone and lateritic mantle of the Chillinup Plain. The cross-sectional profile of the river valley is mostly U-shaped.

**Parent materials:** The dominant geology is Pallinup siltstone underlain by Granitoid gneiss of the Albany–Fraser Orogen. The Pallinup River valley has cut through this profile and exposes the country rock on the stream bed.

**Native vegetation:** Pallinup Vegetation System (Beard 1981). Mallee vegetation is dominant, featuring a black marlock and hook-leaved mallee (*Eucalyptus redunca* and *E. uncinata*) association. Patches of low forest around winter wet depressions and swamps feature low forests of moort, open-fruited mallee and flat-topped yate (*E. platypus, E. annulata* and *E. occidentalis*). Areas of woodland occur in larger valleys featuring flat-topped yate and York gum (*E. loxophleba*) with some wandoo (*E. wandoo*).

**Land use:** The steep slopes have largely resulted in clearing for agriculture being restricted to the valley floor areas and lower slopes.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Pallinup 1 Subsystem</td>
<td>Level to very gently undulating plain and low rises blanketed by sandy aeolian deposits</td>
<td>Grey shallow sandy duplex, Pale deep sand, Duplex sandy gravel, Other soils (mainly Sandy duplex and Ironstone gravelly soils)</td>
<td>32, 25, 21, 22</td>
</tr>
<tr>
<td>(Lp_1) (931 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Pallinup 2 Subsystem</td>
<td>Dissected valley slopes and footslopes (includes some cliff faces and breakaways)</td>
<td>Grey shallow sandy duplex, Yellow/brown shallow sandy duplex, Duplex sandy gravel, Other soils (mainly Sandy and Loamy duplex soils with Bare rock and Stony soils)</td>
<td>17, 12, 10, 61</td>
</tr>
<tr>
<td>(Lp_2) (393 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Pallinup 3 Subsystem</td>
<td>Valley floors</td>
<td>Grey deep sandy duplex, Red deep loamy duplex, Grey shallow loamy duplex, Other soils (mainly Loamy duplex, Loamy earths, Wet soils and Deep sand)</td>
<td>28, 15, 12, 45</td>
</tr>
<tr>
<td>(Lp_3) (6 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Breakaways and valley slopes of the Lower Pallinup 2 Subsystem
Mabinup System 241Mb

6589 ha 1.3% of the survey area

Gently undulating plains with sluggish drainage into the Pallinup River. Large areas of this system are salt affected.

**Parent materials:** Colluvium and alluvium are dominant, overlying small pockets of Eocene sediments and adamellite and granitic bedrock which is largely obscured by residual and colluvial deposits. Small outcrops of sandstone are seen along creek beds.

**Native vegetation:** Pallinup Vegetation System (Beard 1981). Mallee vegetation is dominant, featuring black marlock (*Eucalyptus redunca*) and moort (*E. platypus*). Patches of low forest on plains and depressions with moort, open-fruited mallee and flat-topped yate (*E. platypus, E. annulata* and *E. occidentalis*) and areas of woodland occur in larger valleys featuring flat-topped yate and York gum (*E. loxophleba*) with some wandoor (*E. wandoor*). Sandy deposits are covered by York gum and swamp sheoak (*Casuarina obesa*). Remnants of flat-topped yate, wandoor, moort and swamp sheoak remain on salt-affected land. Often the soil is bare in these areas and any vegetation is generally salt-tolerant such as samphire (*Halosarcia* sp.) or introduced grasses such as barley grass (*Hordeum* spp.).

**Land use:** Salinity is the main constraint to agricultural land uses in this system. The salt-affected areas have mostly been fenced off from stock grazing and most crops cannot be grown. Some revegetation with salt-tolerant plants (e.g. saltbush, *Acacia saligna*) has been implemented to allow strategic grazing in the autumn. The areas of deeper sand on the valley floor are often planted with tagasaste. Areas that are not salt affected (Mb1 and Mb2) are suitable for cereal cropping and clover based pastures.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mabinup 1</td>
<td>Gravelly rises and breakaways</td>
<td>Shallow gravel</td>
<td>47</td>
</tr>
<tr>
<td>Mb_1</td>
<td>(320 ha)</td>
<td>Duplex sandy gravel</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alkaline grey shallow sandy duplex</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy and Loamy duplex soils)</td>
<td>12</td>
</tr>
<tr>
<td>Mabinup 2</td>
<td>Linear dunes above the salt-affected areas</td>
<td>Pale deep sand</td>
<td>66</td>
</tr>
<tr>
<td>Mb_2</td>
<td>(510 ha)</td>
<td>Alkaline grey deep sandy duplex</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex sandy gravel</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alkaline grey shallow sandy duplex</td>
<td>4</td>
</tr>
<tr>
<td>Mabinup 3</td>
<td>Slightly saline and waterlogged areas</td>
<td>Alkaline grey shallow sandy duplex</td>
<td>24</td>
</tr>
<tr>
<td>Mb_3</td>
<td>(2,088 ha)</td>
<td>Saline wet soil</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semi wet soil</td>
<td>22</td>
</tr>
</tbody>
</table>
Other soils (mainly Alkaline loamy and sandy duplex soils) 31

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Description</th>
<th>Area (ha)</th>
<th>Soil Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mabinup 4</td>
<td>Wide saline valley floors and flanking valley slopes</td>
<td>3,672</td>
<td>Saline wet soil</td>
<td>60</td>
</tr>
<tr>
<td>Mb _4</td>
<td></td>
<td></td>
<td>Semi wet soil</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Salt-lake soil</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other soil (mainly Sandy duplexes)</td>
<td>15</td>
</tr>
</tbody>
</table>

A paddock in the Mabinup System with poorly structured Alkaline shallow loamy duplex soil
Mooliup System

13,056 ha 2.6% of the survey area

An area characterised by aeolian dunes and sandsheets in the vicinity of Tambellup where sand was blown out of the bed of the Gordon River across the undulating terrain to the east.

**Parent materials:** The dominant geology is colluvium and alluvium overlying adamellite and granitic bedrock with small pockets of Eocene sediments. A large proportion of this land system is overlain by dunes and sandsheets.

**Native vegetation:** Tambellup Vegetation System (Beard 1981). Woodlands dominated by wandoo (Eucalyptus wandoo) associated with flat-topped yate (E. occidentalis). Sandy areas feature wandoo with scattered patches of heath. Sandy valley flats are dominated by wandoo, and clay flats are predominantly flat-topped yate.

**Land use:** Rotational cropping is dominant with a relatively long annual pasture phase (3–8 years) in rotation with cereal crops (oats, barley or wheat), canola or less often lupins and field peas. Minor valley floors are not cropped and often remain vegetated while the major valley floors are occasionally cropped with oats. Areas of dunes are often protected from wind erosion by pasture cover, and more recently planted with tagasaste and Pinus pinaster plantations. Rising saline groundwater tables pose a threat to agricultural land uses in some low-lying areas.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
</table>
| Mooliup 1 Subsystem (Mp_1) (232 ha) | Hillcrests and upper slopes           | Grey deep sandy duplex  
Duplex sandy gravel  
Deep sandy gravel  
Other soils (mainly Ironstone gravelly soils and Deep sands) | 42  
28  
9  
21 |
| Mooliup 2 Subsystem (Mp_2) (6,363 ha) | Gently undulating broad rises         | Grey deep sandy duplex  
Duplex sandy gravel  
Grey shallow sandy duplex  
Other soils (mainly Deep sands and Ironstone gravelly soils) | 37  
18  
16  
29 |
| Mooliup 3 Subsystem (Mp_3) (4,320 ha) | Linear dunes oriented in NW–SE direction | Pale deep sand  
Grey deep sandy duplex  
Grey shallow sandy duplex  
Other soils (mainly Wet soils) | 55  
29  
7  
9 |
| Mooliup 4 Subsystem (Mp_4) | Swampy plains | Grey deep sandy duplex  
Pale deep sand | 26  
19 |
<table>
<thead>
<tr>
<th>Area Description</th>
<th>Soil Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,413 ha)</td>
<td>Grey shallow sandy duplex, Other soils (mainly Wet soils)</td>
<td>16, 39</td>
</tr>
<tr>
<td>Mooliup 5 Subsystem (Mp _5) (728 ha)</td>
<td>Grey deep sandy duplex, Saline wet soil, Grey shallow sandy duplex, Other soils (mainly Wet soils and Deep sands)</td>
<td>29, 24, 21, 26</td>
</tr>
</tbody>
</table>

*Pale deep sand on a dune swale in the Mooliup System*
North Stirlings System

59,440 ha  11.6% of the survey area

A level to gently undulating alluvial plain dominates the western central region of the survey to the north of the Stirling Range. It is an internally drained basin featuring numerous scattered salt lakes and associated dune ridges of fringing lunettes.

**Parent materials:** The basin is comprised of unconsolidated sediments, largely mixed alluvium and lake and swamp deposits with sand dunes, marginal to the lakes and gypseriferous in areas. This is surrounded by slightly elevated areas dominated by alluvium and colluvium. The area is underlain by Eocene sediments of the Plantagenet Group with a basement of crystalline rocks.

**Native vegetation:** Qualup and Tambellup Vegetation Systems (Beard 1981). Woodlands of wandoo (*Eucalyptus wandoo*) associated with flat-topped yate (*E. occidentalis*) are more prominent in western areas of the system, merging to the mallee-heath formation featuring elsewhere, dominated by blue mallee (*Eucalyptus tetragona*). Sandy areas feature scrub heath dominated by chittick (*Lambertia inermis*) which replaces the mallee. Flat-topped yate is associated with loamy areas around lakes or swampy depressions, and redheart is more common (*E. decipiens*) in sandy depressions.

**Land use:** Dominant mixed cereal grain (mainly barley, oats and wheat) and sheep production. There are also some piggeries and a small number of beef cattle in the area. Additionally, the area features numerous Flora and Fauna Conservation Reserves, mostly around lakes. Farming in much of this area has been hindered by rapidly rising saline groundwater tables which pose the greatest threat to agricultural land uses in the area. Waterlogging and soil structure decline are also common problems.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Stirlings 1 Subsystem</td>
<td>Basin floor with salt lakes, lunettes and saline flats</td>
<td>Alkaline grey deep sandy duplex, Grey deep sandy duplex, Saline wet soil, Other soils (mainly Wet soils and Sandy duplexes)</td>
<td>20 15 13 52</td>
</tr>
<tr>
<td>(Nt_1) (37,322 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Stirlings 2 Subsystem</td>
<td>Lower slopes above basin floor</td>
<td>Alkaline grey shallow sandy duplex, Grey deep sandy duplex, Grey shallow sandy duplex, Other soils (mainly Ironstone gravelly soils, Wet soils and Sandy duplexes)</td>
<td>19 19 12 50</td>
</tr>
<tr>
<td>(Nt_2) (16,269 ha)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Stirlings 3 Subsystem</td>
<td>Undulating low rises above the surrounding alluvial plain</td>
<td>Grey deep sandy duplex, Grey shallow sandy duplex</td>
<td>26 23</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Area (ha)</td>
<td>Landform Characteristics</td>
<td>Soils</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>--------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>(Nt _3)</td>
<td>(182)</td>
<td>Alkaline grey shallow sandy duplex</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplexes and Ironstone gravelly soils)</td>
<td>32</td>
</tr>
<tr>
<td>North Stirlings 4 Subsystem</td>
<td>(Nt _4)</td>
<td>Large lunettes on margins of salt lakes</td>
<td>Pale deep sand</td>
</tr>
<tr>
<td></td>
<td>(4,948)</td>
<td></td>
<td>Grey deep sandy duplex</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Brown sandy earth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Semi-wet soil</td>
</tr>
<tr>
<td>North Stirlings 5 Subsystem</td>
<td>(Nt _5)</td>
<td>Sandsheets on the basin floor</td>
<td>Grey deep sandy duplex</td>
</tr>
<tr>
<td></td>
<td>(719)</td>
<td></td>
<td>Pale deep sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alkaline grey deep sandy duplex</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alkaline grey shallow sandy duplex</td>
</tr>
<tr>
<td>North Stirlings 6 Subsystem</td>
<td>(Nt _6)</td>
<td>Salt lakes and swamps with minor fringing lunettes</td>
<td>Salt-lake soil</td>
</tr>
<tr>
<td></td>
<td>(10,566)</td>
<td></td>
<td>Alkaline grey deep sandy duplex</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Saline wet soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplexes)</td>
</tr>
</tbody>
</table>

Salt-affected land with patchy barley grass (Hordeum sp.) pasture in the North Stirlings 1 Subsystem.
**Stirling Range System**

120,746 ha  
23.7% of the survey area

Undulating low hills to steep mountains of the Stirling Range which dominates the landscape in the southern half of the survey.

**Parent materials:** Sandstone and shale meta-sediments. Outcrops are common on the mountain peaks with colluvial soils occurring on the slopes. Laterisation has occurred on the lower slopes and plains of this system.

**Native vegetation:** Stirling Range and Qualup Systems (Beard 1981). The mountain summits feature a mixed thicket with no clear dominant species, grading to mallee-heath vegetation of the slopes dominated by mallee-form jarrah (*Eucalyptus marginata*). This merges to a jarrah low woodland on the footslopes, combined with marri (*Corymbia calophylla*) in valleys. Mallee-heath or mixed scrub heath surrounds the range, dominated by blue mallee (*E. tetragona*). A high degree of endemism is a feature on isolated peaks.

**Land use:** A large proportion of this system is included in the Stirling Range National Park. There is some land under agriculture in this system to the north of the national park, mainly in the St3, St4, and St6 subsystems. This land is mostly under clover-dominant pastures in rotation with cereal cropping. Some areas of lucerne have also been established in recent years.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stirling Range 1 Subsystem (St_1) (5,857 ha)</td>
<td>Ridge crests, peaks and talus slopes</td>
<td>Bare rock, Stony soil</td>
<td>70, 30</td>
</tr>
<tr>
<td>Stirling Range 2 Subsystem (St_2) (23,005 ha)</td>
<td>Upper slopes and ridge crests</td>
<td>Stony soil, Duplex sandy gravel, Bare rock, Other soils (mainly Ironstone gravelly soils)</td>
<td>72, 9, 5, 14</td>
</tr>
<tr>
<td>Stirling Range 3 Subsystem (St_3) (57,722 ha)</td>
<td>Lower to upper slopes and crests of undulating hills and rises</td>
<td>Stony soil, Duplex sandy gravel, Grey deep sandy duplex, Other soils (mainly Ironstone gravelly soils, Sandy duplexes and Deep sands)</td>
<td>22, 22, 15, 41</td>
</tr>
<tr>
<td>Stirling Range 4 Subsystem (St_4)</td>
<td>Gently undulating footslopes of the range</td>
<td>Grey deep sandy duplex, Grey shallow sandy duplex, Duplex sandy gravel</td>
<td>31, 19, 17</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Area (ha)</td>
<td>Soils Description</td>
<td>Code</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------</td>
<td>------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Stirling Range 5 Subsystem (St_5)</td>
<td>(633)</td>
<td>Sandsheets on lower slopes of the range</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pale deep sand</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alkaline grey deep sandy duplex</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Sandy duplexes and Deep sands)</td>
<td>26</td>
</tr>
<tr>
<td>Stirling Range 6 Subsystem (St_6)</td>
<td>(9,876)</td>
<td>Stream channels and flanking slopes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stony soil</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shallow gravel</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pale deep sand</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils, Sandy duplexes, Shallow sands and Loamy earths.)</td>
<td>40</td>
</tr>
</tbody>
</table>

The diverse flora and rugged abruptness of the Stirling Range National Park attracts many tourists to the area.
**Tambellup-Borden Land Resources Survey**

**Toompup System**

31,882 ha 6.2% of the survey area

Gently undulating plains to gently undulating rises drained by Warperup and Peenebup creeks. The drainage divides are dominated by large, level to gently undulating plains.

**Parent materials:** The system is characterised by sandy surfaced colluvium, commonly with ironstone gravel. This overlies the dominant bedrock of granitoid gneiss of the Yilgarn Craton. Dolerite dykes commonly intrude the area, interrupted by colluvium and islands of laterite.

**Native vegetation:** Pallinup Vegetation System (Beard 1981). Mallee vegetation is dominant, featuring a black marlock and hook-leaved mallee (*Eucalyptus redunca* and *E. uncinata*) association. Patches of merrit and blue mallet low forest (*E. flocktoniae* and *E. gardneri*) are common on gravelly uplands. Winter wet depressions and swamps feature low forests of moort, open-fruited mallee and flat-topped yate (*E. platypus, E. annulata* and *E. occidentalis*). Areas of woodland occur in larger valleys, featuring flat-topped yate and York gum (*E. loxophleba*) with some wandoo (*E. wandoo*). Sandy deposits are covered by York gum and swamp sheoak (*Casuarina obesa*).

**Land use:** The soils in this system are mainly used for cereal cropping in rotation with legume pastures. Areas of deeper sand are better suited to perennials such as tagasaste or *Pinus pinaster* plantations. The sandy topsoils that dominate this system are prone to wind erosion, so care needs to be taken with respect to cultivation practices and stocking rates. Many of the known gravel reserves for road building are found in this system.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toompup 1 Subsystem (Tm_1) (1,600 ha)</td>
<td>Broad upland plain consisting of slopes and flats</td>
<td>Shallow gravel&lt;br&gt;Grey shallow sandy duplex&lt;br&gt;Grey deep sandy duplex&lt;br&gt;Other soils (mainly Ironstone gravelly soils)</td>
<td>45&lt;br&gt;25&lt;br&gt;15&lt;br&gt;15</td>
</tr>
<tr>
<td>Toompup 2 Subsystem (Tm_2) (17,755 ha)</td>
<td>Mid to upper slopes and level to gently undulating plain areas high in the landscape</td>
<td>Grey deep sandy duplex&lt;br&gt;Duplex sandy gravel&lt;br&gt;Grey shallow sandy duplex&lt;br&gt;Other soils (mainly Sandy duplexes and Ironstone gravelly soils)</td>
<td>30&lt;br&gt;15&lt;br&gt;15&lt;br&gt;40</td>
</tr>
<tr>
<td>Toompup 2 sandy phase</td>
<td>Sandsheets</td>
<td>Pale deep sand</td>
<td>80</td>
</tr>
<tr>
<td>Subsystem</td>
<td>Slope Characteristics</td>
<td>Soils</td>
<td>Percentage</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>Toompup 3</td>
<td>Slopes of gently undulating rises</td>
<td>Grey deep sandy duplex, Alkaline grey shallow loamy duplex, Alkaline grey deep sandy duplex, Other soils (mainly Sandy and Loamy duplexes, Cracking and Non-cracking clays)</td>
<td>20, 20, 15, 45</td>
</tr>
<tr>
<td>Toompup 4</td>
<td>Drainage lines and upper tributaries of the Pallinup River</td>
<td>Saline wet soil, Alkaline grey deep sandy duplex, Alkaline grey shallow sandy duplex, Other soils (mainly Sandy and loamy duplexes Deep sands and Sandy earths)</td>
<td>20, 20, 15, 45</td>
</tr>
</tbody>
</table>

Gently undulating upland sandy plain of the Toompup 2 Subsystem.
**Upper Kalgan System**

12,771 ha  
2.5% of the survey area

Undulating sandplain surrounding the upper Kalgan River to the south-east of the Stirling Range. This is interrupted by broad drainage lines and low rounded hills.

**Parent materials:** The dominant geology is deeply weathered siltstone underlain by granitoid gneiss of the Albany–Fraser Orogen which outcrops sporadically.

**Native vegetation:** Kendenup and Qualup Vegetation Systems (Beard 1981). Dominantly a mixed woodland featuring jarrah (*Eucalyptus marginata*) combined with marri (*Corymbia calophylla*) and wandoo (*E. wandoo*). Lower slopes and depressions feature flat-topped yate (*E. occidentalis*) and redheart (*E. decipiens*).

**Land use:** Clover-dominant pastures and lupins are rotated with cereals (mostly barley). Canola has recently grown in importance as a profitable rotation. Minimum tillage and lower stocking rates have proven to be important in protecting the fine sandy topsoils. Tagasaste or *Pinus pinaster* plantations are often located on areas of deep sand. Sheep are the dominant grazing animal with cattle becoming more common in areas closer to the coast.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
</table>
| Pillenorup Subsystem (Uk_PN) (855 ha) | Isolated hills of granite with a fringe of sedimentary rocks | Grey deep sandy duplex  
Duplex sandy gravel  
Grey shallow sandy duplex  
Other soils (mainly Rocky or stony soils and Sandy duplexes) | 49  
20  
15  
16 |
| Takalarup Subsystem (Uk_TK) (10,503 ha) | Flat to broadly undulating plain with small swampy depressions and some sand dunes | Grey shallow sandy duplex  
Shallow gravel  
Grey shallow loamy duplex  
Other soils (mainly Ironstone gravelly soils, Sandy duplexes and Wet soils) | 19  
13  
13  
55 |
| Woogenillup Subsystem Hillslope phase (Uk_WPh) (171 ha) | Flanking slopes of the upper Kalgan River valley | Grey shallow sandy duplex  
Duplex sandy gravel  
Grey deep sandy duplex  
Other soils (mainly Rocky or stony soils, Wet soils, Ironstone gravelly soils and Loamy duplexes) | 22  
15  
15  
48 |
| Woogenillup | Saline valley floor of upper | Saline wet soil | 55 |
The flat to gently undulating plains of the Takalarup Subsystem meets the southern slopes of the Stirling Range.
**Upper Pallinup System**

107,765 ha  
21.1% of the survey area

Gently undulating and undulating rises drained by the upper reaches of the Pallinup River. Dolerite and gabbro dykes are common on the valley slopes.

**Parent materials:** Granite of the Yilgarn Craton that has been exposed on some of the valley slopes. Small areas of lateritic materials occur at high points in the landscape. Dolerite and gabbro dykes are common.

**Native vegetation:** Pallinup and Chidnup Vegetation Systems (Beard 1981). Mallee vegetation is dominant here featuring a black marlock and hook-leaved mallee (Eucalyptus redunca and E. uncinata) association. Patches of merrit and blue mallet low forest (E. flocktoniae and E. gardneri) are common on gravelly uplands and around winter wet depressions and swamps feature low forests of moort, open-fruited mallee and flat-topped yate (E. platypus, E. annulata and E. occidentalis). Areas of woodland occur in larger valleys featuring flat-topped yate and York gum (E. loxophleba) with some wandoo (E. wandoo). Sandy deposits are covered by York gum and swamp sheoak (Casuarina obesa).

**Land use:** Cropping in rotation with annual pastures is the main land use. Common crops include what, barley, oats, canola and field peas. Many merino stud properties are located in this system. Some steeper slopes are susceptible to water erosion. Salinity is developing on the lower valley slopes and drainage lines.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
</table>
| **Upper Pallinup 1 Subsystem (Up_1)** (3,167 ha) | Crests and upper slopes | Duplex sandy gravel  
Alkaline grey shallow sandy duplex  
Shallow gravel  
Other soils (mainly Sandy duplexes and Ironstone gravelly soils) | 30  
15  
15  
40 |
| **Upper Pallinup 1 Subsystem sandy phase (Up _1s)** (67 ha) | Aeolian and colluvial sand deposits on upper to mid slopes | Gravelly pale deep sand  
Pale deep sand  
Pale shallow sand | 70  
20  
10 |
| **Upper Pallinup 2 Subsystem (Up _2)** (49,849 ha) | Lower, middle and upper slopes and broad hillcrests | Grey shallow sandy duplex  
Alkaline grey shallow sandy duplex  
Alkaline grey shallow loamy duplex  
Other soils (mainly Sandy and Loamy duplexes, Cracking and Non-cracking clays) | 24  
17  
12  
47 |
| Upper Pallinup 3 Subsystem (Up _3) (45,911 ha) | Lower to upper slopes, crests and minor drainage depressions associated with shallow granite and dolerite | Bare rock <br> Alkaline grey shallow sandy duplex <br> Alkaline grey shallow loamy duplex <br> Other soils (mainly Sandy and Loamy duplexes, Cracking and Non-cracking clays) | 15 <br> 15 <br> 15 <br> 55 |
| Upper Pallinup 4 Subsystem (Up _4) (2,331 ha) | Lower slopes, footslopes and flats | Grey shallow sandy duplex <br> Alkaline grey shallow loamy duplex <br> Alkaline grey shallow sandy duplex <br> Other soils (mainly Ironstone gravelly soils and Wet soils) | 32 <br> 30 <br> 20 <br> 18 |
| Upper Pallinup 5 Subsystem (Up _5) (4,532 ha) | Valley flats (100–300 m wide) with steam channels and some lower slopes | Saline wet soil <br> Alkaline grey shallow sandy duplex <br> Pale deep sand <br> Other soils (mainly Deep sands and Sandy duplex soils) | 50 <br> 15 <br> 10 <br> 25 |
| Upper Pallinup 6 Subsystem (Up _6) (1,976 ha) | Valley flats and narrow alluvial plains (300–1500 m wide) | Alkaline grey shallow sandy duplex <br> Grey deep sandy duplex <br> Alkaline grey shallow loamy duplex <br> Other soils (mainly Deep sands, Wet soils and Sandy duplexes) | 20 <br> 20 <br> 20 <br> 40 |

Looking uphill towards a gravelly crest in the Upper Pallinup System
Yaraleena System

1383 ha 0.3% of the survey area

On the western edge of the survey, the Yaraleena System features weakly dissected lateritic terrain on broadly undulating rises and long slopes.

**Parent materials:** The geology is dominated by laterite, both massive and pisolithic. Colluvium is more common in lower-lying areas of the system. The granitic basement rock is largely obscured by the overlying weathered mantle.

**Native vegetation:** Kendenup Vegetation System (Beard 1981). Dominantly a mixed woodland featuring jarrah (*Eucalyptus marginata*) combined with marri (*Corymbia calophylla*) and wandoo (*E. wandoo*). Lower slopes and depressions feature flat-topped yate (*E. occidentalis*) and redheart (*E. decipiens*).

**Land use:** Rotational cropping is dominant with a relatively long annual pasture phase (3–8 years) in rotation with cereal crops (oats, barley or wheat), canola or less often lupins. Minor valley floors are not cropped and often remain vegetated while the major valley floors are occasionally cropped with oats. Waterlogging and areas of salinity are common on valleys and lower-lying terrain.

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Landform description</th>
<th>Dominant soils</th>
<th>Proportion of subsystem (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yaraleena 1 Subsystem</td>
<td>Crests and upper slopes</td>
<td>Duplex sandy gravel</td>
<td>26</td>
</tr>
<tr>
<td>(Ya_1) (583 ha)</td>
<td></td>
<td>Yellow/brown deep sandy duplex</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Ironstone gravelly soils, Sandy and Loamy duplexes)</td>
<td>41</td>
</tr>
<tr>
<td>Yaraleena 2 Subsystem</td>
<td>Lower to upper smooth slopes</td>
<td>Duplex sandy gravel</td>
<td>30</td>
</tr>
<tr>
<td>(Ya_2) (703 ha)</td>
<td></td>
<td>Grey deep sandy duplex</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loamy gravel</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Ironstone gravelly soils and Sandy duplexes)</td>
<td>40</td>
</tr>
<tr>
<td>Yaraleena 3 Subsystem</td>
<td>Minor valleys including poorly drained drainage depressions</td>
<td>Duplex sandy gravel</td>
<td>31</td>
</tr>
<tr>
<td>(Ya_3) (98 ha)</td>
<td>(often saline), footslopes and flanking lower slopes</td>
<td>Grey deep sandy duplex</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semi-wet soil</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other soils (mainly Wet soils, Ironstone gravelly soils and Deep sands)</td>
<td>35</td>
</tr>
</tbody>
</table>
Ironstone gravelly soils and jarrah-marri low forest are characteristic features of the Yaraleena System.
Soils

The soils described for this survey are presented at varying levels of detail to cover differing requirements of information:

- **General soil descriptions** give a broad understanding of the soils found across the Soil-landscape systems of the survey area.

- **WA Soil Group and Supergroup** classifications (Schoknecht 2002) are slightly more detailed. They are used as a way of communicating the common soils of the state and are defined by attributes such as texture and the change in texture with depth, water regime, colour, presence of coarse fragments, and alkalinity/acidity.

- **Australian Soil Classification** (Isbell 2002) is a detailed hierarchical system of soil classification which is nationally and internationally recognised. The relationship between the Australian Soil Classification and WA Soil Groups is presented in Table 7.

- **Soil Series** are used when the most detailed descriptions of soils are required. They are closely linked to the Australian Soil Classification and are primarily for technical or research-related uses. The relationship between Soil Series and WA Soil Groups is summarised in Table 8.

### General soil descriptions

The dominant soils described in the survey are sandy duplexes. These mainly have pale grey topsoils and yellow, or less commonly grey or brown, mottled clay subsoils which are usually sodic. Deep sandy duplex soils (sand over clay at 30–80 cm) are seen more frequently, and these often have a layer of ironstone gravel above the clay.

Ironstone gravelly soils are the next most widespread soil type found. Pale (often bleached) gravelly sand over yellow or grey mottled clay is most common. These are mainly found on hillslopes and well-drained plains. Shallow gravels, with a loose ironstone gravel layer over a dense cemented ironstone pan, are often seen on crests and upper slopes or on poorly drained flats.

In the north of the survey, the soils of the systems overlying the crystalline Yilgarn Craton are predominantly sandy duplexes. The systems of the Southern Zone of Rejuvinated Drainage—**Carrolup, Moolup** and **Gordon Flats**—show the dominance of sandy duplex soils on upper to lower slopes. Here they exhibit mainly grey and yellow mottled sodic subsoils in deeper duplex soils and brown subsoils are more dominant in shallower duplexes. Duplex gravels are seen frequently on upper to mid-slope positions with bleached gravelly topsoils over yellow subsoils. Waterlogged soils and sometimes saline soils are seen here, especially in valley floors, lower slopes and alluvial plains. These are poorly structured sodic duplex soils, with grey mottled and often ironstone gravelly subsoils.

To the east is the Pallinup Zone, including the **Upper Pallinup, Toompup, Hydenup, Kokarinup, Dedatup** and **Mabinup** systems. Again, deep and shallow sandy duplex soils over yellow clays are widespread on mid to upper slopes, but brown subsoils are more commonly seen here than in other areas. Again the subsoils are sodic, generally mottled, and sometimes feature an ironstone gravel layer above the clay. Red subsoils are also more
frequently seen in this zone due to the presence of dolerite dykes across the area and also the prominence of shallow granitic bedrock. This is particularly the case in the Dedatup system which has a higher proportion of red and brown (sometimes calcareous) subsoils and loamy and clay topsoils than other systems. Ironstone gravelly soils are usually present in upper parts of the landscape in this zone and on gently undulating upland plains. Again, they appear mainly as pale gravels over yellow mottled clay subsoils, and may be either sodic or non-sodic. Wet soils and particularly salt-affected soils are widespread in some areas here as well. The Mabinup system especially has a high proportion of saline soils, which are generally sodic and often highly calcareous. The Upper Pallinup system also has large areas of its valley floors affected. Deep sands also feature prominently across this zone, particularly in the Hydenup and Kokarinup systems. This is generally deep bleached sand or bleached sand which grades to yellow sand at depth, sometimes with gravel in lower horizons.

The Stirling Range Zone, including the Stirling Range, North Stirlings and Jaffa systems, has distinctly different landscapes and parent materials to those seen to the north. The sandstone and shale geology of the Stirling Range features prominently in the peaks and upper slopes of the mountains, where very rudimentary soil formation has occurred. Here the surface consists largely of bare rock and scree or talus slopes. Upper slopes and crests of lower hills surrounding the peaks often display more soil development, but still feature large amounts of stones through the generally sandy to loamy duplex soils. On hill slopes, ironstone gravels become more prominent, with the gravels being distinct by appearing coarse, with many sand grains. Stony subsoils in many of these areas can appear as various shades of dark pink to brown, reflecting the influences of the parent material.

Mid to lower hillslopes of the range can feature duplex soils, frequently with bleached sandy topsoils over yellow or brown mottled clay subsoils. Grey subsoils are more dominant in lower slopes. Deep bleached sands occur in patches on lower hillslopes of the range, often associated with drainage lines or foothills. In some positions, a shallow cemented ironstone layer is found beneath the pale sandy surface. Alluvial flats close to drainages descending the range are dominated by loamy earths generally with brown subsoils.

The North Stirlings system features mainly duplex soils which are frequently sandy, alkaline and sodic. Clays generally appear between 30-80 cm but are often much shallower than 20 cm. A dense layer of ironstone gravel is regularly seen above the clay. Wet soils feature widely in this landscape. Waterlogging is widespread and the effects of salinity are common in many paddocks on the basin floor. Subsoil clays of the basin floor area are poorly structured and predominantly grey, suggesting frequent interactions with the watertable. In slightly elevated areas surrounding the valley floors, subsoils of the sandy duplex soils become dominantly yellow and are often mottled. Deep bleached sands are seen across the plain, generally associated with the many lakes occurring here. The sands are often in the form of lunettes on the south-eastern lake fringes, although in some cases, these can be quite loamy in texture.

The soils of the Jaffa system are influenced by its underlying crystalline geology that distinguishes it from the surrounding landscape. Areas of rock outcrop and shallow bedrock are associated with loamier soils, while sandy duplexes are associated with brown, yellow and grey mottled subsoils. Ironstone gravels are common on mid to upper slope and crest positions. These are mainly duplex with grey mottled subsoils. In some areas of the slopes, the gravel is bleached and very shallow, over a ferricrete pan. The lower-lying regions of the system near Cranbrook have mainly grey sodic subsoils, also affected by waterlogging and salinity in some cases.
In the south-western corner of the study area is the Warren Denmark Southland Zone which is formed on the Albany–Fraser Orogen. The **Yaraleena** and **Kent** systems are dominated by ironstone gravelly soils. On the undulating uplands duplex gravels are common, with yellow or grey mottled sodic and non-sodic clay subsoils. Grey clay subsoils are more widespread on the soils of the plains, generally beneath bleached sandy gravel topsoils. Shallow gravels are also widespread on mid to upper slopes here, with a layer of very gravelly sand over a cemented ironstone pan, generally at 20 to 50 cm below the surface. Wet soils are widespread, particularly in the **Kent** system. These are often associated with shallow gravels on cemented ‘bog iron ore’ pans and the many lakes and wetlands which are part of this landscape. Bleached deep sands are found throughout, generally with some gravel and a deep grey clay subsoil at greater than 80 cm.

The **Upper Kalgan**, **Chillinup** and **Lower Pallinup** systems are part of the Albany Sandplain Zone which is in the south of the survey area. The plains here are dominated by sandy topsoils, often gravelly and commonly bleached, over mainly yellow sodic and mottled subsoils. Bleached deep sands are more prominent in the eastern area of the sandplain, sometimes associated with lakes, and often have gravel at depth. Duplex gravels are also common on the sandplains, with similar subsoil clays. Siltstone and granitic basement rock outcrop on the **Lower Pallinup** system valley slopes, fringed by lateritic breakaways which are remnants of the undulating upland sandplain. In the western area, which is more influenced by the Young River and its tributaries, shallow sandy and loamy duplex soils are more frequent, generally with yellow sodic subsoils, again often with gravel over the clay. Impacts from rising watertables are apparent in some parts of the **Upper Kalgan** system, with Saline wet soils occurring mainly on poorly drained sodic soils. Across the whole area, Yate swamps and low, swampy depressions often feature Wet and Semi-wet soils in their vicinity. The lakes, which are more prominent in the **Chillinup** system, have Salt-lake soils.
Shallow sandy duplex are widespread, often with yellow or grey sodic subsoils.

Deep sandy duplex soils are common, often with yellow mottled clay subsoils.

Sandy duplex soils often display a gravel horizon above the clay.

Duplex sandy gravel is seen frequently on upper and mid-slope positions.

Four common soils in the survey area.
WA Soil Groups and Supergroups

Within the Tambellup–Borden survey, 43 WA Soil Groups (Schoknecht 2002) have been identified, falling within 12 of the 13 supergroups. The soil supergroups and groups, their interpreted areas and percentage of the survey area are listed in Table 5.

As previously discussed, the most common supergroup in the survey is the Sandy duplexes, occupying 38 per cent of the area, followed by Ironstone gravelly soils (18%), Loamy duplexes (11%) and Wet or waterlogged soils (11%). The most common individual soil group occurring across the survey is Grey deep sandy duplex (15%). Grey shallow sandy duplex soils are also widespread, often with alkaline subsoils. The next most common individual soil group across the survey is Duplex sandy gravel (11%).

Other significant soil groups include Stony soil (6%), Saline wet soil (4%), Shallow gravels (4%) and Alkaline grey shallow loamy duplex soils (4%).

There were some trends apparent in the soils across the survey area from west to east. On the western half of the survey, Wet soil, Semi-wet soil and Shallow gravel are more predominant. On the eastern half, however, more Pale deep sand, Deep sandy gravel, Alkaline grey deep and shallow sandy duplex soils were recorded. The remaining soils occurred equally across the whole area.

Where insufficient data is available, it has not always been possible to attribute Soil Groups to the mapping units in the survey. In some cases, the Supergroup has been used and in others the soils have been described as Undifferentiated soil and fall within the Miscellaneous Supergroup.
Table 5 **Areas of WA Soil Groups and percentage of the survey area**

<table>
<thead>
<tr>
<th>Supergroup</th>
<th>WA Soil Group</th>
<th>Total (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grey deep sandy duplex</strong></td>
<td>Grey deep sandy duplex</td>
<td>75,800</td>
<td>15</td>
</tr>
<tr>
<td><strong>Grey shallow sandy duplex</strong></td>
<td>Grey shallow sandy duplex</td>
<td>50,900</td>
<td>10</td>
</tr>
<tr>
<td><strong>Alkaline grey shallow sandy duplex</strong></td>
<td>Alkaline grey shallow sandy duplex</td>
<td>34,500</td>
<td>7</td>
</tr>
<tr>
<td><strong>Alkaline grey deep sandy duplex</strong></td>
<td>Alkaline grey deep sandy duplex</td>
<td>17,250</td>
<td>3</td>
</tr>
<tr>
<td><strong>Red shallow sandy duplex</strong></td>
<td>Red shallow sandy duplex</td>
<td>5,800</td>
<td>1</td>
</tr>
<tr>
<td><strong>Yellow/brown deep sandy duplex</strong></td>
<td>Yellow/brown deep sandy duplex</td>
<td>4,950</td>
<td>1</td>
</tr>
<tr>
<td><strong>Yellow/brown shallow sandy duplex</strong></td>
<td>Yellow/brown shallow sandy duplex</td>
<td>2,800</td>
<td>1</td>
</tr>
<tr>
<td><strong>Red deep sandy duplex</strong></td>
<td>Red deep sandy duplex</td>
<td>2,650</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sandy Duplexes</strong></td>
<td></td>
<td>194,600 ha</td>
<td>38%</td>
</tr>
<tr>
<td><strong>Ironstone Gravelly Soils</strong></td>
<td>Duplex sandy gravel</td>
<td>53,850</td>
<td>11</td>
</tr>
<tr>
<td><strong>Ironstone Gravelly Soils</strong></td>
<td>Shallow gravel</td>
<td>20,200</td>
<td>4</td>
</tr>
<tr>
<td><strong>Ironstone Gravelly Soils</strong></td>
<td>Loamy gravel</td>
<td>8,800</td>
<td>2</td>
</tr>
<tr>
<td><strong>Ironstone Gravelly Soils</strong></td>
<td>Deep sandy gravel</td>
<td>7,700</td>
<td>2</td>
</tr>
<tr>
<td><strong>Ironstone Gravelly Soils</strong></td>
<td></td>
<td>90,550 ha</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Alkaline grey shallow loamy duplex</td>
<td>20,200</td>
<td>4</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Grey shallow loamy duplex</td>
<td>12,100</td>
<td>2</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Yellow/brown shallow loamy duplex</td>
<td>7,900</td>
<td>2</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Alkaline red shallow loamy duplex</td>
<td>7,500</td>
<td>1</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Red shallow loamy duplex</td>
<td>3,400</td>
<td>1</td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Acid shallow duplex</td>
<td>1,750 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Brown deep loamy duplex</td>
<td>1,100 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Loamy Duplexes</strong></td>
<td>Red deep loamy duplex</td>
<td>1,000 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Wet or Waterlogged Soils</strong></td>
<td>Saline wet soil</td>
<td>19,650</td>
<td>4</td>
</tr>
<tr>
<td><strong>Wet or Waterlogged Soils</strong></td>
<td>Salt-lake soil</td>
<td>16,000</td>
<td>3</td>
</tr>
<tr>
<td><strong>Wet or Waterlogged Soils</strong></td>
<td>Semi-wet soil</td>
<td>11,150</td>
<td>2</td>
</tr>
<tr>
<td><strong>Wet or Waterlogged Soils</strong></td>
<td>Wet soil</td>
<td>7,600</td>
<td>1</td>
</tr>
<tr>
<td><strong>Wet or Waterlogged Soils</strong></td>
<td></td>
<td>54,400 ha</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Deep Sands</strong></td>
<td>Pale deep sand</td>
<td>38,200</td>
<td>7</td>
</tr>
<tr>
<td><strong>Deep Sands</strong></td>
<td>Brown deep sand</td>
<td>3,650</td>
<td>1</td>
</tr>
<tr>
<td><strong>Deep Sands</strong></td>
<td>Yellow deep sand</td>
<td>1,850 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Deep Sands</strong></td>
<td>Gravelly pale deep sand</td>
<td>950 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Deep Sands</strong></td>
<td>Red deep sand</td>
<td>100 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Rocky or Stony Soils</strong></td>
<td>Stony soil</td>
<td>29,800</td>
<td>6</td>
</tr>
<tr>
<td><strong>Rocky or Stony Soils</strong></td>
<td>Bare rock</td>
<td>12,450</td>
<td>2</td>
</tr>
<tr>
<td><strong>Shallow Sands</strong></td>
<td>Pale shallow sand</td>
<td>6,200</td>
<td>1</td>
</tr>
<tr>
<td><strong>Shallow Sands</strong></td>
<td>Yellow/brown shallow sand</td>
<td>1,450</td>
<td>1</td>
</tr>
<tr>
<td><strong>Shallow Sands</strong></td>
<td></td>
<td>7,650 ha</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Loamy Earths</strong></td>
<td>Brown loamy earth</td>
<td>3,900</td>
<td>1</td>
</tr>
<tr>
<td><strong>Loamy Earths</strong></td>
<td>Calcareous loamy earth</td>
<td>2,100 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Loamy Earths</strong></td>
<td>Friable red/brown loamy earth</td>
<td>700 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Loamy Earths</strong></td>
<td>Red loamy earth</td>
<td>10 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Non-cracking Clays</strong></td>
<td>Red/brown non-cracking clay</td>
<td>4,350</td>
<td>1</td>
</tr>
<tr>
<td><strong>Non-cracking Clays</strong></td>
<td>Grey non-cracking clay</td>
<td>2,000 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Cracking Clays</strong></td>
<td>Hard cracking clay</td>
<td>4,550</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cracking Clays</strong></td>
<td>Self-mulching cracking clay</td>
<td>1,100 &lt; 1</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous Soils</strong></td>
<td>No suitable group</td>
<td>1,500</td>
<td>&lt; 1</td>
</tr>
<tr>
<td><strong>Miscellaneous Soils</strong></td>
<td></td>
<td>1,500 ha</td>
<td>&lt; 1</td>
</tr>
<tr>
<td><strong>Sandy Earths</strong></td>
<td>Brown sandy earth</td>
<td>1,350</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>
Australian Soil Classification

The majority of the soil profiles studied during the survey were also classified using the Australian Soil Classification (Isbell 2002) to at least Soil Order. The ten Soil Orders found within the survey area are listed in Table 6. This also lists the WA Soil Groups found within each Soil Order and the area and the estimated proportion of the survey covered by each Soil Order.

The majority of the soils were Sodosols (41%) reflecting the dominance of sodic clay subsoils in the duplex soils surveyed. About 18 per cent of the survey has duplex soils with non-sodic clay subsoils (Chromosols).

Tenosols, with weakly developed horizons, are in approximately 16 per cent of the area and comprise a variety of soils including Ironstone gravelly soils as well as Deep and Shallow sands. Hydrosols represent about 11 per cent of the survey reflecting significant areas of Salt lake soils and Saline wet soils across the region. Rudosols, with minimal horizon development, are represented in 6 per cent of the survey area, largely represented by the dominance of Stony soils associated with the Stirling Range.

The remaining Soil Orders of the Australian Soil Classification occurring within the survey region are each seen in 2 per cent or less of the area. These include Dermosols, Kandosols, Vertosols, Calcarosols and Kurosols.

Red/brown subsoils are more common in the east of the survey, such as this profile from the Dedatup System

**WA Soil Group:** Yellow/brown shallow loamy duplex

**Australian Soil Classification:** Supracalcic Mesonic Brown Sodosol
Table 6 **Australian Soil Classification Orders in the survey area**

<table>
<thead>
<tr>
<th>Order (Suborder)</th>
<th>Description</th>
<th>WA Soil Groups</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcarsol</strong> (Hypercalcic, Calcic)</td>
<td>Calcareous soils lacking a marked texture contrast</td>
<td>Calcareous loamy earths</td>
<td>Very few</td>
</tr>
<tr>
<td><strong>Chromosol</strong> (Yellow, Grey, Brown)</td>
<td>Soils with a marked texture contrast, subsoils do not disperse</td>
<td>Duplex sandy gravel, Grey deep sandy duplex, Grey shallow sandy duplex, Red deep sandy duplex, Red shallow sandy duplex, Yellow/brown deep sandy duplex, Yellow/brown shallow sandy duplex, Red deep loamy duplex, Red shallow loamy duplex, Yellow/brown shallow loamy duplex</td>
<td>Common</td>
</tr>
<tr>
<td><strong>Dermosol</strong> (Brown, Grey, Yellow)</td>
<td>Soils with a structured subsoil lacking a marked texture contrast</td>
<td>Brown loamy earth, Friable red/brown loamy earth, Grey non-cracking clays, Red/brown non-cracking clays</td>
<td>Few</td>
</tr>
<tr>
<td><strong>Hydrosol</strong> (Redoxic, Salic)</td>
<td>Seasonally wet soils</td>
<td>Saline wet soil, Salt-lake soil, Wet soil, Semi-wet soil</td>
<td>Common</td>
</tr>
<tr>
<td><strong>Kandosol</strong> (Brown, Yellow)</td>
<td>Soils with massive subsoils, lacking a marked texture contrast</td>
<td>Loamy gravel, Brown sandy earth</td>
<td>Few</td>
</tr>
<tr>
<td><strong>Kurosol</strong> (Grey)</td>
<td>Soils with a marked texture contrast and strongly acid subsoil</td>
<td>Acid shallow duplex</td>
<td>Very few</td>
</tr>
<tr>
<td><strong>Rudosol</strong> (Arenic, Duric)</td>
<td>Soils with minimal profile development</td>
<td>Stony soils</td>
<td>Few</td>
</tr>
<tr>
<td><strong>Sodosol</strong> (Grey, Yellow, Brown, Red)</td>
<td>Soils with a marked texture contrast and dispersive, sodic subsoils</td>
<td>Alkaline grey shallow sandy duplex, Grey shallow sandy duplex, Grey deep sandy duplex, Duplex sandy gravel, Alkaline grey deep sandy duplex, Yellow/brown shallow sandy duplex, Yellow/brown deep sandy duplex, Red shallow sandy duplex Red deep sandy duplex, Alkaline grey shallow loamy duplex, Grey shallow loamy duplex, Alkaline red shallow loamy duplex, Red shallow loamy duplex, Yellow/brown shallow loamy duplex, Brown deep loamy duplex, Red deep loamy duplex</td>
<td>Many</td>
</tr>
<tr>
<td><strong>Tenosol</strong> (Bleached-Leptic, Leptic)</td>
<td>Weakly developed B horizons, lacking a marked texture contrast</td>
<td>Shallow gravel, Deep sandy gravel, Pale deep sand, Gravelly pale deep sand, Brown deep sand, Yellow deep sand, Pale shallow sand, Yellow/brown sand</td>
<td>Common</td>
</tr>
<tr>
<td><strong>Vertosol</strong> (Red, Black)</td>
<td>Clay soils which crack when dry</td>
<td>Hard cracking clay, Self-mulching cracking clay</td>
<td>Very few</td>
</tr>
</tbody>
</table>

Very few (< 2%); Few (2–10%); Common (10–20%); Many (20–50%), Abundant (50–90%) and Very abundant (> 90%)
Soil Series

A soil series is a taxonomic unit that defines soils with a narrow range of morphological, chemical, physical and mineralogical properties; it can be managed as a single unit for most present and anticipated land uses. Two categories of soil series are currently used in Western Australia: formal and informal (Schoknecht et al. 2004). This report describes the main 26 soil series occurring within the survey. Their descriptions are either at the formal level (for soils where the standardised criteria have been previously established) or the informal level (for soils where the standardised criteria is not complete).

One of the challenges of allocating soil series in this survey has been the variety of parent materials encountered. To overcome this, the soil series have been allocated according to the associated soil-landscape system. This is to better reflect the influences of the differing geological parent materials within the survey area and the resultant variations in soil development. Specifically, the soils of the Stirling Range have been treated as a discrete unit, and the systems to the north and south of the range have also been grouped accordingly. The main soil series, their associated WA Soil Group and the location of their main occurrence are outlined in Table 7. Full details of each soil series are provided on the following pages, set out in alphabetical order.

Table 7 Dominant Soil Series in the survey area

<table>
<thead>
<tr>
<th>SOIL GROUP</th>
<th>DOMINANT SOIL SERIES</th>
<th>MAIN ASSOCIATED SOIL-LANDSCAPE SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands over clays (duplex soils)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grey deep sandy duplex</td>
<td>Warup, Warup 1, Warup 4</td>
<td>Carrolup, Dedatup, Hydenup, Jaffa, Mooliup, Kokarinup, North Stirlings, Toompup, Gordon Flats</td>
</tr>
<tr>
<td></td>
<td>Tarwonga, Tarwonga 1</td>
<td>Carrolup, Dedatup, Hydenup, Kokarinup, Toompup, Gordon Flats</td>
</tr>
<tr>
<td></td>
<td>Indinup</td>
<td>Carrolup, Dedatup, Mooliup, North Stirlings, Toompup, Upper Pallinup, Gordon Flats</td>
</tr>
<tr>
<td></td>
<td>Byangerup, Byangerup 1</td>
<td>Stirling Range</td>
</tr>
<tr>
<td></td>
<td>Fleming, Fleming 2, Fleming 3</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
<tr>
<td>Grey shallow sandy duplex</td>
<td>Tarwonga 3</td>
<td>Carrolup, Dedatup, Hydenup, Kokarinup, Toompup, Gordon Flats</td>
</tr>
<tr>
<td></td>
<td>Warup3</td>
<td>Carrolup, Dedatup, Hydenup, Jaffa, Mooliup, Kokarinup, North Stirlings, Toompup, Gordon Flats</td>
</tr>
<tr>
<td></td>
<td>Indinup 1</td>
<td>Carrolup, Dedatup, Mooliup, North Stirlings, Toompup, Upper Pallinup</td>
</tr>
<tr>
<td></td>
<td>Byangerup 2</td>
<td>Stirling Range</td>
</tr>
<tr>
<td></td>
<td>Waychinicup, Waychinicup 1</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
<tr>
<td></td>
<td>Yilberup</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
<tr>
<td>Alkaline grey deep sandy duplex</td>
<td>Ballard, Ballard 2</td>
<td>North Stirlings, Toompup, Hydenup, Dedatup, Mabinup, Kybelup</td>
</tr>
<tr>
<td></td>
<td>Jaramlee 3</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
</tbody>
</table>
## Alkaline grey shallow sandy duplex

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairclough, Fairclough 1, Fairclough 2</td>
<td>Carrolup, Hydenup, Jaffa, Mabinup, Toompup, Upper Pallinup, Kokarinup</td>
</tr>
<tr>
<td>Ballard 1, Ballard 3, Ballard 4</td>
<td>North Stirlings, Toompup, Dedatup, Mabinup, Kokarinup</td>
</tr>
<tr>
<td>Jaramleec 2</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
</tbody>
</table>

## Ironstone gravelly soils

### Duplex sandy gravel

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lennard, Lennard 1, Lennard 2, Lennard 3, Lennard 4, Lennard 5, Lennard 6</td>
<td>Yaraleena, Kent, Carrolup, Dedatup, Hydenup, Jaffa, Mabinup, Mooliup, Kokarinup, North Stirlings, Toompup, Gordon Flats</td>
</tr>
<tr>
<td>Wahkinup, Wahkinup 1, Wahkinup 2</td>
<td>Hydenup, Toompup, North Stirlings, Mooliup, Carrolup</td>
</tr>
<tr>
<td>Ongarup</td>
<td>Stirling Range</td>
</tr>
<tr>
<td>Napier 1</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
</tbody>
</table>

### Shallow gravel

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorn 1, Gorn 2</td>
<td>Hydenup, North Stirlings, Kent, Carrolup</td>
</tr>
<tr>
<td>Jebarjup 2</td>
<td>Stirling Range</td>
</tr>
</tbody>
</table>

### Deep sandy gravel

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorn</td>
<td>Hydenup, North Stirlings, Kent, Carrolup</td>
</tr>
</tbody>
</table>

## Loams over clays (duplex soils)

### Alkaline grey shallow loamy duplex

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peterson, Peterson 1, Peterson 2, Peterson 4</td>
<td>Toompup, Dedatup, Mabinup, Kokarinup, North Stirlings, Upper Pallinup</td>
</tr>
</tbody>
</table>

### Grey shallow loamy duplex

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moodiarup, Moodiarup 1, Moodiarup 2</td>
<td>Dedatup, Toompup, Mabinup</td>
</tr>
</tbody>
</table>

### Alkaline red shallow loamy duplex

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winspear, Winspear 1</td>
<td>Dedatup, Mabinup</td>
</tr>
</tbody>
</table>

### Red deep loamy duplex

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winspear 2</td>
<td>Dedatup</td>
</tr>
</tbody>
</table>

## Deep and Shallow sands

### Pale deep sand

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauuring 2</td>
<td>Hydenup, Kokarinup, North Stirlings, Upper Pallinup, Carrolup, Mooliup, Gordon Flats</td>
</tr>
<tr>
<td>Heart Echo</td>
<td>Hydenup, Kokarinup, Toompup</td>
</tr>
<tr>
<td>Hamilla</td>
<td>Stirling Range</td>
</tr>
<tr>
<td>Corinup, Corinup 1, Corinup 3</td>
<td>Chillinup, Upper Kalgan, Lower Pallinup</td>
</tr>
</tbody>
</table>

### Gravelly pale deep sand

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauuring</td>
<td>Hydenup, Kokarinup, North Stirlings, Upper Pallinup, Carrolup, Mooliup, Gordon Flats</td>
</tr>
<tr>
<td>Ross</td>
<td>Stirling Range</td>
</tr>
</tbody>
</table>

### Pale shallow sand

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauuring 1</td>
<td>Hydenup, Kokarinup, North Stirlings, Upper Pallinup, Carrolup</td>
</tr>
<tr>
<td>Jebarjup, Jebarjup 1</td>
<td>Stirling Range</td>
</tr>
</tbody>
</table>

## Wet soils

### Saline wet soil

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brynie 1, Brynie 2, Brynie 3, Brynie 4, Brynie 5, Brynie 7, Brynie 9</td>
<td>Yaraleena, Kent, Carrolup, Dedatup, Hydenup, Jaffa, Mabinup, Mooliup, Kokarinup, North Stirlings, Toompup, Gordon Flats</td>
</tr>
</tbody>
</table>

## Rocky and Stony soils

### Stony soil

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sukey Hill</td>
<td>Stirling Range</td>
</tr>
</tbody>
</table>
**Ballard Soil Series**

The Ballard Soil Series has grey sandy topsoils, which range from loose to hardsetting. Mottled grey clay subsoils lie 30 to 80 cm below the surface. The clay subsoil is sodic with weakly to moderately well developed coarse prismatic or columnar structure. The topsoil is slightly acidic and the clay subsoil is alkaline and calcareous.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Hypocalcic Mottled-Hypernatric Grey Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>Sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>Alluvium and colluvium derived from weathered granite and/or Tertiary laterite; weathered granite and aeolian deposits</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2(e) B2tk</td>
</tr>
</tbody>
</table>

**Related soil series**

| Ballard 1 | Shallow sand over mottled grey clay | Calcic Mottled-Hypernatric Grey Sodosol |
| Ballard 2 | Moderately deep sand over mottled brown clay | Hypocalcic Mottled-Hypernatric Brown Sodosol |
| Ballard 3 | Shallow brown clay subsoil at 15–25 cm | Hypocalcic Mottled-Hypernatric Brown Sodosol |
| Ballard 4 | Shallow sand over mottled yellow clay | Hypocalcic Mottled-Mesonatric Yellow Sodosol |

**Reference profiles**

TBO0427; TBO0866 (Ballard 1); TBO0441 (Ballard 2 variant – Yellow); TBO0040 (Ballard 3); TBO0281 (Ballard 4)
KLC0801; KLC1358 (Ballard 1); KLC0126 (Ballard 2), NYA0317 (Ballard 4)

**Characteristic soil properties**

- Medium-grained sand or loamy sand over clay at 30–80 cm
- Clay subsoil is mottled and sodic
- Clay subsoil often has prismatic or columnar structure (domed clay)
- Slightly acid to neutral topsoil
- Clay subsoil is alkaline, calcareous and may contain carbonate
- Usually imperfectly drained but ranges from poorly to moderately well drained
- Surface maybe hardsetting.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Ballard and Ballard 2 usually have moderate rooting depth (50–80 cm), limited by clay subsoils with columnar or prismatic structure
- Ballard 1 and Ballard 4 usually have moderately shallow rooting depth (30–50 cm), also limited by clay subsoils
- Estimated soil water storage is low
- Ballard 1 and Ballard 4 are moderately susceptible to decline in topsoil structure
- Moderately susceptible to subsurface compaction, especially on Ballard and Ballard 2 where clay is deeper than 30 cm
- Ballard 1 and Ballard 4 have fair soil workability due to their hardsetting surfaces.

**Associated native vegetation**

- Dominant trees: flat-topped yate (*Eucalyptus occidentalis*) and mallee eucalypts dominated by blue mallee (*E. tetragona*), with black marlock (*E. redunca*), capped mallee (*E. pileata*), yellow-flowered mallee (*E. xanthonema*) and sand mallee (*E. eremophila*).
• Other trees and shrubs: rock sheoak (*Allocasuarina huegeliana*), York gum (*E. loxophleba*), wandoo (*E. wandoor*), jam (*Acacia acuminata*), Broom bush (*Melaleuca uncinata*), pincushion hakea (*Hakea laurina*), and tea-tree (*Leptospermum erubescens*).
**Brynie Soil Series**

Brynie Soil Series is saline and known locally as salt land. It is a grey deep sandy duplex affected by the accumulation of salts from a shallow saline watertable. Variants cover a large range of salt-affected soils but are grouped together because their high salt content severely restricts agricultural use. Brynie and related series mainly occur on valley floors and along drainage lines, also on slopes associated with hillside seeps.

**Definition**

| Australian Soil Classification | Bleached Sodosolic Salic Hydrosol (Isbell 2002) |
| Texture group                  | sand over clay 30–80 cm |
| Parent material                | alluvium; colluvium derived from weathered granite |
| Essential horizons             | A1 A2(e) or A3 B2tg |

**Related soil series**

| Brynie 1 | Sand over clay at > 80 cm; sodic subsoil | Bleached Sodosolic Salic Hydrosol |
| Brynie 2 | Sand over clay < 30 cm; sodic subsoil | Bleached Sodosolic Salic Hydrosol |
| Brynie 3 | Sand over clay < 30 cm; acidic subsoil | Natric Kurosolic Salic Hydrosol |
| Brynie 4 | Sand over clay 30–80 cm; sodic calcareous subsoil | Bleached Sodosolic Salic Hydrosol |
| Brynie 5 | Loam over clay < 30cm; sodic calcareous subsoil | Calcareous Sodosolic Salic Hydrosol |
| Brynie 7 | Clay > 80 cm; alkaline and calcareous | Calcareous Dermosolic Salic Hydrosol |
| Brynie 9 | Sand over clay < 30 cm; sodic calcareous subsoil | Calcareous Sodosolic Salic Hydrosol |

**Reference profiles**

TBO0089 (Brynie 4); TBO1381 (Brynie 5); TBO0747 (Brynie 9)  
KLC1655; KLC0294; KLC0132 (Brynie 3); KLC0510 (Brynie 4); KLC1169 (Brynie 5); KLC0042 (Brynie 7); KLC1091 (Brynie 9)

**Characteristic soil properties**

- Saline soils often with saline watertable present at shallow depth
- Usually poorly to very poorly drained.

**Land management characteristics**

- High soil salinity is the main limitation, allowing only salt-tolerant plants to grow
- Very shallow rooting depth (< 15 cm) limited by high salinity
- Estimated soil water storage is very low and nutrient availability is low due to high salt content
- High risk of water erosion on slopes as surface is bare or has very low cover
- As soil remains moist, wind erosion risk is generally low, however risk is high if soil dries out
- Poor workability as soil is highly prone to waterlogging and inundation.

**Associated native vegetation**

- Remnants of flat-topped yate (*Eucalyptus occidentalis*), wandoo (*E. wandoo*), moort (*E. platypus*), swamp sheoak (*Casuarina obesa*), paperbark (*Melaleuca* sp.) and jam (*Acacia acuminata*). Often the soil is bare and any vegetation is generally salt-tolerant such as samphire (*Halosarcia* sp.) or introduced grasses such as barley grass (*Hordeum* spp.).
Byangerup (Informal) Soil

Byangerup (Informal) Soil has pale grey or bleached fine sand to clayey fine sand topsoil over mottled yellow sandy light to medium clay subsoil between 30 and 80 cm. It has a loose surface condition. Ironstone and/or sandstone and quartz gravels may occur in a layer above the clay. This soil is usually found on upper to lower slopes of gently undulating to undulating rises and low hills associated with the Stirling Range. Byangerup Soil is named after the area around Byangerup Creek, north-east of Bluff Knoll.

Definition

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Eutrophic Mottled Mesonatric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from weathered sandstone and shale</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e (A2ce) B2t</td>
</tr>
</tbody>
</table>

Related soil series

- Byangerup 1 Sand over grey mottled clay subsoil
- Byangerup 2 Sand over grey mottled clay subsoil at < 30 cm

Reference profiles

TBO1376; TBO0381 (Byangerup 1 – non-sodic variant); TBO1180 (Byangerup 2 – non-sodic variant)

Characteristic soil properties

- Fine sand to clayey fine sand over clay 30–80 cm
- Yellow, mottled clay subsoil
- Sodic subsoil with non-sodic variants
- Loose surface
- Strongly acid to neutral topsoil pH
- Usually imperfectly or moderately well drained.

Land management characteristics

- Loamy to clayey sand topsoils (5–10% clay) have low susceptibility to water repellence
- Moderate unrestricted rooting depth (30–80 cm) limited by massive or weakly structured clay subsoils (shallow for Byangerup 2)
- Estimated soil water storage is moderate
- Moderately to highly susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm), depending on present soil pH.

Associated native vegetation

- Dominant trees: low woodland including marri (Corymbia calophylla), stunted jarrah (Eucalyptus marginata), and wandoo (E. wandoo), and mallees, dominated by blue mallee (E. tetragona).
- Other trees and shrubs: WA Christmas tree (Nuytsia floribunda), redheart (E. decipiens), creeping banksia (Bankia repens), flat-topped yate (E. occidentalis), grass tree (Xanthorrhoea preissii), chittick (Lambertia inermis), parrot bush (Dryandra sessilis), tea-tree (Leptospermum erubescens), prickly moses (Acacia pulchella), red leschenaultia (Leschenaultia formosa), Kunzea spp., prickly poison (Gastrolobium spinosum), wavy-leaved hakea (Hakea undulata), hood-leaved hakea (H. culcullata).
**Corinup Soil Series**

Corinup Soil Series is a deep fine sand, grey at the surface, grading to white then yellow at depth. The sandy surface condition is commonly loose. Topsoil pH is often very strongly to moderately acidic, and subsoils are generally moderately acidic to neutral. Corinup Soil Series frequently occurs on level to gently undulating plains, and on undulating rises and dune slopes. It is mainly associated with undulating sand plains on the South Coast.

**Definition**

| Australian Soil Classification | Basic Arenic Bleached-Orthic Tenosol (Isbell 2002) |
| Texture group                | deep fine sand over clayey fine sand at > 80 cm |
| Parent material              | alluvium, colluvium and aeolian deposits derived from weathered Eocene sediments |
| Essential horizons           | A1 A2e B2w |

**Related soil series**

Corinup Soil Series may be related to Corinup Sand, described by Churchward et al. (1988: Profile 2), from Bettenay and Poutsma (1962), as a Pale deep fine sand > 80 cm with minor gravels, with acidic subsoil pH. Corinup Soil Series may also be similar to Heart Echo Soil Series, but Corinup has a deep bleached horizon over the pale yellow sand at depth.

| Corinup 1                  | Deep fine sand, bleached to > 150 cm | Basic Arenic Bleached-Orthic Tenosol |
| Corinup 3                  | Deep fine sand with minor ironstone gravels | Basic Arenic Bleached-Orthic Tenosol |

**Reference profiles**

TBO0032, TBO1156; TBO0241 (Corinup 1); TBO0522 (Corinup 3)
JSJE3, EAC0057

**Characteristic soil properties**

- Sandy to fine sandy throughout
- Minor ironstone gravels at depth in Corinup 3
- White or light grey in colour (bleached) under a low organic sandy topsoil
- Loose to soft surface
- Strongly to moderately acid topsoils
- Well to rapidly drained.

**Land management characteristics**

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth for Corinup is usually deep (80–150 cm)
- Rooting depth for Corinup 1 and Corinup 3 is usually very deep (> 150 cm)
- Estimated soil water storage is very low
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

**Associated native vegetation**

- Dominant trees: mallee eucalypt species mainly blue mallee (*Eucalyptus tetragona*), with capped mallee (*E. pileata*) and sand mallee (*E. eremophila*).
### Fairclough Soil Series

**Alkaline grey shallow sandy duplex**

The Fairclough Soil Series has a hardsetting or firm surface and its topsoil is grey, sandy and massive. This overlies shallow sodic, alkaline subsoils with layers containing soft carbonates and hard carbonate concretions or nodules. The subsoils have weakly to moderately developed coarse blocky, prismatic or less commonly, columnar structure. Because of its shallow hard sandy topsoil, Fairclough is often called grey clay. Soils mainly occur on valley flats and broad alluvial plains. They also occur on lunettes and dunes near lakes and, less commonly, on footslopes and hillslopes of rises. On slopes they are usually found on mid to lower slope positions.

#### Definition

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Calcic Mesonatic Brown Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at &lt; 30 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium and colluvium derived from weathered granite, gneiss or adamellite and Tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 or Ap (A2/A2e) B2tk</td>
</tr>
</tbody>
</table>

#### Related soil series

<table>
<thead>
<tr>
<th>Fairclough 1</th>
<th>Grey subsoil</th>
<th>Calcic Mesonatic Grey Sodosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairclough 2</td>
<td>Yellow subsoil</td>
<td>Calcic Mesonatic Yellow Sodosol</td>
</tr>
</tbody>
</table>

#### Reference profiles

TBO0346; TBO0550 (Fairclough 1); TBO0445 (Fairclough 2)  
KLC1583; KLC2314 (Fairclough 1); KLC1200 (Fairclough 2)

#### Characteristic soil properties

- Clayey fine or medium sand topsoil when clay subsoil < 15 cm
- Fine or medium sand to loamy fine or medium sand topsoil when clay 15-30 cm
- Hardsetting or firm surface
- Alkaline subsoil with free carbonate
- The amount of carbonate in the subsoil is variable
- Weakly to moderately structured subsoil
- Coarse blocky prismatic or less commonly columnar structured subsoil
- Sodic (ESP> 15) subsoil
- Poorly to moderately well drained.

#### Land management characteristics

- Loamy to clayey sand topsoils (5-10% clay) have low susceptibility to water repellence
- Shallow unrestricted rooting depth (< 30 cm) limited by the presence of clay subsoils with columnar or prismatic structure
- Estimated soil water storage is moderate
- Moderately susceptible to a decline in topsoil structure
- Soil workability limited to fair where there is a hardsetting surface

#### Associated native vegetation

- Dominant trees: mallee including blue mallee (*E. tetragona*), open-fruited mallee (*E. annulata*), and black marlock (*E. redunca*) with moort (*E. platypus*).
- Other trees and shrubs: flat-topped yate (*E. occidentalis*), York gum (*E. loxophleba*), rock sheoak (*Allocasuarina huegeliana*), wandoo (*E. wandoo*), jam (*Acacia acuminata*), broom bush (*Melaleuca uncinata*), pincusion hakea (*Hakea laurina*)
**Fleming Soil Series**

Fleming Soil Series is a loamy fine sand to fine sand, gravelly in the lower part over gravelly medium clay. This soil is characterised by a thin ironstone gravel layer between 30 and 80 cm. It is mainly found on mid to lower slopes of undulating rises and on undulating plains.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Ferric Mottled-Subnatric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from weathered Eocene sediments and tertiary laterite over weathered granite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e A3c/B1c B2tc</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Description</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleming 2</td>
<td>Sand over gravelly sand over grey clay subsoil at 30–80 cm</td>
<td>Ferric Mottled-Subnatric Grey Sodosol</td>
</tr>
<tr>
<td>Fleming 3</td>
<td>Sand over grey clay subsoil at 30–80 cm</td>
<td>Mesotrophic Mottled-Subnatric Grey Sodosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0246; TBO0534 (Fleming 2); TBO1375 (Fleming 3);

**Characteristic soil properties**

- Fine sand to clayey fine sand over clay 30–80 cm, with a gravelly layer above the clay subsoil
- Yellow, mottled clay subsoil
- Sodic subsoil (ESP > 15)
- Loose surface
- Slightly acid to neutral.

**Land management characteristics**

- Loamy to clayey sand topsoils (5–10% clay) have low susceptibility to water repellence
- Moderate unrestricted rooting depth (30–80 cm) limited by massive or weakly structured clay subsoils (shallow for Byangerup 2)
- Estimated soil water storage is moderate
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm), depending on present soil pH.

**Associated native vegetation**

- Dominant trees: wandoo (*Eucalyptus wandoo*), blue mallee (*E. tetragona*), flat-topped yate (*E. occidentalis*).
- Other trees and shrubs: four-winged mallee (*E. tetraptera*), jarrah (*E. marginata*), redheart (*E. decipiens*), sheoak (*Allocasuarina sp*), *Hakea* spp., *Acacia* spp., *Calothamnus* spp., chittick (*Lambertia inermis*), grass tree (*Xanthorrhoea* sp.), featherflower (*Verticordia* sp.), smokebush (*Conospermum* sp.).
**Gorn Soil Series**

Gorn Soil Series is a pale deep sandy gravel with light grey gravelly sandy topsoils. It is sandy throughout, white or light grey in colour, and its gravel content is generally more than 50%, increasing to 80% with depth. It is usually found on upper slopes and crests of broad hills as well as mid to upper slopes. It is less common on lower slopes. Gorn is similar to the Kauering Soil Series in colour but is gravelly throughout.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Basic Regolithic Sesqui-Nodular Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand &gt; 80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>weathered ferricrete, colluvium derived from weathered ferricrete, colluvial sand and gravel</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A2ec B2wc</td>
</tr>
</tbody>
</table>

**Related soil series**

Other Gorn soils are recognised as series and are shallow gravels as a ferricrete layer is present within 80 cm.

<table>
<thead>
<tr>
<th>Gorn 1</th>
<th>Bleached gravelly sand to sandy gravel on ferricrete at 30–80 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic Petroferric Sesqui-Nodular Tenosol</td>
</tr>
<tr>
<td>Gorn 2</td>
<td>Shallow bleached sandy gravel on ferricrete at &lt; 30 cm</td>
</tr>
<tr>
<td></td>
<td>Basic Ferric-Petroferric Bleached-Leptic Tenosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO1104; TBO0939 (Gorn 1); TBO0779 (Gorn 2)  
KLC0254, KLC1607 (Gorn 1), KLC1966 (Gorn 2)

**Characteristic soil properties**

- Gravelly sand to sandy gravel > 80 cm deep
- Gravelly medium sand grading to clayey sand in the B horizon
- Pale grey or white in colour
- Loose to soft, gravelly surface
- Ferricrete layer between 30 and 80 cm (Gorn 1) and less than 30 cm (Gorn 2)
- Acid to slightly acid
- Well to rapidly drained.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth usually deep (80–150 cm) but may be restricted to moderate depth (50–80 cm) by highly gravelly layers (> 70% gravel by volume) for Gorn
- Rooting depth for Gorn 1 is moderately shallow to moderate (30–80 cm) depending on depth to ferricrete
- Rooting depth for Gorn 2 is usually shallow (15-30 cm) due to the presence of a hard ferricrete layer
- Estimated soil water storage is very low
- Low levels of nutrients and low retention
- Moderately susceptible to subsurface compaction
- Highly susceptible to subsoil acidification (10–20 cm)
- Soil workability is poor on Gorn 2 due to shallow ferricrete.
Associated native vegetation

- Dominant trees: wandoo (*Eucalyptus wandoo*), rock sheoak (*Allocasuarina huegeliana*), dwarf sheoak (*A. humilis*) and jam (*Acacia acuminata*).
- Other trees and shrubs: WA Christmas tree (*Nuytsia floribunda*), marri (*Corymbia calophylla*), redheart (*E. decipiens*), jarrah (*E. marginata*), tea-tree (*Leptospermum erubescens*), chittick (*Lambertia inermis*), parrot bush (*Dryandra sessilis*).
Hamilla (Informal) Soil

Hamilla (Informal) Soil is a pale grey clayey sand to clayey fine sand topsoil over bleached clayey fine sand to > 80 cm. Soil surface condition is normally loose, and topsoil and subsoil pH is generally moderately to slightly acidic. Hamilla Soil is usually found on the mid to lower slopes of low hills associated with the Stirling Range. It is named after Hamilla Hill, east of Cranbrook.

Definition

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Basic Arenic Bleached Orthic Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand &gt; 80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium and alluvium derived from sandstone and shale</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e</td>
</tr>
</tbody>
</table>

Reference profile

TBO1327

Characteristic soil properties

- Sand to clayey fine sand throughout
- White or light grey in colour (bleached) under a sandy topsoil low in organic matter
- Loose to soft surface
- Slightly to moderately acid
- Well to rapidly drained.

Land management characteristics

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth is usually deep (80–150 cm)
- Estimated soil water storage is very low
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

Associated native vegetation

- Dominant trees: low woodland including marri (*Corymbia calophylla*), stunted jarrah (*Eucalyptus marginata*), wandoo (*E. wandoo*) and mallee, dominated by blue mallee (*E. tetragona*)
- Other trees and shrubs: WA Christmas tree (*Nuytsia floribunda*), redheart (*E. decipiens*), Prickly poison (*Gastrolobium spinosum*), grass-leaf hakea (*Hakea multilineata*), tea-tree (*Leptospermum erubescens*), parrot bush (*Dryandra sessilis*).
**Heart Echo Soil Series**

Heart Echo Soil Series is a pale fine sand grading to a yellow clayey sand often below 50 cm. It has a loose surface and is generally moderately acidic to neutral pH. Heart Echo is usually found on mid to upper slopes and crests. Soils also occur on valley depressions and swales. A small percentage of ironstone gravels may occur at depth.

### Definition

<table>
<thead>
<tr>
<th><strong>Australian Soil Classification</strong></th>
<th>Basic Arenic Bleached-Orthic Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texture group</strong></td>
<td>sand &gt; 80 cm</td>
</tr>
<tr>
<td><strong>Parent material</strong></td>
<td>colluvial and alluvial sand derived from weathered Eocene sediments over weathered granite</td>
</tr>
<tr>
<td><strong>Essential horizons</strong></td>
<td>A1 A2e B2w</td>
</tr>
</tbody>
</table>

### Related soil series

Heart Echo Soil Series may be similar to Corinup Soil Series, but Corinup has a deep bleached horizon over the pale yellow sand at depth.

### Reference profiles

TBO0201
MTB P018, MTB P025

### Characteristic soil properties

- Fine sand grading to clayey sand
- White or light grey in colour (bleached), grading to pale yellow at depth
- Loose to soft surface
- Slightly acid
- Well to rapidly drained.

### Land management characteristics

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth is usually deep (80–150 cm)
- Estimated soil water storage is very low and a major contributor to groundwater recharge
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

### Associated native vegetation

- Dominant trees: forest or woodland including marri (*Eucalyptus calophylla*), jarrah (*E. marginata*), and wandoo (*E. wandoo*).
- Other trees and shrubs: WA Christmas tree (*Nytsia floribunda*), slender banksia (*Banksia attenuata*), flat-topped yate (*E. occidentalis*), rock sheoak (*Allocasuarina hageleii*), coneflower (*Isopogon* sp.).
**Indinup Soil Series**

Indinup Soil Series has grey sandy topsoils over pale sand with clay subsoils, usually between 40 and 60 cm. The mottled grey clay subsoils are sodic and often have prismatic or columnar structure. It often occurs on valley flats and broad alluvial plains but is also found on hillslopes, particularly in lower to mid-slope positions.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Mesotrophic Mottled-Subnatric Grey Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium and colluvium derived from weathered granite and/or Tertiary laterite; weathered granite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Related soil series</th>
<th>Indinup 1</th>
<th>Sand, usually hardsetting over clay &lt; 30 cm; may include some variants with acid subsoils</th>
<th>Mesotrophic Mottled-Mesonatric Grey Sodosol</th>
</tr>
</thead>
</table>

**Reference profiles**

TB00196; TB00802 (Indinup 1)
KLC2311, KLC1674 (Indinup 1)

**Characteristic soil properties**

- Medium grained sand to clayey sand over sandy light to medium clay at 30–80 cm
- Sand may be coarse-grained and gritty if the soil is formed on weathered granite
- Pale bleached A2
- Mottled grey subsoil
- Sodic subsoil
- Loose to firm surface
- Poorly to moderately well drained, less commonly well drained.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth usually moderate (50–80 cm) for Indinup, limited by the presence of clay subsoils with columnar or prismatic structure and/or very strongly acid layers at these depths
- Rooting depth usually moderately shallow (30–50 cm) for Indinup 1, limited by the presence of clay subsoils with columnar or prismatic structure
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Indinup has subsoils (10–20 cm) that are acid or highly susceptible to subsoil acidification
- Indinup 1 is moderately susceptible to subsoil acidification; has fair workability limited by hardsetting surface.

**Associated native vegetation**

- Dominant trees: flat-topped yate (*Eucalyptus occidentalis*), wandoow (*E. wandoo*).
- Other trees: rock sheoak (*Allocasuarina huegelii*), blue mallee (*E. tetragona*), marri (*C. calophylla*), jam (*Acacia acuminata*), flooded gum (*E. rudis*).
- Shrubs: tea-tree (*Leptospermum erubescens*), broom bush (*Melaleuca uncinata*), gorada (*Melaleuca lateriflora*), parrot bush (*Dryandra sessilis*), coneflower (*Isopogon* sp.), pajang (*Acacia laesiocarpa*), bottlebrush (*Callistemon* sp.).
**Jaramlee 2 (Informal) Soil**  
**Alkaline grey shallow sandy duplex**

Jaramlee 2 (Informal) Soil is a shallow gravelly sand, often with an indurated layer over a mottled, gleyed, yellow clay at < 30 cm which has an alkaline trend. It has a firm to soft surface and is generally moderately acidic to neutral pH in the topsoil. Jaramlee 2 is usually found on mid to lower slopes of gently undulating rises and on alluvial plains.

### Definition

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Ferric Mottled-Mesosaric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>gravelly sand over clay &lt; 30 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium and colluvium derived from weathered Eocene sediments and Tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A3c B2tc B2t</td>
</tr>
</tbody>
</table>

### Related soil series

Jaramlee 2 Soil is similar to the Jaramlee Soil Series, which has non-sodic and non-alkaline subsoils.

| Jaramlee 3 | Gravelly sand over grey clay at 30–80 cm | Ferric Mottled-Mesosaric Grey Sodosol |

### Reference profiles

TBO1146; TBO1147 (Grey subsoil variant); TBO1154 (Jaramlee 3)

### Characteristic soil properties

- Gravelly sand over clay at < 30 cm
- Clay subsoil is mottled and sodic
- Clay subsoil often has prismatic or columnar structure (domed clay)
- Moderately acid to neutral topsoil with an alkaline trend
- Usually imperfectly drained but ranges from poorly to moderately well drained.

### Land management characteristics

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Jaramlee 3 usually has a moderate rooting depth (50–80 cm), limited by clay subsoils with columnar or prismatic structure. High densities of gravel content (> 70%) may also restrict rooting
- Jaramlee 2 usually has moderately shallow rooting depth (30–50 cm), also limited by clay subsoils. High densities of gravel content (> 70%) may also restrict rooting
- Estimated soil water storage is low.

### Associated native vegetation

- Dominant trees: flat-topped yate (*Eucalyptus occidentalis*), wandoo (*E. wandoo*)
- Other trees: rock sheoak (*Allocasuarina huegeliana*), blue mallee (*E. tetragona*), WA Christmas tree (*Nuytsia floribunda*), redheart (*Acacia decipiens*), jam (*Acacia acuminata*), quandong (*Santalum acuminatum*).
- Shrubs: prickly moses (*Acacia pulchella*), parrot bush (*Dryandra* sp.), tea-tree (*Leptospermum erubescens*), broom bush (*Melaleuca uncinata*), gorada (*M. lateriflora*), coastal jugflower (*Adenanthos cuneatus*).
**Jebarjup (Informal) Soil**

Jebarjup (Informal) Soil has a clayey sand to clayey fine sand topsoil over a bleached clayey fine sand subsoil. An ironstone gravel and/or sandstone gravel layer occurs generally below 20 cm, over a cemented ironstone duricrust at < 50cm. These soils are generally found on upper to lower slopes and sometimes flats on undulating rises to low hills associated with the Stirling Range. It is named after a property with that name near Jebarjup Swan Lake and Nature Reserve, north of Salt River Road.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Basic Ferric-Petroferric Bleached-Leptic Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand on duricrust at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvial and alluvial sand derived from sandstone and shale</td>
</tr>
<tr>
<td></td>
<td>and Tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e / A2ec Ccm</td>
</tr>
</tbody>
</table>

**Related soil series**

| Jebarjup 1                     | Non-gravelly sand over duricrust at 30–80 cm                  |
| Jebarjup 2                     | Sandy gravel over duricrust at 30–80 cm                       |
|                               | Basic Petroferric Bleached-Orthic Tenosol                     |
|                               | Bleached Petroferric Sesquinozulular Tenosol                  |

**Reference profiles**

TBO1183; TBO1320 (Jebarjup 1); TBO1195 (Jebarjup 2)

**Characteristic soil properties**

- Fine sand to clayey fine sand throughout
- Sandy gravel or gravelly sand subsoil
- White or light grey in colour (bleached) under a low organic sandy topsoil
- Loose to soft surface
- Slightly acid.

**Land management characteristics**

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth is usually moderate (50–80 cm) to moderately shallow (30–50 cm), limited by hard ferricrete often at < 50 cm
- Rooting depth for Jebarjup 2 may also be limited by gravel content
- Estimated soil water storage is very low
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

**Associated native vegetation**

- Dominant trees: low woodland and mallee including blue mallee (*Eucalyptus tetragona*), marri (*Corymbia calophylla*), stunted jarrah (*E. marginata*) and wandoo (*E. wandoo*).
Kauring Soil Series

Kauring Soil Series has a loose, grey sandy surface over white or light grey sand. This overlies a gravelly sand layer usually below 50 cm. The sand is most commonly medium to coarse-grained and may be gritty. Kauring is associated with gravelly soils and is usually found on mid to upper slopes, rarely extending to lower slopes. It is known locally as Christmas tree sand or gutless sand.

**Definition**

<table>
<thead>
<tr>
<th><strong>Australian Soil Classification</strong></th>
<th>Basic Regolithic Sesqui-Nodular Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texture group</strong></td>
<td>sand &gt; 80 cm</td>
</tr>
<tr>
<td><strong>Parent material</strong></td>
<td>colluvial sand and gravel derived from weathered ferricrete, aeolian sand</td>
</tr>
<tr>
<td><strong>Essential horizons</strong></td>
<td>A1 A2e B2wc</td>
</tr>
</tbody>
</table>

**Related soil series**

Some unnamed variants have a clay loam or light clay layer below 80 cm. Kauring is similar to the Ravenscliffe Soil Series, which has pale deep sand > 120 cm deep and < 20% gravel in profile.

<table>
<thead>
<tr>
<th><strong>Kauring 1</strong></th>
<th>Sand over gravelly sand on ferricrete at 30–80 cm</th>
<th>Basic Petroferric Sesqui-Nodular Tenosol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kauring 2</strong></td>
<td>Sand over gravelly sand at &gt; 80 cm</td>
<td>Basic Ferric Bleached-Orthic Tenosol</td>
</tr>
</tbody>
</table>

**Reference profile**

TBO00258; TBO0936 (Kauring 2)
KLC0498, KLC0431 (Kauring 1); KLC1044 (Kauring 2)

**Characteristic soil properties**

- Medium to coarse sand throughout
- Sandy gravel or gravelly sand subsoil
- White or light grey in colour (bleached) under a low organic sandy topsoil
- Loose to soft surface
- Slightly acid
- Well to rapidly drained.

**Land management characteristics**

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth is usually moderate (50–80 cm), limited for Kauring by high gravel content (> 70% by volume) and for Kauring 1 by hard ferricrete
- Rooting depth for Kauring 2 is usually deep (80–150 cm)
- Estimated soil water storage is very low and a major contributor to groundwater recharge
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

**Associated native vegetation**

- Dominant trees: stunted jarrah (*Eucalyptus marginata*), blue mallee (*E. tetragona*),
- Other trees and shrubs: WA Christmas tree (*Nuytsia floribunda*), slender banksia (*B. attenuata*),
  creeping banksia (*B. repens*), rock sheoak (*Allocasuarina hugeliana*), capped mallee (*Eucalyptus pileata*),
  lerp mallee (*E. incrassata*), tea-tree (*Leptospermum erubescens*),
  coastal jugflower (*Adenanthos cuneatus*), broom bush (*Melaleuca sp.*),
  thick-leaved hakea (*Hakea pandanicarpa* subsp. *crassifolia*),
  chittick (*Lambertia inermis*).
**Lennard 2 Soil Series**

Lennard 2 Soil Series has a gravelly surface and yellowish brown gravelly sand or sandy gravel subsoil below a dark grey sandy topsoil. The clay subsoil occurs between 30 and 80 cm and is yellow in colour. Lennard 2 was first described in the Katanning survey (Percy 2000) and is closely related to the Lennard Soil Series described in the Wellington–Blackwood survey (Tille 1996). Lennard 2 is most common on mid to upper slopes and may also be found on crests and lower slopes.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Ferric Mottled-Subnatric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from weathered granite and/or Tertiary laterite, in particular weathered ferricrete. Less commonly parent material may include alluvium.</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A2c/A3c B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

Lennard
- Yellow clay subsoil
- Ferric Dystrophic Yellow Chromosol

Lennard 1
- Brown clay subsoil
- Ferric Mesotrophic Brown Chromosol

Lennard 3
- Mottled brown sodic clay subsoil
- Ferric Mottled-Subnatric Brown Sodosol

Lennard 4
- Sodic brown clay subsoil
- Ferric Hypernatric Brown Sodosol

Lennard 5
- Yellow, sometimes mottled, clay loam subsoil
- Ferric Mesotrophic Yellow Chromosol

Lennard 6
- Gravelly brown loam subsoil
- Ferric Mesotrophic Brown Chromosol

**Reference profiles**

TBO0306 (Lennard); TBO0502 (Lennard 2); TBO0822 (Lennard 3); TBO0348 (Lennard 5); TBO0787 (Lennard 6)

WBW1078, (Lennard); KLC1947 (Lennard 1), KLC0160 (Lennard 2), KLC0128 (Lennard 4); KLC1771 (Lennard 5)

**Characteristic soil properties**

- Gravelly loamy to clayey medium sand over light to medium clay at 30–80 cm
- Gravelly topsoil
- Yellow brown below grey topsoil
- Subsoil whole coloured and non-sodic
- Slightly acid to neutral, some variants with alkaline subsoils
- Imperfectly to well drained.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth for Lennard 1 and Lennard is usually deep (80–150 cm) as subsoil is non-sodic
- Rooting depth for Lennard 2 and Lennard 4 is usually moderately deep (50–80 cm) and is restricted by sodic, poorly structured clay subsoils
- Estimated soil water storage for Lennard 1 and Lennard is moderately low
- Estimated soil water storage for Lennard 2 and Lennard 4 is low
- Moderately susceptible to subsurface compaction
- Low to moderately susceptible to subsoil acidification (10–20 cm), depending on present pH.
**Associated native vegetation**

- Dominant trees: wandoo (*Eucalyptus wandoo*), rock sheoak (* Allocasuarina huegeliana*).
- Other trees: jam (*Acacia acuminata*), redheart (*E. decipiens*), blue mallee (*E. tetragona*), marri (*Corymbia calophylla*), jarrah (*E. marginata*), yellow-flowered mallee (*E. xanthonema*), black marlock (*E. redunca*), York gum (*E. loxophleba*), flat-topped yate (*E. occidentalis*).
- Shrubs: grass tree (*Xanthorrhoea preissii*), broom bush (*Melaleuca uncinata*), poison bush (*Gastrolobium* spp.), parrot bush (*Dryandra sessilis*), one-sided bottlebrush (*Calothamnus quadrifidus*), wavy-leaved hakea (*Hakea undulata*), tea-tree (*Leptospermum erubescens*).

1. Soil water storage estimated as moderate in Percy (2000). This range has now been subdivided into moderately low (70–100 mm/m) and moderate (100–140 mm/m).
**Moodiarup Soil Series**  
**Grey shallow loamy duplex**

The Moodiarup Soil Series has grey loamy topsoils with a hardsetting massive surface. The grey clay subsoil is usually very shallow, between 10 and 15 cm. The subsoil is sodic and slightly acid to slightly alkaline.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Eutrophic Subnatric Grey Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>loam over clay at &lt; 30 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium and colluvium derived from weathered granite, gneiss or adamellite and Tertiary laterite; kaolinitized clay (pallid zone or mottled zone); weathered granite; weathered gneiss</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 or Ap B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Moodiarup 1</th>
<th>Yellow subsoil</th>
<th>Eutrophic Subnatric Yellow Sodosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moodiarup 2</td>
<td>Brown subsoil</td>
<td>Eutrophic Mesonatric Brown Sodosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0883; TBO0719 (Moodiarup 1); TBO0194 (Moodiarup 2)  
KLC0131; KLC2178; KLC0467 (Moodiarup 1)

**Characteristic soil properties**

- Sandy loam or sandy clay loam over clay < 15 cm
- Hardsetting surface
- Sodic clay subsoil, sometimes displaying columnar or prismatic structure
- Whole-coloured grey subsoil
- Poorly to moderately well drained.

**Land management characteristics**

- Low susceptibility to water repellence as topsoils are loamy
- Shallow unrestricted rooting depth (< 30 cm) limited by the presence of clay subsoils with columnar or prismatic structure
- Estimated soil water storage is moderate
- Moderately susceptible to a decline in topsoil structure
- Fair soil workability limited by hardsetting surface and sodic clay < 15 cm.

**Associated native vegetation**

- Dominant trees: flat-topped yate (*Eucalyptus occidentalis*).  
- Other trees and shrubs York gum (*E. loxophleba*), wandoo (*E. wandoo*), moort (*E. platypus*), broom bush (*Melaleuca uncinata*), gorada (*M. lateriflora*), pincushion hakea (*Hakea laurina*).
**Napier 1 (Informal) Soil**

Napier 1 (Informal) Soils have pale brown to grey gravelly sand over gravelly mottled yellow sandy clay. Topsoil pH ranges from moderately acidic to neutral. Napier 1 Soils are most commonly found on mid to lower slopes of gently undulating rises and on level plains of the South Coast.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Ferric Mottled-Mesosatric Yellow Sodosol (Ishbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from weathered Eocene sediments and Tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A2c B2tc</td>
</tr>
</tbody>
</table>

**Related soil series**

Napier 1 Soils are related to Napier Gravelly Sand described by Churchward et al. (1988: Profile 92), and Napier Soil Series. Napier 1 soils may be similar to Ongarup soils except they have different parent materials. Additionally, Ongarup soil gravels are normally an ironstone and sandstone gravel mixture.

**Reference profiles**

TBO1372

**Characteristic soil properties**

- Gravelly sand or loamy sand over sandy light clay to medium clay at 30–80 cm
- Gravelly topsoil and surface
- Clay subsoil is yellow, mottled and usually sodic
- Imperfectly to well drained
- Top soil pH strongly acidic to neutral; subsoil pH slightly acidic to neutral.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth is moderate (50–80 cm), limited by massive or weakly structured clay subsoils
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm).

**Associated native vegetation**

- Dominant trees: mallee eucalypts including blue mallee (*E. tetragona*), lerp mallee (*E. incrassata*), silver mallet (*E. falcata*), four-winged mallee (*E. tetraptera*).
**Ongarup (Informal) Soil**

Ongarup (Informal) Soil has greyish brown to pale brown gravelly (ironstone and/or sandstone) sand topsoil over pale grey or bleached gravelly sand over mottled yellow sandy clay subsoil between 30 and 80 cm. Ongarup Soil is named after the area around Ongarup Creek, north west of Bluff Knoll. Ongarup Soil is usually found on upper to lower slopes of undulating rises to low hills and on undulating plains associated with the Stirling Range.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Ferric Mottled-Mesonatric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>gravelly sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from sandstone and shale and Tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A2ec B2t(c)</td>
</tr>
</tbody>
</table>

**Related soil series**

Ongarup soils may be similar to Napier 1 soils except they have different parent materials. Ongarup soil gravels are also normally an ironstone and sandstone gravel mixture.

**Reference profile**

TBO0583

**Characteristic soil properties**

- Gravelly sand or loamy sand over sandy light clay to medium clay at 30–80 cm
- Gravelly topsoil and surface
- Clay subsoil is yellow, mottled and usually sodic
- Imperfectly to well drained
- Topsoil and subsoil pH is slightly acidic to neutral.

**Land management characteristics**

- Gravelly sand topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth is moderate (50–80 cm) limited by massive or weakly structured clay subsoils
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm).

**Associated native vegetation**

- Dominant trees: mallee and low woodland including marri (*Corymbia calophylla*), wandoo (*E. wandoo*), blue mallee (*E. tetragona*).
**Peterson Soil Series**  
**Alkaline grey shallow loamy duplex**

The Peterson Soil Series has hardsetting grey sandy loam to loam topsoils over clay subsoils at 10 cm or less. The subsoil is sodic, yellowish brown in colour and alkaline. It has a calcareous subsoil layer within 50 cm. Peterson is usually found on broad alluvial plains and valley flats but also occurs on rises, usually on mid-slopes. This soil series is commonly referred to as ‘Moort soils’ or ‘grey clays’ due to the hardsetting loamy topsoil and shallow clay subsoil.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Hypocalcic Subnatric Brown Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>loam over clay at &lt; 30 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium, colluvium; kaolinised clay; strongly weathered granite or gneiss</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 or Ap B2t(k)</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Peterson 1</th>
<th>Grey subsoil</th>
<th>Calcic Subnatric Grey Sodosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peterson 2</td>
<td>Yellow subsoil</td>
<td>Calcic Subnatric Yellow Sodosol</td>
</tr>
<tr>
<td>Peterson 4</td>
<td>Yellow subsoil</td>
<td>Calcic Mottled-Subnatric Yellow Sodosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0435; TBO0490 (Peterson 1 mottled variant); TBO0836 (Peterson 2); TBO0451 (Peterson 4)  
KLC1291; KLC1803 (Peterson 1); KLC1317 (Peterson 2)

**Characteristic soil properties**

- Sandy loam, or less commonly loam, over light to medium heavy clay < 20 cm
- Sodic, alkaline subsoil
- Clay subsoil often has coarse blocky or prismatic structure
- Carbonate content is variable
- Hardsetting surface
- Slightly acidic topsoil over alkaline to strongly alkaline subsoil
- Poorly to imperfectly drained, less often moderately well drained.

**Land management characteristics**

- Low susceptibility to water repellence as topsoils are loamy
- Rooting depth is usually moderately shallow (30–50 cm), limited by the presence of clay subsoils with coarse blocky or prismatic structure
- Estimated soil water storage is low¹
- Moderately susceptible to a decline in topsoil structure
- Fair soil workability limited by hardsetting surface.

**Associated native vegetation**

- Dominant trees: moort (*Eucalyptus platypus*), flat-topped yate (*E. occidentalis*).

¹. Soil water storage estimated as moderate in Percy (2000). This was calculated over 100 cm of soil. Current estimates of low soil water storage assume roots only penetrate 30 cm into the clay subsoil.
**Ross (Informal) Soil**

Ross (Informal) Soil is a pale grey clayey sand to clayey fine sand topsoil over bleached clayey fine sand to > 80 cm. An ironstone and/or sandstone gravelly layer is generally found at depth, below 50 cm and sometimes below 80 cm. Soil surface condition is normally loose, and topsoil and subsoil pH is generally moderately to slightly acidic. Ross Soil is usually found on the mid to lower slopes of low hills in the Stirling Range. It is named after Ross Peak, near Red Gum Pass Road, in the western region of the Stirling Range.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Basic Ferric Bleached Orthic Tenosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand &gt; 80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvial and alluvial sand derived from weathered sandstone and shale and tertiary laterite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e A3c</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0380

**Characteristic soil properties**

- Fine sand to clayey fine sand throughout
- Sandy gravel or gravelly sand subsoil
- White or light grey in colour (bleached) under a sandy topsoil low in organic matter
- Loose to soft surface
- Slightly acid
- Well to rapidly drained.

**Land management characteristics**

- Sandy topsoils with less than 2% clay are highly susceptible to water repellence
- Rooting depth for Ross Soil is usually deep (80–150 cm)
- Estimated soil water storage is very low
- Infertile soil with very low levels of nutrients and low retention
- Highly susceptible to subsoil acidification (10–20 cm)
- High risk of wind and water erosion.

**Associated native vegetation**

- Dominant trees: mallee eucalypts and low woodland including blue mallee (*E. tetragona*), marri (*Corymbia calophylla*), stunted jarrah (*E. marginata*), and wandoo (*E. wandoo*).
Sukey Hill (Informal) Soil

Sukey Hill (Informal) Soil has fine sand to fine sandy loam over grey clay subsoil, with rounded and sub angular colluvial sandstone fragments common throughout the profile. Sukey Hill soils usually occur on mid to upper slopes, crests and ridges associated with the hills and mountains of the Stirling Range.

Definition

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Mottled Eutrophic Grey Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>weathered sandstone and shale</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1/A2ec B2(c)t</td>
</tr>
</tbody>
</table>

Reference profile

TBO1323

Characteristic soil properties

- Rocks and stones common throughout
- Sandy matrix
- Neutral to acid pH.

Land management characteristics

- Shallow to moderate rooting depth
- Water-holding capacity is low due to the amount of stone and rock
- Variable permeability
- Stoniness or rockiness may severely limit most land uses.

Associated native vegetation

- Dominant trees: mallee eucalypts (*Eucalyptus* spp.) are prominent, dominated by blue mallee (*E. tetragona*).
- Other trees and shrubs: stunted marri (*Corymbia calophylla*) and jarrah (*E. marginata*) with open-fruited mallee (*E. annulata*) and sheoak (*Allocasuarina* spp.), grass tree (*Xanthorrhoea* and *Kingia* spp.), chittick (*Lambertia inermis*), heath-leaved honeysuckle (*L. ericifolia*), broom bush (*Melaleuca uncinata*), fan hakea (*Hakea baxteri*), hood-leaved hakea (*H. culcullata*), poison bush (*Gastrolobium* spp.) and parrot bush (*Dryandra* spp.).
**Tarwonga Soil Series**

The Tarwonga Soil Series has a grey sandy surface over a mottled brown clay subsoil usually at 40 to 50 cm. The sandy topsoil is medium to coarse-grained, often gritty and has a paler, sometimes bleached, sandy layer above the clay subsoil. Tarwonga occurs on hillslopes, on rises and low hills as well as valley flats and broad alluvial plains. It is most common on lower slopes and valley flats.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Eutrophic Mottled Mesotrophic Brown Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>alluvium and colluvium derived from weathered granite, and/or Tertiary laterite and weathered granite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2(e) B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

- Tarwonga 1 Non-sodic mottled brown subsoils
  - Mottled Mesotrophic Brown Chromosol
- Tarwonga 3 Sodic, mottled brown subsoils < 30 cm
  - Magnesic Mottled-Hypernatric Brown Sodosol

**Reference profiles**

TBO0294; TBO0103 (Tarwonga 1 variant – non-mottled); TBO0807 (Tarwonga 3); KLC0139, KLC0559 (Tarwonga 1); KLC0037 (Tarwonga 3)

**Characteristic soil properties**

- Loamy to clayey sand over clay at 30–80 cm
- Sandy, often medium to coarse, may be gritty
- Brown, mottled clay subsoil
- Sodic subsoil (ESP > 15)
- Firm to hardsetting surface
- Slightly acid to neutral
- Usually imperfectly or moderately well drained.

**Land management characteristics**

- Loamy to clayey sand topsoils (5–10% clay) have low susceptibility to water repellence
- Moderate unrestricted rooting depth (30–80 cm) limited by massive or weakly structured clay subsoils (shallow for Tarwonga 3)
- Moderate soil water storage
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm), depending on present soil pH.

**Associated native vegetation**

- Dominant trees: wandoo (*Eucalyptus wandoo*), rock sheoak (*Allocasuarina huegelii*), flat-topped yate (*E. occidentalis*)
- Other trees and shrubs: blue mallee (*E. tetragona*), hook-leaved mallee (*E. uncinata*), black marlock (*E. reducna*), yellow-flowered mallee (*E. xanthonema*), York gum (*E. loxophleba*), jarrah (*E. marginata*), jam (*Acacia acuminata*), tea-tree (*Leptospermum erubescens*), many-headed dryandra (*Dryandra polycephala*), *Hakea pandanicarpa* and grass tree (*Xanthorrhoea preissii*).
**Wahkinup Soil Series**

The topsoil of the Wahkinup Soil Series is grey, gravelly sand and overlies a bleached sandy gravel layer. Its clay subsoil is mottled, non-sodic and occurs between 30 and 80 cm. It is commonly found on upper slopes but also on mid-slopes and crests.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Bleached-Ferric Mesotrophic Yellow Chromosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>colluvium derived from weathered granite and/or Tertiary laterite, in particular weathered ferricrete, over weathered, often kaolinsed, granite</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1c A2ec A3c/B1c B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Wahkinup 1</th>
<th>Bleached A2, clay loam subsoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wahkinup 2</td>
<td>Bleached A2, sodic grey subsoil</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO1334; TBO0765 (Wahkinup 1); TBO0842 (Wahkinup 2 – mottled non-sodic variant); WBW1081, KLC0497 (Wahkinup 2)

**Characteristic soil properties**

- Gravelly sand or loamy sand over sandy light clay to medium clay at 30–80 cm
- Gravelly topsoil and surface
- Clay subsoil is brownish yellow, mottled and usually non-sodic
- Imperfectly to well drained.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth is moderate (50–80 cm), limited by massive or weakly structured clay subsoils
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm).

**Associated native vegetation**

- Dominant trees: wandoo (*Eucalyptus wandoo*), jarrah (*E. marginata*), rock sheoak (*Allocasuarina huegeliana*), marri (*Corymbia calophylla*).
- Other trees and shrubs: redheart (*E. decipiens*), dwarf sheoak (*A. humilis*), wandoo (*E. wandoo*), jam (*Acacia acuminata*), tea-tree (*Leptospermum erubescens*) and grass tree (*Xanthorrhoea preissii*).
**Warup Soil Series**

The Warup Soil Series has grey sandy topsoils over white or light grey layers of sand. The sand is often coarse-grained and gritty, particularly in the lower sandy layers. The clay subsoil usually occurs between 30 and 50 cm below the surface. The subsoil is yellow, mottled and sodic. Warup is usually found on mid to upper slopes and is often associated with outcrops of granite or adamellite. The soil may also occur on crests and lower slopes and on some broad valley flats.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Mesotrophic Mottled-Subnatric Yellow Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>sand over clay at 30–80 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>weathered granite, colluvium derived from weathered granite and/or Tertiary laterite and alluvium</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 A2e/A3e B2t</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th></th>
<th>Warup 1</th>
<th>Yellow/brown sand over yellow mottled clay subsoil</th>
<th>Mottled Mesotrophic Yellow Chromosol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warup 2</td>
<td>Yellow/brown sandy A2 over sodic clay subsoil</td>
<td>Mesotrophic Mottled-Subnatric Yellow Sodosol</td>
</tr>
<tr>
<td></td>
<td>Warup 3</td>
<td>Sand over mottled clay subsoil &lt; 30 cm</td>
<td>Mesotrophic Mottled-Subnatric Yellow Sodosol</td>
</tr>
<tr>
<td></td>
<td>Warup 4</td>
<td>Bleached sand over yellow loam subsoil</td>
<td>Bleached-Mottled Mesotrophic Yellow Chromosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0393; TBO0318 (Warup 1); TBO0471 (Warup 3); TBO0404 (Warup 4)
KLC0720; KLC0854 (Warup 1), KLC1838 (Warup 2), KLC2317 (Warup 3), KLC0137 (Warup 4)

**Characteristic soil properties**

- Medium to coarse-grained sand to clayey sand A horizons over clay at 30–80 cm
- Clay content may increase slightly in the sand layer above the clay subsoil
- Small amounts (< 20%) of ferruginous gravel or rock fragments often occur at the base of the A horizons
- Yellow mottled clay subsoil
- Sodic subsoil
- Slightly acid to neutral
- Usually imperfectly or moderately well drained but ranges from poorly to well drained.

**Land management characteristics**

- Sandy topsoils with less than 5% clay are moderately susceptible to water repellence
- Rooting depth is moderate (50–80 cm), limited by massive or weakly structured clay subsoils (moderately shallow (30–50 cm) for Warup 3)
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Subsoils (10–20 cm) are presently acid or highly susceptible to subsoil acidification.

**Associated native vegetation**

- Dominant trees: mallee eucalypts dominated by blue mallee (*Eucalyptus tetragona*) with capped mallee (*E. pileata*), leerp mallee (*E. incrassata*), open-fruited mallee (*E. annulata*).
Waychinicup 1 (Informal) Soil  Grey shallow sandy duplex

Waychinicup 1 (Informal) Soils have pale brown to pale grey gravelly sand over gravelly mottled yellow sandy clay at < 30 cm. The soft to firm topsoil has a pH which ranges from strongly acidic to neutral. Waychinicup Soils are most commonly found on mid to lower slopes of gently undulating rises and on gently undulating plains of the South Coast.

Definition

| Australian Soil Classification | Ferric Mottled-Mesonatric Yellow Sodosol (Isbell 2002) |
| Texture group                 | sand over clay at < 30 cm                              |
| Parent material               | colluvium derived from weathered Eocene sediments and Tertiary laterite |
| Essential horizons            | A1c A2ec B2tc                                         |

Related soil series

Waychinicup Soils are related to Waychinicup Sand described by Churchward et al. (1988: Profiles 70 and 76).

<table>
<thead>
<tr>
<th>Reference profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBO1302; TBO1295 (Waychinicup 2)</td>
</tr>
</tbody>
</table>

Characteristic soil properties

- Gravelly sand over clay at < 30 cm
- Yellow, mottled clay subsoil
- Sodic subsoil
- Loose surface
- Strongly acid to neutral topsoil
- Usually imperfectly or moderately well drained.

Land management characteristics

- Gravelly sand topsoils (2–5% clay) have moderate susceptibility to water repellence
- Moderate unrestricted rooting depth (30–80 cm) limited by massive or weakly structured clay subsoils; high gravel contents (> 70%) may also restrict rooting
- Low susceptibility to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm), depending on present soil pH
- Estimated water storage is low.

Associated native vegetation

- Dominant trees: blue mallee (Eucalyptus tetragona), wandoo (E. wandoo), flat-topped yate (E. occidentalis).
- Other trees and shrubs: jarrah (E. marginata), redheart (E. decipiens), Acacia spp., Calothamnus spp., chittick (Lambertia inermis), grass trees (Xanthorrhoea spp.), feather flowers (Verticordia spp.) and smokebush (Conospermum sp.).
**Winspear Soil Series**

The Winspear Soil Series has a hardsetting surface and reddish-brown loamy topsoils. Below this are red alkaline clay subsoils, usually within 15 cm. The subsoil is whole coloured, sodic and usually has a carbonate layer within 50 cm. This soil is formed on weathered dolerite or gabbro and, as it usually occurs on dykes, is often distributed linearly across the landscape. This soil occurs on mid to upper slopes, usually covering only small areas. Winspear sometimes occurs on crests and lower slopes.

**Definition**

<table>
<thead>
<tr>
<th>Australian Soil Classification</th>
<th>Calcic Subnatric Red Sodosol (Isbell 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture group</td>
<td>loam over clay at &lt; 30 cm</td>
</tr>
<tr>
<td>Parent material</td>
<td>weathered dolerite or gabbro, weathered gneiss or adamellite or alluvium</td>
</tr>
<tr>
<td>Essential horizons</td>
<td>A1 or Ap B2tk</td>
</tr>
</tbody>
</table>

**Related soil series**

<table>
<thead>
<tr>
<th>Winspear 1</th>
<th>Sand or gravelly sand over clay &lt; 30 cm</th>
<th>Hypercalcic Mesonatric Red Sodosol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winspear 2</td>
<td>Loam over clay 30–80 cm</td>
<td>Calcic Subnatric Red Sodosol</td>
</tr>
</tbody>
</table>

**Reference profiles**

TBO0460; TBO0283 (Winspear 2)
KLC1203; KLC2338; KLC0468 (Winspear 1)

**Characteristic soil properties**

- Sandy loam, sandy clay loam or less commonly, clay loam over clay, often < 15 cm
- Red sodic subsoil
- Clay subsoil has coarse blocky or prismatic structure
- May contain black ferromanganiferous gravel in topsoil or throughout clay subsoil
- Slightly acid to neutral topsoil
- Alkaline subsoil with a calcareous layer within 50 cm
- Amount of carbonate in the subsoil is variable
- Moderately well drained, less often imperfectly drained.

**Land management characteristics**

- Low susceptibility to water repellence as topsoils are loamy
- Shallow unrestricted rooting depth (< 30 cm) limited by clay subsoils with coarse blocky or prismatic structure
- Estimated soil water storage is low
- Moderately susceptible to decline in topsoil structure
- Fair soil workability limited by hardsetting surface; rock outcrops reduce workability.

**Associated native vegetation**

- Dominant trees: York gum (*Eucalyptus loxophleba*) often with jam (*Acacia acuminata*).
- Other trees and shrubs: flat-topped yate (*E. occidentalis*), wandoo (*E. wandoo*), capped mallee (*E. pileata*), open-fruited mallee (*E. annulata*), needle tree (*Hakea preissii*), broom bush (*Melaleuca uncinata*).
Yilberup (Informal) Soil

Yilberup (Informal) Soils have pale brown to pale grey fine sand over mottled yellow sandy clay at < 30 cm. Topsoil pH ranges from moderately acidic to neutral. Yilberup Soils are most commonly found on mid to lower slopes of gently undulating rises and on level plains of the South Coast.

Definition

| Australian Soil Classification | Mesotrophic Mottled-Subnatric Yellow Sodosol (Isbell 2002) |
| Texture group                 | sand over clay at < 30 cm                                      |
| Parent material               | colluvium derived from weathered Eocene sediments              |
| Essential horizons            | A1 A2e B2t                                                   |

Related soil series

Yilberup (Informal) Soils are related to Yilberup Sand described by Churchward et al. (1988: Profiles 74 and 102).

Reference profiles

TBO0535; TBO0614 (Grey clay variant)

Characteristic soil properties

- Fine sand to clayey fine sand over clay < 30 cm
- Yellow mottled clay subsoil
- Sodic subsoil
- Loose surface
- Moderately acid to neutral topsoil and neutral subsoil
- Usually imperfectly or moderately slow drainage.

Land management characteristics

- Fine sandy topsoils (5–10% clay) have low susceptibility to water repellence
- Moderate unrestricted rooting depth (30–80 cm) limited by massive or weakly structured clay subsoils
- Estimated soil water storage is low
- Moderately susceptible to subsurface compaction
- Moderately to highly susceptible to subsoil acidification (10–20 cm), depending on present soil pH.

Associated native vegetation

- Dominant trees: blue mallee (*Eucalyptus tetragona*).
- Other trees and shrubs: ridge-fruiting mallee (*E. angulosa*), wandoo (*E. wando*), flat-topped yate (*E. occidentalis*), corky honeymyrtle (*Melaleuca suberosa*), manna wattle (*Acacia microbotrya*), berry poison (*Gastrolobium parviflorum*), chittick (*Lambertia inermis*), *Dryandra* spp., grass trees (*Xanthorrhoea* sp.), sheoak (*Allocasuarina* sp.), southern plains banksia (*Banksia media*), *Calothamnus* spp., *Hakea* spp., coastal jug flower (*Adenanthis cuneatus*).
Interpretation of land resource survey results

One of the major uses of information provided by a land resources survey is to help identify management, conservation and degradation issues in the region, and implications of these for land use and land management (Van Gool et al. 2005).

The major regional land management constraints or degradation issues observed during the survey are outlined below.

Salinity

Salinity is classified as either primary (naturally saline areas) or secondary (salinity which has developed as a result of rising watertables, often due to land clearing). In the survey region, both forms of salinity are part of the landscape.

The primary salt lakes occurring to the north and the south of the Stirling Range are discharge areas for groundwater which is recharged from the higher land of the range and other surrounding areas of greater topographical relief. These areas, particularly in the case of the North Stirlings, have limited external drainage, and land and water salinisation has resulted in the development of extensive salt lakes. According to Smith (1997), areas of poor drainage where the regolith is thick and clayey, such as the upper Kent, or silty as in the North Stirlings, have accumulated the most salt.

The increased recharge in cleared agricultural landscapes and the subsequent salt mobilisation from rising groundwater has led to the development of secondary salinisation in many parts of the study area. This has resulted in a particularly serious problem in the North Stirlings basin. Since clearing, there is extra water in the system. According to Lewis (1992), this has led to both a rise in the watertable, leading to widespread problems with secondary salinity across the North Stirlings area, and also a possible increase in groundwater flow out of the basin. One of the more likely corridors for this outward flow, Lewis (1992) concludes, is via fractured zones in the basement rocks to the Six Mile Creek and Salt Creek aquifer. This outward flow of saline groundwater appears to coincide with the high level of salt-affected land mapped as part of the Mabinup soil-landscape system to the east of the North Stirlings system, described as part of this report.

In the remainder of the survey area, many of the valley floor, floodplain and lower slope landscapes such as the Gordon Flats, Carrolup and Upper Pallinup systems, have become saline because of rising groundwater levels and are at risk from this increasing in the future. Saline hillside seeps are also a problem in many areas, associated with faults, dykes and other geological structures.

Wind erosion

Aeolian action has contributed to the formation of many of the landscapes within the survey area, which suggests that the region is very vulnerable to this form of land degradation, given the right conditions. Wind erosion occurs in situations where there is insufficient groundcover to protect the ground surface, when the soil surface is loose and dry, and when there are erosive winds (Moore et al. 1998). The susceptibility of any particular soil to wind erosion is related to both the level of disturbance needed to bring the soil to a loose and erodible...
condition, and its position in the landscape—which governs wind speed influences and exposure (van Gool et al. 2005). Soil-landscape systems that exhibit significant susceptibility to wind erosion in the region include the Kokarinup, Hydenup, Mooliup, Toompup, Chillinup and North Stirlings systems.

Surface and subsurface soil acidification

Field assessments during the survey showed that surface and subsurface pH for soils with sandy topsoils were generally strongly to slightly acid (pHw 5.3–6.5) across the area. For profiles with loamy to clayey topsoils, the pH was generally closer to neutral (pHw 6.5–8). While acid soils occur naturally in our environment, Dolling et al. (2001) stated that most acidity has been caused by agriculture. Agriculture increases the amount of acid entering the soil, and, therefore, increases the rate of pH decline. This is due mainly to the addition of acid fertilisers, increased nitrate leaching and export of produce. Low pH values in the subsurface (10–20 cm) are more serious than low pH values in the surface soil (0–10 cm) because it is more difficult to correct the pH at depth.

A compounding concern with low pH soils can be accompanying high concentrations of potentially toxic aluminium (Al\textsuperscript{3+}), as reported in Moore et al. (1998a). As pH declines below about 5, Al\textsuperscript{3+} commonly increases. To date, chemical analyses performed on selected profile samples across the area show that levels of Al\textsuperscript{3+} (extractable in CaCl\textsubscript{2}) are mainly moderate to low. This suggests that the effects of acidification are not yet as serious as in some wheatbelt areas.
Waterlogging and inundation

Waterlogging is excess water in the root zone accompanied by anaerobic conditions, and inundation is when water ponds on the soil surface (Moore & McFarlane 1998). While this problem is widespread across the survey area, it is extremely variable in its severity from season to season, from year to year and from soil-landscape system to system. The systems that are particularly susceptible to waterlogging and inundation are the low-lying alluvial plains of the North Stirlings, Kent and Gordon Flats systems, as well as the more undulating Carrolup, Jaffa and Mabinup systems. In the remaining areas, the lower slopes and valleys are often subject to seasonal waterlogging and inundation, and seasonally perched watertables are also common in many landscape positions.

Water erosion

The incidence of water erosion is influenced by many factors, including rainfall erosivity, soil erodibility, slope angle, slope length and management practices (Coles & Moore 1998). Many areas across the survey region are moderately to highly susceptible to water erosion but, as discussed in Van Gool et al. (2005), it is highly variable depending on seasonal and climatic factors, with most soil loss occurring from a small proportion of areas. One of the greater erosion risks in the area is rainfall erosivity where the intensity of rainfall from summer or winter storms can result in large soil losses. Another important influence in this region is the slope angle: in general, the steeper the slope, the greater the erosion (Coles & Moore 1998). A local example of this is provided when heavy rainfall from intense winter or summer storms causes rapid run-off from the steep slopes of the Stirling Range, leading to flash flooding of adjacent low-lying areas (Department of Conservation and Land Management 1999).

The undulating topography of some parts of the survey makes areas of some soil-landscape systems moderately to highly susceptible, including Stirling Range (and adjoining systems), Dedatup, Upper Pallinup and Jaffa. Landscapes exhibiting degradation from salinity are also very vulnerable to the effects of water erosion, such as in the Mabinup and North Stirlings systems.
Acknowledgments

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Glossary

Adamellite: A form of granite with roughly equal calcium and potassium-bearing minerals.

Alluvium: Material transported and deposited by flowing water such as rivers.

Apedal: Structureless soil with no observable peds.

  *Apedal massive*: Describes a soil which is coherent and separates into fragments when disturbed. These may be crushed to ultimate particles.

  *Apedal single-grained*: Describes a soil that consists of loose, incoherent particles.

Archaean: Represents the period of time about 2700 million years ago.

Cainozoic: Represents the period of time from about 65 million years ago to the present.

Colluvium: Materials transported and deposited by gravity.

Craton: Major structural unit of the earth’s crust, consisting of a large stable mass of rock.

Crystalline rock: An igneous or metamorphic rock such as granite or gneiss.

Dolerite: A medium-grained basic igneous rock that has crystallised near the surface, typically occurring as a dyke, sill or plug.

Duplex soil: A soil with a sudden increase in texture between the topsoil and subsoil, e.g. a sand over a clay.

Dyke: A sheet-like body of igneous rock cutting across the bedding or structural planes of the host rock. Dykes typically appear on the surface as relatively narrow, linear features.

Earthy fabric: A coherent soil material characterised by the presence of pores and few (if any) peds.

Eocene: The epoch of the Tertiary period between the Palaeocene and Oligocene epochs.

Ferricrete: A layer of material strongly cemented by iron which looks like rock. Formed in laterite and often called sheet laterite, ironstone caprock or duricrust.

Gabbro: A coarse-grained basic igneous rock similar to dolerite.

Gneiss: Banded rocks which are generally coarse-grained and formed through high-grade regional metamorphism.

Granite: A coarse-grained igneous rock consisting essentially of quartz (20–40%), feldspar and very commonly a mica.

Granulite: A metamorphic rock of regional origin and granular texture, usually consisting of feldspars, pyroxenes and garnets.

Halophyte: Salt-tolerant species of plant such as samphire.
**Hardsetting:** Describes a soil which is compact, hard and apparently apedal when dry, but softens on wetting.

**Horizons:** A term used to describe individual layers in a soil profile. Each horizon has morphological properties different from those above and below it.

**Igneous rock:** Formed from magma which has cooled and solidified at the earth’s surface or within the earth’s crust.

**Laterite:** The term laterite is often a cause of confusion. It is sometimes used to refer only to the iron and aluminium-rich duricrust (cemented gravel and ironstone), but it may also be applied to the whole deeply weathered profile, including the leached clays. The lateritic profile (ranging from 2 to 50 m thick) typically consists of sand or gravel on top of a ferruginous duricrust where the iron oxides have accumulated. This overlies a mottled clay and then a pallid zone (white clay) from which the leaching has occurred.

**Loam:** A medium-textured soil composed of approximately 10–25% clay, 25–50% silt and less than 50% sand.

**Loose:** Describes the condition of an incoherent mass of individual soil particles or aggregates easily disturbed by pressure of the forefinger.

**Lunette:** A crescent-shaped dune at the margin of a lake, formed by wind action. The sediments originate from the floor of the lake during dry periods.

**Metamorphic rocks:** Rocks such as gneiss which have been altered by heat and/or pressure.

**Migmatite:** Rock composed of two sources: the metamorphic host rock and an invading granitic material.

**Orogen:** A tectonic belt characterised by regional metamorphism and abundant plutonic intrusion.

**Pallid zone:** White to pink kaolinitic clay formed in the lower part of the lateritic profile. See laterite above.

**pH:** A measure of the acidity or alkalinity of the soil which can range from 1 to 14. Most plants grow best when soil pH is in the range of 5.5 to 8.0.

**Physiography:** A broad term used to refer to the general shape of the land surface.

**Plateau:** A level to rolling landform pattern of plains, rises or low hills standing above a cliff or escarpment.

**Peds:** Natural soil aggregates consisting of primary soil particles held together by cohesive forces or secondary materials such as iron oxides, silica and organic matter.

- **Blocky peds** are cube-shaped with six relatively flat, roughly equal faces.
- **Crumb peds** are small (1–5 mm diameter) soft, porous and more or less rounded. They are usually bonded by organic matter.
- **Polyhedral peds** have an uneven shape with more than six faces.
Rough-faced peds have porous surfaces.

Smooth-faced peds have smooth, sometimes shiny, surfaces.

Quartzite: A metamorphosed rock where the constituent grains recrystallise and develop an interlocked mosaic texture, with little or no trace of cementation.

Rooting condition: Refers to the soil volume available for plant roots and the mechanical impedance to root development. Soil volume can be reduced by rock and gravel content, by dense pans and clay layers. Plants have varying ability to explore the soil profile. Restrictions to root growth reduce moisture and nutrient availability.

Salinity: Usually refers to the condition of a high level of soluble salts, especially sodium chloride, in water or a soil profile. High salt levels in the soil water increase the osmotic pressure and reduce the plant’s ability to take up moisture. Salinity in the soil profile can come from rising saline groundwater and by the addition of water with low to moderate levels of salt, which is concentrated as the water evaporates.

Sandy fabric: Sand grains provide the characteristic appearance of the soil mass.

Saprolite: Soft, more or less decomposed rock remaining in its original place.

Sedimentary deposits: Materials which have been moved from their site of origin by the action of wind, water, gravity or ice and then deposited. When these materials become consolidated and hard they are known as sedimentary rocks.

Silcrete: Strongly indurated siliceous material.

Sodic: Description of a soil where the B horizon has an exchangeable sodium percentage (ESP) of more than 6. Sodic soils can be structurally unstable and plant growth may be adversely affected.

Structured: Describes a soil that contains peds.

Subsoil: Layer/s of a soil below the topsoil which are usually higher in clay and lower in organic matter than the topsoil. Often called the B horizon/s of a soil profile.

Swale: A linear, level floored open depression excavated by wind or formed by the build-up of two adjacent ridges. Typically associated with the depression between adjacent sand dunes.

Tertiary: Represents the period of time from about 65 to 1.8 million years ago.

Texture: The proportion of sand, silt or clay particles in the soil, defining the coarseness or fineness of the soil material as it affects the behaviour of a moist ball of soil when pressed between the thumb and forefinger.

Topsoil: Surface layer/s of a soil which are usually higher in organic matter (at least at the surface) and lower in clay than the lowest layers (subsoil). Often called the A horizons of the profile.

Weathering: The physical and chemical disintegration, alteration and decomposition of rocks and minerals at or near the earth’s surface by atmospheric and biological agents.
References


Beard, J.S. (1981). *Vegetation Survey of Western Australia—Swan, Map and Explanatory Notes*, 1:1,000,000 Vegetation Series, University of Western Australia Press, Nedlands.


Appendix: Guide to viewing Soil-landscape maps on website

Step 1. Go to the NRM Info home page where you may read more about SLIP NRM Info or go straight to viewing the maps by selecting Go to Maps. The NRM Toolkit just above the maps button will provide full details on the website.

Step 2. A range of products is available on this page. A quick way to access the Soil-landscape Mapping is to select the box of that name, and select Regional from the drop down box, and click on View.
Step 3. An information box titled ‘Soils and Soil-landscapes’ appears. This page gives some background to the statewide mapping program and links to related soil information products. By scrolling down the page, reading and agreeing to the disclaimer, you may then proceed to the maps.

Step 4. Survey Index. By moving your cursor over the statewide index, the name and code of the underlying soil-landscape survey will appear. The location of the Tambellup–Borden (TBO) survey is indicated in the image below. By clicking on the icon indicated by the arrow below, you can click and drag the icon over the survey area to zoom in closer.
Step 5. When you have selected the survey area of interest, you can then select the **Regional** mapping level of the soil-landscape mapping.

![Image of the regional mapping level](image)

Step 6. A soil-landscape systems map will appear for the survey area. By moving your cursor over the map, labels will appear, as shown below. By clicking on these labels, information about the system will appear.

![Image of the soil-landscape systems map](image)
Step 7. You can view the information on screen or save it to a file on your own computer by following the instructions on the screen.

Step 8. The information about the soil-landscape systems appears as is shown below. This provides descriptions of the area, the vegetation, the subsystems and the soils and the proportions in which they occur in the system. If you zoom in closer to the map, you will see a more detailed level of mapping appear at a sub-system level (see Step 9). You can also click on the label information and receive detailed information about each subsystem as well.
Step 9. By zooming in on the map you will see more detailed mapping at a soil-landscape subsystem and phase level. You can access detailed information about the subsystem by following the previous steps. You will also see some pink dots on the screen, like those circled below. These pink dots are where soil descriptions have been done on the ground. If you move the cursor over the pink dot, information about the site will appear, including the site code number and the WA Soil Group that has been allocated to the soil at that point. These detailed maps may be printed or saved to your computer by selecting the printing or snapshot icons on the right-hand side of the toolbar, as indicated by the arrow below.

Maps showing Land Degradation Hazards (including salinity risk, subsurface acidification, flood risk, waterlogging and wind erosion) and Soil-landscape Capability (including annual and perennial horticulture, and dryland cropping) are also available by selecting the suitable map legend heading on the right-hand side of the maps (you may need to scroll down the list to find the legend item).

For more information, select the Help button on the left-hand side of the toolbar for assistance and information on other features of the map window.
Land Resources Series Reports

No. 1. Land capability assessment methodology for rural-residential development and associated agricultural land uses (1989)
No. 2. Land capability study of the shires of Mandurah and Murray (1989)
No. 3. Darling Range rural land capability study (1990)
No. 4. Geraldton rural-residential land capability study (1990)
No. 5. Busselton, Margaret River–Augusta land capability study (1990)
No. 6. Land capability study for horticulture in the Swan Valley (1991)
No. 7. Soils of the Mount Beaumont area (1996)
No. 9. Land resources study of the Carnarvon Land Conservation District and part of Boolathana Station, Western Australia (1992)
No. 10. Soils and landforms of the Manjimup area (1992)
No. 11. Land resources of the Northam region (1993)
No. 12. Land resources of the Bencubbin area (1995)
No. 15. Soil assessment of the West Gingin area (1996)
No. 20. Corrigin area land resources survey (2005)
No. 21. Tambellup–Borden area land resources survey (2009)

Digital or hard copy linework of the maps accompanying these reports, or a combination of areas from neighbouring surveys, can also be purchased separately.

Other land resource maps

Land Resources of the Peel–Harvey North Region
Land Resources of the Peel–Harvey South Region

Maps and reports are available from:
Department of Agriculture and Food
3 Baron-Hay Court, South Perth WA 6151
Some copies are also held in local offices.