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Corrigin area land resources survey

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National Landcare Program (Australia)

Natural Heritage Trust (Australia)

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CORRIGIN AREA
LAND RESOURCES SURVEY

by Bill Verboom and Paul Galloway

Land Resources Series No. 20

Department of Agriculture, Western Australia

3 Baron-Hay Court

South Perth 6151

Part funded by the National Landcare Program and Natural Heritage Trust
Disclaimer

Maps are a representation of the land. Soils form a continuum in the landscape, therefore, unit boundaries are placed by surveyor judgment on evidence available at the time of mapping. These boundaries do not necessarily indicate a sharp change in soil but rather a position where the rate of change of soil and landscape is greatest.

This survey report, including maps, is designed for use at the publication scale of 1:100,000. The scale influences:

- how homogeneous the map units are,
- how accurate the lines are, and
- how accurate the descriptions and attributions are.

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 selected area, not a definitive statement.

Salmon gums growing on Alkaline grey shallow loamy duplex soils fringing Canal Road in the Toolibin catchment
The authors:

Bill Verboom and Paul Galloway are research officers with the Department of Agriculture, Western Australia, based in Narrogin.

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Cover Photo: A view of wheatbelt farmland from Yilliminning Rock, just east of Narrogin.

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Summary

This land resource survey of the Corrigin area covers some 1.8 million hectares of the central wheatbelt over the shires of Beverley, Brookton, Bruce Rock, Corrigin, Cuballing, Cunderdin, Dumbleyung, Kellerberrin, Kondinin, Kulin, Lake Grace, Merredin, Narembeen, Narrogin, Pingelly, Quairading, Tammin, Wandering and Wickepin. The survey is part of a regional scale soil-landscape mapping program designed to deliver seamless soil information for the agricultural area of south western Australia. The information provided will assist planners, researchers and land managers make decisions affecting sustainable land use and is designed for use at regional and catchment scales.

This report and accompanying CD-ROM summarizes primary and interpreted information on the soil-landscapes of the Corrigin area. The report outlines the main degradation issues and supplies background information on climate, native vegetation and geology. An important additional outcome of the survey is a new theory on soil formation that has wide-ranging ramifications for agriculture, soil science, botany and geomorphology.

Thirty-six soil-landscape systems, together with their component sub-systems and phases were recognised, mapped and described during the survey. This information, together with unmapped soil types and land qualities, is provided in the CD-ROM. The CD also showcases the main soils, provides geo-referenced soil pit and auger descriptions, maps of soil-landscapes and maps of selected degradation hazards.
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Introduction

This study aims to improve land use and reduce land degradation in the central and eastern wheatbelt through a greater understanding of its soil and land resources. It is one of a series of studies of the Western Australian wheatbelt undertaken by the Department of Agriculture with funding assistance from the National Landcare Program and the Natural Heritage Trust.

Prior to this survey, the only consistent source of soil information for the survey area has been Atlas of Australian Soils (Northcote et al. 1967) at a scale of 1:2,000,000. Whilst this atlas has provided a broad overview of the soils of the state, it has been of limited use for land-use planning and the extension of site-specific experimental results.

There is now also a need to accommodate salinity management, precision agriculture and land-value assessment. These kinds of application require more detailed spatial information and better characterization of soil, a difficult task given available manpower and the extent of productive areas within the state. To deal with these competing demands we have extracted from air photographs what reliable soil and landscape information we can in the time available without being constrained by scale. In the future, these ‘primary map-units’ can be combined with geophysical and other evidence layers to generate paddock-scale information. For now, these ‘primary map-units’ have been parcelled up into a hierarchy of landforms to provide a consistent product across the state (see Purdie 1999). ‘Individual’ soils are linked to map units by description.

Much of our report is presented in electronic format to reduce costs and maximize information content. We encourage users to print relevant portions of maps and data for their field work. Commissioned maps and other soil information are available from the Department of Agriculture’s Natural Resources Management Group.
Location

The study area covers some 1.8 million hectares around Corrigin, and includes some or all of the shires of Beverley, Brookton, Bruce Rock, Corrigin, Cuballing, Cunderdin, Dumbleyung, Kellerberrin, Kondinin, Kulin, Lake Grace, Merredin, Narembeen, Narrogin, Pingelly, Quairading, Tammin, Wandering and Wickepin (Figure 1.) It also covers parts of four crop variety testing (CVT) areas.

<table>
<thead>
<tr>
<th>CVT Code</th>
<th>Zone</th>
<th>Rainfall region</th>
<th>Rainfall range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H3</td>
<td>South Central</td>
<td>High</td>
<td>450-750</td>
</tr>
<tr>
<td>M3</td>
<td>South Central</td>
<td>Medium</td>
<td>325-450</td>
</tr>
<tr>
<td>L3</td>
<td>South Central</td>
<td>Low</td>
<td>&lt; 325</td>
</tr>
<tr>
<td>H4</td>
<td>South Central</td>
<td>High</td>
<td>450-750</td>
</tr>
<tr>
<td>M4</td>
<td>South Central</td>
<td>Medium</td>
<td>325-450</td>
</tr>
</tbody>
</table>

Figure 1. Location of the survey and its relationship to shires and crop variety testing areas.
How to use this report

This report with its accompanying 1:100,000 maps and CD-ROM has three main functions:

- to provide general information on the physiography of the Corrigin area;
- to identify the landscapes, soil and soil properties in an area of interest; and,
- to assist the reader with identifying land-use risk and suitability.

The section below outlines how to access this information.

To obtain general information on the physiography of the Corrigin area

Read the chapters on the history of land use, climate, geology, geomorphology, vegetation, soil development and the soil-landscape zones and systems of the Corrigin area. The latter chapter includes references to representative soils of the survey area. Photographs, standard morphological descriptions (McDonald et al. 1990) and available chemical and physical data on these representative soils as well as their relationship to the landscape are provided in the electronic version of this report. An appreciation of soil types and their pattern of distribution can be obtained by inspecting the maps “Major soils of the Corrigin Survey area” (.pdf files at 1:200,000 and 1:100,000 on the CD-ROM). Inspection of these maps augments the map unit descriptions given later in this report.

To identify soils and their properties in an area of interest

If using a hard copy map (printed from the .pdf files on the CD-ROM),
1. Locate the area of interest
2. From the map identify the map unit and symbol for the area of interest.
3. Go to the map legend and locate the map symbol (the map unit colour will also assist). The map legend will show the full map unit name and a brief description of soil-landscapes.
4. The CD-ROM will have to be used to obtain more detail on map unit components. This can be done by selecting the name of the map unit from the home page of the CD-ROM and stepping down to the required level of information.

If using the CD-ROM,
1. Click on the “Interactive Maps” on the home page. This will open up a map window in which a series of map topics can be viewed.
2. Click on the “Sub-systems”, the most detailed soil-landscape mapping.
3. Navigate using zooming or locating tool buttons to area of interest.
4. Information on a selected map unit can be viewed by clicking on it.
5. The site number and WA Soil Group of soil point observations (ie. pits and augers) is shown in a tool tip when the cursor hovers over such an object.
6. More detailed information is available for purple soil points and this can be viewed by clicking on them.
To identify land-use risk and suitability.

The land quality of a particular map unit is not directly available. However, each map unit can be assessed by inspecting the land qualities of its unmapped components, available on the CD-ROM. A selection of thematic maps focusing on the major degradation issues is also provided through the Interactive Maps on the CD-ROM.

Land use specialists can evaluate risks and capability by inspecting the photographs, standard morphological descriptions and available chemical and physical data of representative profiles (available on the CD-ROM).

The Department of Agriculture can also provide an assessment of land capability in a particular area if the area’s coordinates and intended use are specified.

York gum and jam vegetation growing on Red shallow loam in the Zone of Rejuvenated Drainage
Published Land Resource Data

Teakle (1938) described three soil zones in the Corrigin survey area.
1. The zone of grey, yellow and red podsolised soils of temperate sclerophyll forest
2. The zone of red-brown earths of the *Eucalyptus-Acacia* woodlands
3. The zone of grey and brown calcareous, solonised soil of the low rainfall *Eucalyptus* woodlands

Mulcahy (1967) overlaid these soil zones with corresponding laterite zones, respectively: the detrital laterites, the younger laterites and the lateritic sand plains. In latter years, the commonly used source for regional soil information in the Corrigin survey area was map sheet 5 of the Atlas of Australian soils (Northcote et al. 1967). This mapping was subsequently used by Stoneman (1990, 1991a,b, 1992) to develop several regional soil information packages. These products have now been replaced by the present series of land resource surveys. Surveys in this series bordering the Corrigin survey area are shown in Figure 2.

![Figure 2. Land Resource Surveys surrounding the Corrigin survey area.](image)

Other resource information available for the area, at a scale of 1:250,000, is original vegetation by Beard (1979, 1980a and 1980b) and geology by Wilde and Low (1980) and Chin (1986a & 1986b). Land use data is available from the Department of Agriculture, and climatic information can be obtained from the Bureau of Meteorology (see [http://www.bom.gov.au/climate/averages](http://www.bom.gov.au/climate/averages)). Relatively high-resolution digital elevation models (DEMs) are available from the Land Monitor project, ([http://www.landmonitor.wa.gov.au](http://www.landmonitor.wa.gov.au)). Radiometric and other geophysical data is available for the Lake Toolibin catchment (National Airborne Geophysics Project).
Survey methods

Field work for this regional scale soil-landscape mapping survey was undertaken between April 1995 and November 1997. Methodology included:

- Review of previous work in the area;
- Field reconnaissance to identify soils already described;
- The study of soil/vegetation/topographical and geological relationships at a number of study sites across the survey area;
- Identification of preliminary map unit boundaries (mainly phases and subsystems) by stereoscopic air photo interpretation of 1:25,000, colour photos taken in the early nineteen nineties (job numbers WA2332, 3018, 3022, 3024, 3312, 3448, 3679 and 3799). In places, interpretation was frustrated by poorly contrasting photography taken late in the year when stubble blanketed the fields (See Figure 3 for affected areas);
- Line work was captured by registering the aerial photographs against DOLA cadastre reference files and digitising the soil-landscape boundaries using MicroStation software;
- Soil System and Zone boundaries were delineated using the interpreted information described above, 1:250,000 scale total magnetic intensity maps from the Bureau of Mineral Resources and geological maps (1:250,000) and explanatory notes from the Geological Survey of Western Australia (Wilde and Low 1980, Chin 1986a & 1986b);
- Sampling sites were chosen using free survey techniques (Gunn et. al. 1988). Observed relationships between soil profiles and the wider landscape were used in conjunction with geophysical evidence to test and improve the conceptual models of soil genesis and distribution;
- Description, photography and sampling of soil profiles and their environment was conducted according to procedures stipulated by Gunn et. al. (1988) and McDonald et al. (1990). Soil profiles were described from pits and/or hand auger borings to a depth of at least 1 m, where possible. Morphological, chemical and physical data together with methodologies, were coded according to Purdie (1993) and entered into the Department of Agriculture’s Soil Profile database;
- 2130 soil profiles were described (an average density of 1 per 845 ha). Their distribution is shown in Figure 4. The level of detail ranges from comprehensive descriptions of soil pits (data points) to abbreviated description of auger borings (observation points). The 198 pits generally have photographs, morphological descriptions and chemical data. Replicated bulk density determinations are available for a few of these.
- The soil at each point was classified according to the Western Australian Soil Group (Schoknecht, 2002). Most pits were also classified according to the Australian Soil Classification (Isbell, 1996). However, for this report, ASC is provided in terms of the revised edition (Isbell 2002).
Figure 3. Quality of air photography across the survey area

Figure 4. Distribution of field sites within the survey area
- Map line work was stored in a Geographical Information System (Intergraph MGE/Oracle database). Map unit descriptions are held in a Map Unit database according to the format of Purdie (1999). All data is held in digital form by the Natural Resources Management Group at the Department of Agriculture.

- Assessment of land qualities, that affect the capability of the land to support various land uses without undesirable on-site or off-site effects, are based on methods outlined by van Gool and Moore (1999).

Flooded gum growing on Yellow/brown shallow loamy duplex in a valley of the eastern Darling Range
History of Land Use

Before European settlement, most of the survey area appears to have been the territory of Aboriginal people from the Njaki - Njaki or Kojar tribal groups. They were nomadic people who moved regularly through the area stopping near waterholes for hunting and ceremonial purposes. Over the centuries well-beaten paths developed between the waterholes and beneficial features of the landscape.

Following the establishment of the Swan River Colony in 1829, Ensign Dale, who was attached to the Lands Office, lead an exploration expedition east from the newly discovered Avon Valley into the north eastern part of the survey area to the edge of the Bruce Rock shire. The Avon Valley was permanently settled by Europeans soon afterwards. An expedition by Hillman passed through the western areas of the Narrogin shire in 1835. Hillman conducted another expedition in 1836 through to the south coast. These explorations foreshadowed a new line of homesteads stretching from York to Albany.

The desire of colonists to expand areas available to cropping and grazing prompted Roe, as Surveyor General of the fledgling colony, to mount further expeditions. In 1836, he led a party from the newly established settlement of York through to Narembeen and Mt Walker. Then again in 1848-9 they travelled down the Avon to Nalyaring, a sheep station near Brookton, then inland though Kulin, Kondinin, and Karlgarin, to east of Hyden, before turning SSW and heading for the Stirling Ranges.

In 1843, following reports by Aborigines of an inland sea south-east of Beverley, Landor and Lefroy travelled through the country along the headwaters of the Hotham and Williams rivers, through Wickepin to the vicinity of Lake Dumbleyung. Despite their unfavourable reports, much of this country appears to have been taken up as pastoral leases within 20 years.

Informal exploration of the area continued from about 1845 as Sandalwood cutters slowly worked their way in from the west, branching off from key trails which followed old Aboriginal trails from soak to soak and camp to camp. By the mid 1870s the best stands of sandalwood within the region had been cut.

The rough tracks cut by these men for their horse and drays were followed initially by pastoralists looking for land beyond the fringes of the settled areas on which to run their sheep. These flocks were under the control of shepherds who walked their stock to areas where water and forage could be found. By the 1860s shepherding had spread as far as Quairading and the edges of the Bruce Rock shire despite severe stock losses to poison plants particularly on the sandy ridges. Lefroy mounted an expedition into the Bruce Rock and Narembeen areas in 1863 to look for new country suitable for cropping and grazing. It is of interest that in his expedition journal, Lefroy comments on the difficulty in obtaining bush feed for his horses as far east as Narembeen and that “…probably the sheep had destroyed all feed near the station”.

The colony's population and economic problems were resolved for a time with the gold rush that started in the Kimberley in 1885 and in the southern goldfields in 1892. The gold rush resulted in a six-fold increase in population between 1880 and 1900, from 30,000 to 180,000, which aggravated the scarcity of local food supplies. Government revenue increased from £180,000 to £3,000,000 over the same period. These funds were used to encourage
agriculture, which were anticipated to power the economy after easily accessible gold reserves were exhausted.

The railway played a big part in the agricultural development of the region. It began with the opening of the Great Southern Railway from Beverley to Albany in 1889. With transport then available to cart grain and bring in supplies, areas adjacent to the line were opened up for farming. From 1889, strategically placed estates were repurchased by the Government, and resurveyed as Agricultural Areas. The Wickepin Agricultural Area was declared in 1905, and grew quickly with the completion of a spur line from Narrogin to Wickepin in 1909 and the continuation of the line through Yealering to Corrigin in 1911. Most of the arable land along the railways was taken up even before the construction of the line. To the east small farming settlements grew around reliable water supplies or in areas where the land was considered of particularly high quality. Tincurrin, Dudinin, Jitarning, Kulin and Kondinin were all settled from about 1908 and were connected by a loop line junction from Yilliminning in 1915. This was extended to Narembeen in 1917, and later to Merredin.

A spur line was built from York to Quairading and extended to Bruce Rock in 1913. This area was settled by farmers from about 1905, although the Bruce Rock area was not surveyed for farming until 1910. At the same time another connecting line was built between Brookton and Corrigin.

For farming purposes, land was surveyed into 100, 500 or 1,000 acre blocks and classified as either first, second, or third class land. First class land included the heavily wooded clayey land of the valley floors, while hillslope duplexes were generally classified as second class land. Sandplain, ironstone gravels, rocky outcrops, swamps, and lakes were classified as third class land.

As farming spread from the medium rainfall areas in the west to the lower rainfall of the eastern wheatbelt, farming practices were also forced to change from mixed farming to a reliance on cropping. In these areas, ringbarking of the trees was not followed (as happened further west) by the lush growth of native grasses. Thus this first class land, although excellent cropping country, was only of limited value for grazing. This remained the case until the introduction of clovers and medics in the 1920s and 1930s.

Superphosphate was introduced in the early 1900s and its use as a cropping fertiliser steadily increased when its local manufacture commenced in 1910. With this came a re-evaluation of the relative value of some of the soil types for cropping. The salmon gum, gimlet, and morrel country always produced good crops, especially with the addition of 70-100 kg/ha of super. However, it was also found that the lighter soil supporting mallee and small jam, although generally lower yielding, and more reliant on superphosphate, in drier seasons had a yield advantage over the heavier soil.

The value of third class land continued to rise as trace element research from the late 1920s onwards indicated that deficiencies of Cu, Zn, Mo, Mn, and Co on the lighter, low yielding sandplain soil could be rectified by fertilizer application. However, this practice did not become widespread until after further research by the Department of Agriculture after WW2.

In the early 1920s, the Department of Agriculture showed that the legume, subterranean clover, could provide valuable pasture. However, its use did not become widespread until after many farming areas were rehabilitated by returning ex-servicemen in the late 1940s. Clearing after world war II was promoted by Government and continued to the mid 1970s. Many less experienced farmers on small blocks proved to be unprofitable and a period of
consolidation followed. Wheat quotas, falling wool prices and increases in the price of superphosphate contributed to declining profitability margins, which resulted in some farmers leaving the land. Many remaining farmers borrowed to expand their properties and this increased indebtedness. Today, large properties in eastern parts of the Corrigin area seem to be locked in boom and bust cycles. Production in the west is much more reliable. A comprehensive account of agriculture in Western Australia between 1829-1979 is provided by Burvill (1979).

Today, land use continues to be based on dryland agricultural production using annual, winter growing, pastures and crops. Livestock production is dominated by wool production with trade in sheep for meat increasing in importance. The types of crops and rotations are greatly influenced by soil types and rainfall.

The main pastures are annual pastures based on subterranean clover often mixed with annual grasses such as rye grass and broad-leaved species such as capeweed. Annual medics occupy a niche on some alkaline soils. The length of pasture phases range from longer-term pastures of 4 to 5 years to year in year out crop/pasture and continuous cropping. There is an increasing trend towards multiple cropping alternating with pasture phases. Recently, alternative pasture species have been introduced into specific environmental niches. Balansa clover is often mixed with perennial grasses on waterlogged and slightly saline land and serradella grows well on well-drained sandy surfaced soils. Some landholders are incorporating lucerne as a perennial pasture phase to increase water use, help reduce groundwater recharge and increase soil fertility. Although sheep numbers declined during most of the 1990s, they remain a part of the rotation on many farms.

Cereals (wheat, barley, oats, and hay) remain the main crops within the rotation. Canola on a wide range of soils, and lupins on sandier, acid soils, are widely grown to break disease cycles and reduce herbicide resistance. Small areas of faba beans, field peas, chickpeas, and lentils are grown as break crops on neutral to alkaline soils.

Over the past decade, farmers have become more aware of land conservation issues, particularly increasing salinity. There is increasing interest in re-establishing perennials but options for commercial species are relatively limited due to low rainfall. Options include oil mallees in belts and saltbush species on salt-affected land. Research continues into farming systems that include perennials. Sandalwood (*Santalum spicatum*) and maritime pine (*Pinus pinaster*) show some promise.
Climate

The survey area has a dry to extra dry Mediterranean climate with hot dry summers and cool wet winters. Average annual rainfall increases from 325 mm in the north east to 600mm in the west. It falls mainly in the winter months during the passage of cold fronts. Summer storms are infrequent but may be intense and can cause significant erosion and agronomic problems. Rainfall, evaporative demand and temperatures from recording stations in and close to the Corrigin survey area are summarised in Table 1. Stations within the Corrigin Survey area are located and the monthly rainfall and temperatures for five selected stations are summarised in Figure 5.

Table 1: Climatic summary for recording stations in and close to the Corrigin Survey Area. (Towns arranged roughly on the rainfall gradient from east to west.)

<table>
<thead>
<tr>
<th>Town</th>
<th>Annual Rainfall (mm)</th>
<th>Annual Rain Days</th>
<th>Annual Evaporation (mm)</th>
<th>January Mean Max Temp (°C)</th>
<th>January Mean Min Temp (°C)</th>
<th>July Mean Max Temp (°C)</th>
<th>July Mean Min Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narembeen</td>
<td>336</td>
<td>71</td>
<td>2153</td>
<td>33.5</td>
<td>16.4</td>
<td>16.4</td>
<td>5.4</td>
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<tr>
<td>Kondinin</td>
<td>343</td>
<td>76</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Lake Grace</td>
<td>357</td>
<td>89</td>
<td>1935</td>
<td>31.4</td>
<td>14.9</td>
<td>15.5</td>
<td>5.7</td>
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<td>Kulin</td>
<td>364</td>
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<td>n/a</td>
<td>n/a</td>
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<td>Quairading</td>
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<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Corrigin</td>
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<td>15.1</td>
<td>4.9</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Wickepin</td>
<td>417</td>
<td>82</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Brookton</td>
<td>459</td>
<td>88</td>
<td>2080</td>
<td>33.0</td>
<td>15.1</td>
<td>16.0</td>
<td>4.5</td>
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<tr>
<td>Pingelly</td>
<td>454</td>
<td>90</td>
<td>1934</td>
<td>31.7</td>
<td>15.6</td>
<td>15.2</td>
<td>5.8</td>
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<td>Narrogin</td>
<td>506</td>
<td>98</td>
<td>1715</td>
<td>30.8</td>
<td>14.6</td>
<td>14.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

The beginning of winter rains (the break of the growing season) is generally between late April and early May although in some years the break may occur as late as June or even July. The growing seasons (determined as that part of the year when actual rainfall exceeds the effective rainfall) are, mostly, between 5 to 6 months in the West to 3.5 to 5.5 months in the east. Frosts occur throughout the survey area from late March to mid November, although most commonly between mid May and mid October. From an agricultural viewpoint, the most damaging frosts occur in September and October when cereal seed set can be seriously affected. The severity is largely a function of local topography and soil type. Areas with sandy-surfaced soil in low-lying landscape positions are most susceptible, while north-east facing upper slopes are least susceptible.

Throughout summer, wind patterns are controlled by the movement of high-pressure systems and the development of low-pressure heat troughs. During winter, strong winds accompany the passage of cold fronts which move in an easterly direction across the survey area. In autumn, the change from summer to winter weather patterns is associated with strong winds which cause erosion to over grazed or cultivated paddocks or paddocks where stubble has been burnt. The remains of cyclones from the north-east can also result in erosive winds. Further information and explanatory notes on climate statistics are available from the Bureau of Meteorology [http://www.bom.gov.au/climate/averages](http://www.bom.gov.au/climate/averages)
Figure 5. Annual average rainfall isohyets and weather recording stations in and around the Corrigin Survey area with insets of monthly temperature, rainfall and evaporation for five selected stations.
Geology and Geomorphology

The geological setting of the Corrigin Survey area is essentially one of an Archaean crystalline basement comprising an arcuate belt of gneisses along the western margin of an ancient shield. This shield, or Yilgarn Craton as it is locally known, was initially intruded by granite plutons and later by sub-parallel swarms of dolerite, diorite and quartz-feldspar dykes of Proterozoic age. The batholithic remains of two of these plutons, a major dyke suite and a major metamorphic belt are designated in a simplified geological map of the area (Figure 6). Mafic, ultramafic and metasedimentary enclaves occur in amongst gneisses, with migmatites mainly along the margins of the granite plutons.

Figure 6. Simplified geological map of the Corrigin survey area.

The Yilgarn Craton is rigid relative to adjacent geological provinces to its west and as such, concentrates intra-plate stresses along its seaward margin. Failures along this margin have resulted in a series of earth movements and landscape rejuvenating events. ‘Recent’ tectonic activity along the north-north-westerly trending Yandanooka-Cape Riche lineament, west of Meckering (Chin 1986b), has had a considerable influence on the geomorphology, soil and vegetation of the Avon catchment. The most affected areas are assigned to the Zone of Rejuvenated Drainage. The Avon and Murray rivers, with their relatively narrow valley floors, drain this area. Landscapes on the Craton itself (the Zone of Ancient Drainage) are
characterized by broad, gently undulating interfluves and wide, flat-floored valleys laden with sediments and exhibiting very low down-stream gradients.

The general landscape trend is relatively hilly in west becoming flatter in the east. In the far western areas (west of Brookton), the landscape is lateritic with high relative relief. The central west is hilly and stripped, with incised V-shaped valleys and common fresh rock exposures. Valleys in the east are broad and flat with low down-stream gradients. Salt lake chains are common in the lowest positions of the trunk valleys. The eastern interfluves are broad and subdued.

Secondary salinity is particularly marked along the western margin of the Zone of Ancient Drainage. In our opinion, episodic salinisation has probably occurred here in the geological past. We discuss evidence for this in a companion *poster* provided on the CD-ROM (see Appendix B “Salinity in the Central Wheatbelt”).

Intact and denuded laterites in various stages of development are prominent on uplands across the survey area. These kinds of soil have been forming and eroding in south-west Western Australia throughout much of the Tertiary and in our view these processes continue as a contemporary phenomenon where native vegetation remains. For a more complete discussion see Pate *et al.* (2001). The landscapes are described in greater detail in the Map Units section below.

![Lateritic breakaway formed on mafic substrate near Jitarning](image-url)
Vegetation

Western Australia is divided into three Botanical Provinces - the South-Western, the Eremaean and the Northern. The Botanical Provinces are in turn divided into Botanical Districts and then into Vegetation Systems and vegetation units.

The Corrigin Survey lies within the Darling, Avon and the Roe Botanical Districts of the South-West Botanical Province. Each district contains portions of several Vegetation Systems, which define a series of plant communities occurring in mosaic patterns linked to topographic and soil features. Vegetation Systems are shown in the accompanying map (Figure 7). Unfortunately for that mapping, some 85-95% of the Corrigin area’s very diverse native vegetation had been cleared for agriculture with attendant loss of species. Thus, it relied on remnants for much of the botanical mapping (Beard, 1979, 1980a, 1980b).

Botanical Districts

The survey area intersects three Botanical districts. In turn these are subdivided into vegetation systems, each representing a particular series of plant communities recurring in a catenary sequence or mosaic pattern linked to topographic, pedological and or geological features. These districts and systems are shown in Figure 7 and summarized below. These summaries are based on Beard’s memoirs (Beard, 1972a, 1972b, 1979, 1980a, 1980b, 1980c).

The Dale Subdistrict of the Darling Botanical District is for the most part, the jarrah and wandoo forests on the Darling Ranges north of Collie.

Typical sequences of vegetation in the Avon Botanical District comprise proteaceous scrub-heath or *Acacia-Allocasuarina* thickets on lateritic sandplain, woodlands of York gum (*E. loxophleba*) and jam (*A. acuminata*) on gradational well drained loams, salmon gum (*E. salmonophloia*) and wandoo (*E. wandoo*) on less well drained loams and duplexes and halophytes on saline soil.

The general cover in the Roe Botanical District is mallee with *E. eremophila* being the most consistent species. Patches of eucalypt woodland occur on lower ground, and scrub heath and *Allocasuarina* thickets on residual plateau soil.
Figure 7. Botanical Districts and simplified Vegetation Systems of the Corrigin Survey area.
Soil

The landscapes of the Corrigin survey area are characterized by widespread occurrences of inherently infertile soil that used to be vegetated by unique flora displaying extraordinary adaptations, endemism, species diversity and specificity for soil type. Examples of these features and relationships can still be seen in remnant patches of native vegetation in natural condition. On uplands in such areas, one frequently encounters domains of proteaceous and casuarinaceous vegetation on ironstone gravelly and sandy (lateritic) soils, interspersed with areas of richer ‘granitic’ loams under York gum and jam woodland. Lower slopes and valley flats generally contain various types of eucalyptus woodland on an assortment of duplexes and clays. (The word ‘richer’ has to be used advisedly as on a world scale all these soil would be regarded as nutrient poor.)

The reason for the high proportion of ‘low’ phosphorous (P) soil in Australia, and the decrease in available soil P from the rain forests of the east to the sclerophyll heath of south-west Western Australia has never been clear. Wild (1958) associated Australia’s low P soil with extensive leaching and lateritic weathering during the mid to late-Tertiary while Beadle (1954) attributed this to the prevalence of worked and transported materials that, over time, lost P-rich fines and coarser P-rich plant material to water and wind erosion. Why this type of process should have been more efficacious in Australia and why it should peak in the south west of Western Australia was never properly explained. Beadle (1962) saw that the distribution of the ‘scleromorphic’ habit in native vegetation might be related to trends in soil P and evolution of angiosperm flora entering Australia via a land bridge from Asia. He also realised that the low P status of their habitat soil ‘protected’ these plant communities from invasion by plants with higher nutrient requirements. Gardner (1944) and Prescott (1952) felt that the above relationships arose from edaphic adaptations to low P and this view has remained largely unchallenged.

However, in recent publications we (Verboom and Galloway 2000; Pate et al. 2001; Verboom and Pate 2002; Verboom and Pate 2003) speculate that laterite generation in Western Australia is causally linked to nutrient acquisition strategies of proteaceous and casuarinaceous heath and woodland in nutrient deficient settings. One might well speculate further about plant-soil interactions, as minerals having a strong influence on the bioavailability of P can be found, in nodular form, in horizons conforming to the rooting zone of native flora. For example, under *E. salmonophloia* woodland communities one commonly encounters biogenic carbonate. This soil and vegetation type can change abruptly over a lateral distance of less than a metre to nodular ferricretes under proteaceous and casuarinaceous communities. Such field arrangements are consistent with different groupings of taxa having subtly different mechanisms for P and micro-nutrient uptake depending on their microbial/mycorrhizal associates, the types of organic anions secreted and whether or not protons accompany such secretion (see Lambers, et al. 1998; Roelofs et al. 2001; Jones et. al. 2003 and Hinsinger et. al. 2003). Plants may also be engineering soil conditions (see Appendix B “Can Darwinian …”) that deny water to competitors, or create phyto-toxic levels of acidity, aluminium and salts.

Influences on soil formation, other than those described above, are particularly active in the flat valleys where soil make-up is affected by sedimentation regime, source of the sediments, and the influence of water and wind (hydro-aeolian activity). The general trend in the valleys from the south-west to north-east of the survey area is increasing alkalinity and redness of colour and heavier textured topsoils. More specifically, acid to neutral sandy sodic duplexes
and alkaline grey clays in the south west give way to red calcareous loamy duplexes and red clays towards the north east.

Many valley profiles are being invaded by rising acid-saline groundwaters. Ferrolysis and oxidation of sulphides (some of it by microbes - Aspandiar - *pers. comm.*) result in further profile acidification. Sodic soils become flocculated by the high salt concentrations, carbonates dissolve and many low-lying depressions contain fluffy salt/mud/iron efflorescences. Field observations of soil-landscapes suggest that groundwaters have risen and fallen on a number of occasions (see Appendix B “Salinity in the Central Wheatbelt”) prior to European settlement.

Common Australian Soil Classification soil orders in the survey area are Chromosols and Sodosols in valleys in south-western parts with Calcarosols increasingly frequent in valleys towards the north-west. Tenosols, Kandosols and Chromosols occur in intimate association on interfluves across the survey area with loamy Tenosols becoming prominent towards the north-west.

**Classification of Soil Profiles**

There are numerous ways to classify soil profiles. This survey has used two formal classification systems – the Soil Groups of Western Australia (WASG) and the Australian Classification System (ASC), plus a locally applicable soil name that emphasizes the important relationship of soil and the native vegetation.

The Soil Groups of Western Australia (Schoknecht 2002) is a Western Australian system that emphasizes soil conditions impacting on the growth of annual plants and standardizes the common naming of soils across the state. The system relies on wetness, rockiness, ironstone gravellyness, and the arrangement of texture down the profile to distinguish a broad level called Supergroups, and other features such as colour, structure and carbonate content to differentiate at the Soil Group level.

The Australian Soil Classification (Isbell 2002) is a widely used national system. The ASC is based on features of the profile having genetic or morphological significance. Representative profiles have also been assigned an Australian Soil Classification class (Isbell, 1996, 2002) for correlation purposes.

The local soil naming system describes natural soil classes that directly link to the fundamental inter-relationships between soil and the original native vegetation. They also provide an appropriate level of detail for land management.

Conflict between soil classes prescribed by the WASG and ASC systems and the local surveyors judgment on what constitutes a natural soil class that can be managed as a single unit occurs quite frequently. It arises because traditional or highly structured classification systems are not always tailored for local conditions and so may unnecessarily divide a perceived natural soil class (habitat soil), thus creating artifacts, or more seriously, may wrongly combine quite different habitat soil. Our view is that soil classifications would benefit from recognition of the impact of evolution on pedogenesis (see Appendix B “Salinity in the Central Wheatbelt”). Although WASG and ASC classes were used it was also considered important that the concept of natural soil classes was presented. To achieve this, natural soil classes have been named and described (local soils) using native vegetation or...
other terms used by local farmers. These local soils are in effect Soil Series as described by Purdie (1999).

It is also worthwhile to associate representative profiles with the broader management units of the kind used by the original land surveyors (see History of land use chapter). These broad categories recognize fundamental land qualities that repeat across the wheatbelt. Indeed, Corrigin and Elashgin survey experience utilizing radiometric imagery (see Verboom and Pate 2003) shows that broad scale Potassium (K) patterns define four main ecosystem/pedogenetic categories (or “landscape types”). These are:

- Lateritic/Podzolic (equivalent to the old surveyors third class land),
- ‘Fresh’ rocky soils (equivalent to the old surveyors second or third class land),
- Hillslope duplexes (equivalent to second class land) and
- Flat Valley soils (heavy variants were first class land).

Each representative profile has been assigned to one of these ecosystem/pedogenetic categories.

**Representative Soil Profiles**

A summary of common soils in each of the soil-landscape zones in the Corrigin area is provided in Table 2.

The constitution of representative profiles is exhibited on the CD-ROM, using photographs, standard morphological descriptions (McDonald *et al.* 1990) and available chemical and physical data using methods outlined in Appendix A. Some mineralogical data and information on other, more detailed, profile studies can be found in the Reference soils of south-western Australia (McArthur 1991). The representative profiles on the CD-ROM are composed of two components:

1. a local soil name and general characteristics of the soil (including one or more WASG and ASC), and
2. details of a type profile.
Table 2: Representative profiles for each soil-landscape zone.

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group/s</th>
<th>Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eastern Darling Range Zone</td>
</tr>
<tr>
<td>1792</td>
<td>Jarrah/Marri Yellow Sand</td>
<td>Yellow deep sand</td>
<td>X</td>
</tr>
<tr>
<td>1789</td>
<td>Flooded Gum Duplex</td>
<td>Brown deep loamy duplex, Yellow/brown shallow loamy sand</td>
<td>X</td>
</tr>
<tr>
<td>1793-</td>
<td>Marri/Wandoo Duplex</td>
<td>Grey deep sandy dupl</td>
<td>X</td>
</tr>
<tr>
<td>1791</td>
<td>Jarrah Pea Gravel</td>
<td>Deep sandy gravel</td>
<td>X</td>
</tr>
<tr>
<td>1796</td>
<td>York Gum/Jam Soil</td>
<td>Brown or Red sandy or loamy duplexes</td>
<td>X</td>
</tr>
<tr>
<td>1795</td>
<td>Rock-Sheoak Sand</td>
<td>Brown deep sand, Brown sandy earth, Yellow/brown shallow sand</td>
<td>X</td>
</tr>
<tr>
<td>1794</td>
<td>York Gum/Wandoo Soil</td>
<td>Brown shallow loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>0895</td>
<td>Wandoo Sheoak Sand</td>
<td>Pale deep sand, Brown deep sand</td>
<td>X</td>
</tr>
<tr>
<td>0891</td>
<td>Dolerite loam</td>
<td>Red or brown deep loamy duplex, Yellow/brown or red shallow loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>WAR</td>
<td>Wandoow/Sheoak Sandy</td>
<td>Grey deep sandy dupl</td>
<td>X</td>
</tr>
<tr>
<td>UP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1485</td>
<td>Rocky Red Loam</td>
<td>Red sandy or loamy earth, Red shallow sand or loam</td>
<td>X</td>
</tr>
<tr>
<td>1482</td>
<td>Salt Lake Soil</td>
<td>Salt lake soil, Saline wet soil, Brown loamy earth (saline)</td>
<td>X</td>
</tr>
<tr>
<td>1483</td>
<td>Salt Land Soil</td>
<td>Variable soils including Brown loamy earth (saline) and Saline wet soil</td>
<td>X</td>
</tr>
<tr>
<td>1481</td>
<td>Morrel Soil</td>
<td>Alkaline red shallow loamy duplex, Calcareous loamy earth</td>
<td>X</td>
</tr>
<tr>
<td>1480</td>
<td>Salmon Gum Red Soil</td>
<td>Alkaline red shallow loamy duplex, Red or Calcareous loamy earth</td>
<td>X</td>
</tr>
<tr>
<td>1474</td>
<td>Shallow Tammar Gravel</td>
<td>Shallow gravel</td>
<td>X</td>
</tr>
<tr>
<td>1473</td>
<td>Grevillea/Wodjil Yellow Sand</td>
<td>Yellow loamy or sandy earth, Acid yellow sandy earth</td>
<td>X</td>
</tr>
<tr>
<td>1472</td>
<td>Deep Tammar Gravel</td>
<td>Reticulite deep sandy duplex, Duplex sandy gravel</td>
<td>X</td>
</tr>
<tr>
<td>1471</td>
<td>Mallee/Jam Soil</td>
<td>Brown deep sand, Brown loamy earth, Brown deep sandy or loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>0181</td>
<td>Gimlet Soil</td>
<td>Alkaline red loamy duplex, Calcareous loamy earth</td>
<td>X</td>
</tr>
<tr>
<td>0215</td>
<td>Kwongan Sandy Gravel</td>
<td>Gravelly pale deep sand, Pale deep sand</td>
<td>X</td>
</tr>
<tr>
<td>0212</td>
<td>Good Yellow Sand</td>
<td>Yellow or brown sandy earth</td>
<td>X</td>
</tr>
<tr>
<td>0211</td>
<td>Kwongan Cap rock</td>
<td>Yellow/brown shallow sand, Shallow gravel</td>
<td>X</td>
</tr>
<tr>
<td>0099</td>
<td>Salmon Gum Grey Duplex</td>
<td>Alkaline grey shallow loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>0091</td>
<td>York Gum Valley Duplex</td>
<td>Grey deep sandy duplex</td>
<td>X</td>
</tr>
<tr>
<td>0090</td>
<td>Wandoo Brown Duplex</td>
<td>Yellow/brown deep sandy duplex</td>
<td>X</td>
</tr>
<tr>
<td>NYA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1776</td>
<td>Heavy Eastern York Gum Soil</td>
<td>Red shallow loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>1770</td>
<td>Light Eastern York Gum Soil</td>
<td>Brown deep loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>1773</td>
<td>Mallee Broombush Soil</td>
<td>Grey deep sandy duplex</td>
<td>X</td>
</tr>
<tr>
<td>1772</td>
<td>Mallee/White Gum Soil</td>
<td>Yellow/brown shallow loamy duplex</td>
<td>X</td>
</tr>
<tr>
<td>NDS4</td>
<td>Mallee Gravel Soil</td>
<td>Grey deep sandy duplex, gravelly</td>
<td>X</td>
</tr>
<tr>
<td>1774</td>
<td>Saline Wet Grey Loam</td>
<td>Saline wet soil</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: Munsell colour classification is used in both WA soil group and ASC classifications. Grey, yellow or brown soils may be classified differently than intuition might suggest.
Map Units

Map Unit Hierarchy

The Corrigin area was mapped using soil-landscape units that identify areas of similar soil and landforms. The soil-landscape mapping utilizes a map unit hierarchy to maintain a consistent approach with different scales of mapping and varying levels of complexity of soils and landscapes (Purdie 1999). Moving down the hierarchy, the units cover smaller areas and complexity within each unit usually decreases (Figure 8).

Each soil-landscape map unit in Western Australia has a unique symbol indicating its place in the mapping unit hierarchy. (For example: 257Pn_1s indicates the map unit is in the Western Region (2), Avon Province (25), Zone of Rejuvenated Drainage (257), Pingelly System (257Pn), Pingelly 1 Subsystem (259Pn_1), Pingelly 1 Sandy Phase (259Pn_1s).

The full symbol is used in digital maps and in the Soil Profile and Map Unit Databases. On small scale maps designed for hard copy production (in .pdf format) the leading numerals are omitted to improve readability.

Morrels growing on dunes of Calcareous loamy earth on the margin of a salinised lake near Lake Toolibin
1. Regions
Broad subdivisions of the Australian continent (Division of Soils, Bettenay, 1983).
e.g. The Western Region (2)

2. Provinces
Provides a broad overview of the whole state suitable for maps at scales of about 1:5,000,000 (Division of Soils, Bettenay, 1983).
e.g. The Avon Province (25)

3. Zones
Areas defined on geomorphological or geological criteria, suitable for regional perspectives.
e.g. Zone of Rejuvenated Drainage (257)

4. Systems
Areas with recurring patterns of landforms, soils and vegetation, suitable for regional mapping at scales of 1:250,000.
e.g. Pingelly System (257Pn)

5. Subsystems
Areas of characteristic landforms features containing definite suites of soils, suitable for mapping at regional scales of 1:100,000.
e.g. Pingelly 1 Subsystem (257Pn_1)

6. Subsystem phases
Division of subsystems based on land use interpretation requirements.
e.g. Pingelly 1 Subsystem sandy phase (257Pn_1s)

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

Figure 8. Hierarchy of soil-landscape map units used in this report.
Map Unit Description

This section describes the characteristics of the provinces, zones and systems that occur in the study area. The systems are further divided into subsystems or phases on the map, and descriptions of these units can be found on the map legend and by selecting the relevant unit on the interactive CD-ROM.

The Corrigin survey is located within the Western 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). One soil-landscape province, the Avon, is represented in the survey area.

The Avon Province is a lateritised plateau on Precambrian granites and gneisses, dissected at its margins by rivers including the Swan-Avon, Murray and the Blackwood (Bettenay 1983). This province incorporates the Western Darling Range Zone, the Eastern Darling Range Zone, the Northern and Southern Zones of Rejuvenated Drainage, the Northern, the South-Eastern and South-Western Zones of Ancient Drainage. All except the Western Darling Range Zone occur in the survey area.

The extent of these zones in the Corrigin survey area is shown in Figure 9. The distribution of soil-landscape systems is provided on the CD-ROM.

Figure 9. Soil-landscape zones of the Corrigin survey area.
Eastern Darling Range Zone (253)

The Eastern Darling Range Zone occurs in the far west of the survey area between the Western Darling Range Zone and the Northern and Southern Zones of Rejuvenated Drainage. It is characterised by partial and variable dissection of the Darling Range laterites at the upper reaches of the eastward-flowing Dale River and its tributaries. Many lateritic scarps align with dolerite dykes and there is little concordance between laterite survival and peneplanation as might be expected from traditional theories emanating from Woolnough (1927). Indeed, deeply weathered lateritic profiles are perhaps even more abundant on the Darling Ranges than on some of the more subdued surfaces further inland and this is seen on the southern margins of the shield block as well. This is not to say that rejuvenation has no influence on laterite distribution. It certainly does. Where headward incision denudes lateritic mantles exposing nutrient-bearing basement, one encounters ‘fertile’ York gum/jam country. Similar incision into sediments stimulates new laterite formation, which some have interpreted as landscape inversion. However, we believe that nutritional effects of erosion guide colonization by vegetation and trajectories of soil formation and landscape evolution (see Appendix B “Landscape inversion”.

The Eastern Darling Range Zone roughly coincides with eastern portion of the Dale Subdistrict of the Darling Botanical District, as defined by Beard (1979). This area is dominated in the main by wandoo or jarrah-marri forests. Within the survey area, this zone includes four soil-landscape systems and six main soil types. Exemplary landscape positions for these soil types are marked on an oblique view of an aerial photograph which has been draped over a digital elevation model (Figure 10). Local names and WA Soil groups are tabulated in Table 3.

The Wundowie System occupies the far south-west corner of the survey area and is relatively unaffected by stripping. It is thus dominated by a relatively intact undulating lateritic mantle with occasional granite outcrop. The soil contains various ferricretes and their ‘breakdown’ products. This assemblage includes duricrusts (Parrotbush Caprock), “pea” shaped gravels (Jarrah Pea Gravel) and yellow sands (Jarrah/Marri Yellow Sand) that have been vigorously bioturbated and colluviated in the native condition. The vegetation suite conforms to the lateritic component of Beards (1979) Bannister System, which is mainly vegetated by jarrah-marri-wandoo-powder bark woodland (E. marginata-E. calophylla-E. wandoo-E. accedens) with a proteaceous understorey that becomes denser on the duricrusts and ferricrete gravels. Minor vegetation elements are mallet on breakaway faces (Mallet Soil), marri-wandoo woodland on slopes mantled by sandy duplex soils (Marri/Wandoo Duplex) mixing with blackbutt (E. patens) in the valleys and finally flooded gum (E. rudis) and scattered York gum (E. loxophleba) on clayey and loamy duplex soil (Flooded Gum Duplex) in the drainage lines.
Figure 10: Relief air photograph of a portion of the Eastern Darling Range Zone showing locations of representative soil profiles. Red points locate actual pit sites. Yellow points simulate likely position of a type profile drawn from a nearby area. Dotted lines indicate likely position of dolerite dykes.

Table 3. Typical soil profiles in the Eastern Darling Range Zone.

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1790</td>
<td>Mallet Soil</td>
<td>Duplex sandy gravel, Acid shallow duplex</td>
</tr>
<tr>
<td>0247</td>
<td>Parrotbush Caprock</td>
<td>Shallow gravel</td>
</tr>
<tr>
<td>1791</td>
<td>Jarrah Pea Gravel</td>
<td>Deep sandy gravel</td>
</tr>
<tr>
<td>1792</td>
<td>Jarrah/Marri Yellow Sand</td>
<td>Yellow deep sand</td>
</tr>
<tr>
<td>1793</td>
<td>Marri/Wandoo Duplex</td>
<td>Grey deep sandy duplex</td>
</tr>
<tr>
<td>1789</td>
<td>Flooded Gum Duplex</td>
<td>Brown deep loamy duplex, Yellow/brown shallow loamy duplex</td>
</tr>
</tbody>
</table>

Low-lying, winter waterlogged heath surrounded by jarrah/marri/wandoo forest in the Darling Range
Further east and north in the **Clackline System**, headward incision by the Dale River has stripped more of the lateritic mantle to partially expose gneissic and granitic bedrock. Soil formed from these fresher and hence nutritionally ‘richer’ parent materials are gradational granitic sandy earths and sands under marri and *Allocasuarina* (rock she-oak) (**Rock-Sheoak Sand**), loamy and sandy earths under York gum (**York Gum/Jam Soil**), granitic duplex soil under wandoo (**York Gum/Wandoo Soil**) and wet loamy duplex soil under flooded gum (**Flooded Gum Duplex**), in the lowest landscape positions. Duricrust areas (**Parrotbush Caprock**) resist erosion by rain and so form prominent scarps with lateritic gravels (**Jarrah Pea Gravel**) and colluvial sands and gravels on the ‘protected’ side of the scarp (**Verboom and Galloway 2000**). These lateritic surfaces are dominated by powderbark wandoo and wandoo woodland with minor areas of jarrah and marri forest. Both woodland and forest have a proteaceous understorey. Beard (1979) defined this vegetation system as the Dryandra System in the Dale Subdistrict, distinguishable from the Bannister System by the declining dominance of jarrah and an increase in powderbark wandoo (**E. accedens**) and wandoo (**E. wandoo**) woodland.

The **Boyagin System** occupies the eastern-most portion of the Eastern Darling Range and is mostly stripped of lateritic mantle. Like the Clackline System, it lies within the Dryandra vegetation system (Beard 1979). Numerous small lateritic mesas remain, along with several larger remnants that display similar characteristics to the lateritic components of the above systems. The small mesas are dominated by duricrust (**Parrotbush Caprock**) and ironstone gravelly soil (**Jarrah Pea Gravel**), with powderbark wandoo (**E. accedens**) and parrotbush (**Dryandra sessilis**) vegetation. Mesa scarps contain characteristic mallet vegetation with water repellent soil (**Mallet Soil**), commonly loamy duplexes with some colluvial ironstone gravels over residual kaolinitic clays. Duplex soils under wandoo (**York gum/Wandoo Soil**) become more prominent further downslope from the scarp. Granite outcrop and soil formed from granite and dolerite are similar to those formed on similar bedrock in the above-mentioned Clackline System. York gum (**E. loxophleba**) and wandoo are dominant components of the vegetation in these situations. Valley terraces and streamlines have loamy duplex and semi-wet (waterlogged) soil (**Flooded Gum Duplex**) vegetated by York gum (**E. loxophleba**) and flooded gum (**E. rudis**) respectively.

The **Dale System** occupies the eastern margin of the Eastern Darling Range Zone in the survey area. It comprises the alluvial flats of both the existing Dale River and the older sediments extending to the Helena Valley. The soils on these sediments have differentiated into sandy duplexes and lateritic podzols with the latter comprising deeper sands with ironstone gravels overlying clayey subsoil. The vegetation is mostly wandoo with proteaceous understorey becoming dominant where duplex soil gives way to pale deep sands and ironstone gravelly soil. Away from the river channel, external drainage is poor and swamps and fresh lakes are common features in some areas. Vegetation surrounding these swamps is typically *Melaleuca* thicket and rushes. Beard (1979) regarded the landscape and vegetation of the Dale soil-landscape System as a “special situation” within the Bannister vegetation system.
Southern Zone of Rejuvenated Drainage (257)

The Southern Zone of Rejuvenated Drainage extends from the Eastern Darling Range Zone eastwards to the Meckering line (Mulcahy, 1967) – here defined as the eastern limit of major headward incision of the Avon and Blackwood Rivers. It extends from roughly the southern limit of the Jimperding Metamorphic Belt southwards to just beyond Tambellup. The Southern Zone of Rejuvenated Drainage lies mostly on granitic and gneissic basement whereas the Northern Zone of Rejuvenated Drainage lies mostly on meta-sediments.

The Southern Zone of Rejuvenated Drainage is an erosional surface of gently undulating rises to low hills, formed by erosion of the lateritic mantle by the above-mentioned rivers. It is typified by flowing streams and active colluvial processes, with most soil formed in colluvium or weathered granitic rock. Small gravelly remnants of laterite profiles remain on hillcrests flanked by steep breakaways.

The vegetation in this Zone corresponds to the Pingelly and the Narrogin vegetation systems (not to be confused with the Pingelly and Narrogin soil-landscape systems) in the west of the Avon Botanical District (Beard 1979).

Seven systems of this zone lie within the survey area. The Pingelly, West Kokeby, and Brookton Systems are found in the Avon catchment roughly between the southern branch of the Dale river in the west and the main branch of the Avon river in the east. The Arthur River, Dellyanine and Whinbin Systems occupy the upper-western part of the Blackwood catchment, from the western margin of the survey area to the Cobline river and Toolibin and Taarblin lakes. The Narrogin System occupies parts of the divide between the Avon, Blackwood and Hotham catchments.

Examples of main soil types are located on a relief photograph (Figure 11). Local names and soil groups are tabulated in Table 4.

**Table 4. Typical soil profiles in the Southern Zone of Rejuvenated Drainage**

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1795</td>
<td>Rock-Sheoak Sand</td>
<td>Brown deep sand, Brown sandy earth, Yellow/brown shallow sand</td>
</tr>
<tr>
<td>1796</td>
<td>York Gum/Jam Soil</td>
<td>Brown or Red sandy or loamy duplexes</td>
</tr>
<tr>
<td>1794</td>
<td>York Gum/Wandoo Soil</td>
<td>Brown shallow loamy duplex</td>
</tr>
<tr>
<td>0891</td>
<td>Dolerite Loam</td>
<td>Red or Brown Deep Loamy Duplex, Yellow/brown or Red shallow loamy duplex</td>
</tr>
<tr>
<td>0895</td>
<td>Wandoo Sheoak Sand</td>
<td>Pale deep sand, Brown deep sand</td>
</tr>
<tr>
<td>1790</td>
<td>Mallet Soil</td>
<td>Duplex sandy gravel, Acid shallow duplex</td>
</tr>
<tr>
<td>0247</td>
<td>Parrotbush Caprock</td>
<td>Shallow gravel</td>
</tr>
<tr>
<td>WARUP</td>
<td>Wandoo/Sheoak Sandy</td>
<td>Grey deep sandy duplex</td>
</tr>
</tbody>
</table>

The Pingelly System is largely stripped of laterite, with isolated, prominent mesas remaining throughout the landscape, most commonly on sub-catchment divides. These mesas contain duricrust (Parrotbush Caprock) and shallow gravel soil vegetated by powderbark wandoo (*Eucalyptus accedens*) and parrotbush (*Dryandra* species). Scarp slopes are covered by water-repellent loamy duplex soils (Mallet Soil) vegetated by mallet. These mesas are similar to those of the above-mentioned Boyagin System in form, soil and vegetation. A few larger plateau remnants remain and these display the range of lateritic soil that exist on similar
landforms further west. The vegetation, however, is dominated by Proteaceous ‘Kwongan’ heath, largely without the eucalypt forest that dominates further west. The Tutanning nature reserve on the divide between the Avon and Hotham Rivers east of Pingelly provides a good example of a larger ‘plateau’ remnant.

Granite outcrops are common in the Pingelly System and, together with associated ‘fresh’ granitic soil, become dominant on stripped sub-catchment and catchment divides. The soils are generally granitic sandy (Rock-Sheoak Sand) and loamy earths (York Gum/Jam Soil) under York gum (*E. loxophleba*) and jam (*Acacia acuminata*) and occasionally rock sheoak (*Allocasuarina heugeliana*) vegetation. Granitic sandy duplexes (York Gum/Wandoo Soil) under York gum and wandoo vegetation occur further downslope. Wandoo with a proteaceous understorey becomes progressively dominant as weathering (and distance from fresh bedrock materials) increases. Iron in these soils differentiates rapidly under this vegetation and sandy duplexes (Wandoo/Sheoak Sandy Duplex) with ironstone gravels and ‘younger’ lateritic soil form in areas most removed from fresh sources of phosphorus.
Small areas of the Pingelly System have been identified as having aeolian (windblown) sands that appear to have been blown in from ephemeral fresh lakes or saline areas in adjacent valleys. These deposits are dominated by pale and yellow sandy soil and are vegetated by Banksia and Allocasuarina tree species.

The West Kokeby System lies west of Yenyening Lakes and is related to the Dale System of the Eastern Darling Range Zone. It is characterised by old sediments from the ancestral Avon River, that have been partially incised by the Dale River and the southern branch of the Avon river. These are now lateritised under Banksia, Dryandra and Hakea species where free drainage permits. Pale deep sands and gravelly sands occur extensively. The progress of Proteaceae colonisation, lateritisation and subsequent inversion (see Appendix B “Can Darwinian …”) of the Avon paleo-valley sediments can be followed up the headwardly incising Avon River near Brookton. Swamps, fresh lakes and recently salinised lakes have formed in depressions.

The Brookton System incorporates valley floors, mostly, to the north of, and surrounding, Brookton. It is a small system, equivalent to the Goomalling System in the Northern Zone of Rejuvenated Drainage and is, in essence, an extension of that system into the Southern Zone of Rejuvenated Drainage. It contains poorly drained sandy duplex soils (Flooded Gum Duplex and Wandoo/Sheoak Sandy Duplex) that are increasingly affected by secondary salinity. The vegetation is mainly wandoo and flooded gum.

The Narrogin System follows the Widgiemooltha Dyke suite between Wickepin and Williams. This dyke suite seems to have played an important role in shaping parts of the divide that separates the Avon and Hotham Rivers from the -Blackwood River. Irregularity in the terrain is partly caused by the annealing of the country-rock by the mafic intrusions and the surface armouring qualities of the ferricretes generated on ‘iron-rich’ dykes (Verboom and Galloway, 2000).

The native understorey on small, isolated mesas in fields is often degraded and only the powderbark wandoo and mallet woodland canopy remain on the shallow gravel and duricrust soil (Parrotbush Caprock). Larger mesas in near-pristine condition are usually vegetated by marri, jarrah, parrotbush and Allocasuarina species. Duricrust extends several metres in from the scarp face with unconsolidated gravels (Jarrah Pea Gravel) merging to yellow and pale sands as one moves in to the main body of the mesa and away from the scarp face. Scarp slopes are covered by water-repellent loamy duplex soil (Mallet Soil) vegetated by mallet, as found on similar landscape elements in nearby systems.

Many rock outcrops and rocky soil are exposed in rejuvenated parts of this system. Soil formed on dolerite, diorite, granodiorite and granite are often well-structured, moderately fertile red loams (Dolerite loam) vegetated by York gum and jam woodland. Wandoo and Allocasuarina vegetation grows on the less fertile sands and sandy duplex soils (Wandoo/Sheoak Sandy Duplex) developed in granitic colluvium on smooth, waning lower slopes.

The systems of the Blackwood catchment that lie within the Corrigin survey area have been described in detail by Percy (2000) and only summaries are provided below.

The Dellyanie System occupies the south-western most portion of the survey area. It consists of low hills and rises with grey deep sandy duplex soils and common granite outcrops flanked by red loamy soil, gritty brown deep sands and sandy duplex soils.
The **Whinbin System** occurs east of the Dellyanine System and is distinguished from the latter by generally more subdued terrain, fewer rock outcrops or rocky soil and a greater dominance of grey sandy duplex soils and soil displaying lateritic character. Percy (2000) attributed the increase of lateritic soil to soil formation on colluvial deposits of lateritic origin. Colluvial lateritic deposits certainly exist, often in close proximity to duricrust mesas (see the colluvial gravel pit on the Narrogin-Toolibin road). Even so, we contend that the large areas of sandy and ironstone gravelly soil of lateritic nature were, until clearing, forming *in situ*, under proteaceous vegetation.

The **Arthur River System** defines the broad alluvial plains of the Arthur River and the eastern-most extent of the Southern Zone of Rejuvenated Drainage within the Survey area. It consists mostly of grey deep and shallow sandy duplex soil and saline wet soil.

A prominent breakaway near Dryandra with powderbark wandoo on crest and mallett on pediment slope
Northern Zone of Rejuvenated Drainage (256)

The Northern Zone of Rejuvenated Drainage lies in the north-west corner of the survey area. It stretches from the Yenyenning lakes in the south to north of Moora. Its south-eastern flank is demarcated by the flat Salt River valley running from Quairading to the Yenyenning lakes. (see Appendix B “Salinity in the Central Wheatbelt”). The zone lies mostly on the Jimperding metamorphic belt and the western margin of the Kellerberrin batholith and is an erosional surface of gently undulating rises to low hills. Eastward incision by the Mortlock River and westward incision by tributaries of the Salt River accounts for much of the rejuvenation of the landscape.

The Northern Zone of Rejuvenated Drainage, formed by erosion of the lateritic mantle by tributary streams of the Avon, Mortlock South and Salt rivers. It is typified by flowing streams and active colluvial processes, with most soil formed in colluvium or weathered granitic rock. Small gravelly remnants of laterite profiles remain on hillcrests flanked by steep breakaways.

The vegetation in this Zone corresponds to the York and the Meckering vegetation systems in the Avon Botanical District (Beard 1980b).

Four systems of this zone lie within the survey area. The Greenhills and Morbingin, Systems occupy the catchment divide between the rejuvenated reach of the Avon and South Mortlock rivers and the sluggish Salt River. The Goomalling System comprises narrow alluvial valleys that drain to the Mortlock and Avon rivers. The Jelcobine System occupies a small area to the west of the main Avon river.

Most map-units within this zone were originally defined by Lantzke and Fulton (1993). Their units have been packaged up into soil-landscape systems to provide coherent mapping across the state and some of these systems have been used in the Corrigin for edge matching purposes. Bear in mind that the original packaging was done by surveyors with limited experience of the area (Noel Schoknecht pers comm.).

Examples of main soil types found within the intersecting area of the Corrigin survey and the Northern Zone of Rejuvenated Drainage are located on a relief photograph (Figure 12). Local names and Soil groups are tabulated in Table 5. These soils and landscapes may not be representative of the broader Northern Zone of Rejuvenated Drainage.

The Goomalling System consists of narrow alluvial deposits of the upper Avon and Mortlock Rivers. The system is flat and poorly-drained, and salinity is prominent and increasing. Many soils are saline, wet and poorly drained sandy duplexes with sodic ‘B’ horizons. The vegetation is dominated by wandoo woodland (York Gum/Wandoo Soil) with some areas of salmon gum (Salmon Gum Grey Duplex and Salmon Gum Red Soil) and York gum woodlands.

The Greenhills System comprises undulating low hills with few rock outcrops and few remnant lateritic mesas. This system occupies the slopes next to the broad valleys of the Avon and South Mortlock rivers, east of Beverley. The dominant soils are shallow and deep sandy duplexes (Wandoo/Sheoak Sandy Duplex) with neo-forming laterites on well-drained positions. These soils take the form of sandy duplex soil with ironstone gravels forming at the top of a ‘B’ horizon that is being progressively enriched in iron and aluminium and depleted in clays.
Figure 12: Relief air photograph of a portion of the Northern Zone of Rejuvenated Drainage showing locations of representative soil profiles for the Corrigin survey area. The yellow points simulate likely position of a type profile drawn from a nearby area.

Table 5. Typical soil profiles in the intersection of the Corrigin Survey area and the Northern Zone of Rejuvenated Drainage.

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1790</td>
<td>Mallet Soil</td>
<td>Duplex sandy gravel, Acid shallow duplex</td>
</tr>
<tr>
<td>0247</td>
<td>Parrotbush Caprock</td>
<td>Shallow gravel</td>
</tr>
<tr>
<td>0215</td>
<td>Kwongan Sandy Gravel</td>
<td>Gravelly pale deep sand, Pale deep sand</td>
</tr>
<tr>
<td>1795</td>
<td>Rock-Sheoak Sand</td>
<td>Brown deep sand, Brown sandy earth, Yellow/brown shallow sand</td>
</tr>
<tr>
<td>1794</td>
<td>York gum/Wandoo Soil</td>
<td>Brown shallow loamy duplex</td>
</tr>
<tr>
<td>0895</td>
<td>Wandoo Sheoak Sand</td>
<td>Pale deep sand, Brown deep sand</td>
</tr>
<tr>
<td>0891</td>
<td>Dolerite loam</td>
<td>Red or brown deep loamy duplex, Yellow/brown or red shallow loamy duplex</td>
</tr>
<tr>
<td>1485</td>
<td>Rocky Red Loam</td>
<td>Red sandy or loamy earth, Red shallow sand or loam</td>
</tr>
<tr>
<td>1480</td>
<td>Salmon Gum Red Soil</td>
<td>Alkaline red shallow loamy duplex, Red or Calcareous loamy earth</td>
</tr>
<tr>
<td>0099</td>
<td>Salmon Gum Grey Duplex</td>
<td>Alkaline grey shallow loamy duplex</td>
</tr>
<tr>
<td>WARUP</td>
<td>Wandoo/Sheoak Sandy Duplex</td>
<td>Grey deep sandy duplex</td>
</tr>
</tbody>
</table>

The Morbinning System defines upland areas with more ‘intact’ laterite than the Greenhills system. The scarp slopes contain Mallet Soil and vegetation similar to those in the Southern Zone of Rejuvenated Drainage. Slopes stripped of the lateritic mantle have sandy and loamy duplex soils (Rocky Red Loam, York Gum/Wandoo Soil and Dolerite Loam) vegetated by York gum/jam associations. These soils are usually redder and more fertile than soil in similar landscape positions further south, largely because of the different geology.

The Jelcobine System is an interfluve system on the Jimperding metamorphic belt. Seven map-units occupying a total of 275 hectares exist in Corrigin survey area between Beverley and Brookton. These units were required to edge-match with the Northam survey (Lantzke and Fulton 1993).
Northern Zone of Ancient Drainage (258)

The Northern Zone of Ancient Drainage is an ancient peneplain on the granites and gneisses of the Yilgarn Block, extending northward from a line from Brookton through Corrigin and on to the edge of the area cleared for agriculture. It is, therefore, confined to the northern part of the survey area and mostly approximates the eastern part of the Avon Botanical District of Beard (1979). Salt lake chains in broad flat valleys occur in ancient drainage systems that now only function as connected waterways in very wet years. The interfluves of the Northern Zone of Ancient Drainage, at least within the survey area, are characterised by yellow lateritic sandy earths vegetated by tammar scrub. This contrasts with the grey sandy lateritic gravels under Kwongan heath on interfluves of the South-western Zone of Ancient Drainage and the grey mallee soil on the interfluves of the South-eastern Zone of Ancient Drainage.

Examples of main soil types are located on two relief photographs (Figure 13). Local names and Soil groups are tabulated in Table 6. Seven soil-landscape systems exist in the Corrigin survey in this zone. Five of these are upland systems. They have been distinguished by geology and the relative proportions of sandplain versus rock outcrop and rocky soil. Two are flat valley systems.

Table 6. Typical soil profiles in the Northern Zone of Ancient Drainage

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1474</td>
<td>Shallow Tammar Gravel</td>
<td>Shallow gravel</td>
</tr>
<tr>
<td>1472</td>
<td>Deep Tammar Gravel</td>
<td>Reticulite deep sandy duplex,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex sandy gravel</td>
</tr>
<tr>
<td>1473</td>
<td>Grevillea / Wodjil Yellow Sands</td>
<td>Yellow loamy or sandy earth,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acid yellow sandy earth</td>
</tr>
<tr>
<td>1471</td>
<td>Mallee-Jam Soil</td>
<td>Brown deep sand, Brown loamy earth,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brown deep sandy or loamy duplex</td>
</tr>
<tr>
<td>1485</td>
<td>Rocky Red Loam</td>
<td>Red sandy or loamy earth,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red shallow sand or loam</td>
</tr>
<tr>
<td>0181</td>
<td>Gimlet Soil</td>
<td>Alkaline red loamy duplex,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcareous loamy earth</td>
</tr>
<tr>
<td>1480</td>
<td>Salmon Gum Red Soil</td>
<td>Alkaline red shallow loamy duplex,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red or Calcareous loamy earth</td>
</tr>
<tr>
<td>1481</td>
<td>Morrel Soil</td>
<td>Alkaline red shallow loamy duplex,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcareous loamy earth</td>
</tr>
<tr>
<td>1482</td>
<td>Salt Lake soil</td>
<td>Salt lake soil, Saline wet soil,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brown loamy earth (saline),</td>
</tr>
<tr>
<td>1483</td>
<td>Salt Land Soil</td>
<td>Variable soils including Brown loamy earth (saline) and Saline wet soil</td>
</tr>
</tbody>
</table>

The Bendering System occupies the south-easternmost portion of the Northern Zone of Ancient Drainage in the survey area and is underlain by an arcuate belt of gneisses cut by dolerite and diorite dykes. Uplands tend to be dominated by rocky, often mafic, soil interspersed with lateritic-sandplain. However, mallee and mallee-heath vegetation and duplex soil that dominate in the South-eastern Zone of Ancient Drainage do occur here to a limited extent. This grading of soil-landscapes across the Bendering System is reflected in Beard’s (1980a) vegetation classification of the area. Beard designated the northern portion...
Figure 13 Relief air photograph of an upper and mid slope portion (above) and a valley and lower slope portion (below) of the Northern Zone of Ancient Drainage showing locations of representative soil profiles. Red points locate actual pit sites. Yellow point simulates likely position of a type profile dug in another area.
of the Bendering System as the Muntagin Vegetation System in the Avon Botanical District and the southern portion of the Bendering System as the Hyden Vegetation System in the Roe Botanical District. Like the soils the vegetation systems gradually change across the Bendering System. The sandplain of the Bendering System consists of duricrust (Shallow Tammar Gravel) and gravel crests and ridges (Deep Tammar Gravel) vegetated by proteaceous heath and shrubland (mainly Allocasuarina, Dryandra and Hakea species) with long gravelly slopes containing pockets of deep yellow sand (Grevillea/Wodjil Yellow Sands) under proteaceous shrub (mainly hakeas and grevilleas). These pockets occupy about a quarter of the lateritised surface.

Mid to lower slope soils have a complex, mosaic-like distribution. Vegetation distribution is a similarly complex mix of mallee, mixed mallee-heath, heath and woodland. The soils are dominated by sandy duplexes (Mallee Broombush Soil) inhabited by several dominant mallee-form eucalypts. Proteaceous ‘Kwongan’ heath species have ‘intruded’ and, where this occurs, the soils display characteristics of both mallee- and heath-type soil, often forming sandy surfaces with an ironstone gravelly subsoil overlying a sodic clay ‘B’ horizon (Mallee Gravel Soil). The patches of gravelly soil on the mid-slopes are vegetated almost exclusively by the proteaceous heath species.

Soil formed in the more mafic colluvium on smooth lower slopes have loamy surfaces with clayey, alkaline and sodic subsoil (Salmon Gum Red Soil and Gimlet Soil). The vegetation on these landscape elements mostly consists of salmon gum and gimlet. Mallee-form York gum and jam woodlands occupy loamy gradational soil (Rocky Red Loam) surrounding rock outcrops.

The Tandegin System occurs around Bruce Rock in the north-east corner of the Corrigin survey area. It consists of an intricate mosaic of gently undulating soil-landscapes, dominated by yellow lateritic sandplain mostly underlain by granites and siliceous gneisses.

Mid to lower slope soils have a complex, mosaic-like distribution. Vegetation distribution is a similarly complex mix of mallee, mixed mallee-heath, heath and woodland. The soils are dominated by sandy duplexes (Mallee Broombush Soil) inhabited by several dominant mallee-form eucalypts. Proteaceous ‘Kwongan’ heath species have ‘intruded’ and, where this occurs, the soils display characteristics of both mallee- and heath-type soil, often forming sandy surfaces with an ironstone gravelly subsoil overlying a sodic clay ‘B’ horizon (Mallee Gravel Soil). The patches of gravelly soil on the mid-slopes are vegetated almost exclusively by the proteaceous heath species.

Soil formed in the more mafic colluvium on smooth lower slopes have loamy surfaces with clayey, alkaline and sodic subsoil (Salmon Gum Red Soil and Gimlet Soil). The vegetation on these landscape elements mostly consists of salmon gum and gimlet. Mallee-form York gum and jam woodlands occupy loamy gradational soil (Rocky Red Loam) surrounding rock outcrops.

The Tandegin System occurs around Bruce Rock in the north-east corner of the Corrigin survey area. It consists of an intricate mosaic of gently undulating soil-landscapes, dominated by yellow lateritic sandplain mostly underlain by granites and siliceous gneisses.

The Tandegin System conforms to Beard’s Muntadgin vegetation system (Beard 1980b). Individual soil-landscapes were difficult to map due to the poor quality of the aerial photos.

Ironstone gravelly soils under tammar (Shallow Tammar Gravel and Deep Tammar Gravel) occupy crests and commonly surround rock outcrop. Crestal duplexes developed on clayey saprock (Mallee Broombush Soil) are vegetated by mallee-type vegetation. Down-slope are extensive yellow sandplains (Grevillea/Wodjil Yellow Sands) vegetated by casuarinaceous and proteaceous tall scrub with Acacia species. Proteaceous vegetation becomes dominant over Acacia and Allocasuarina species on lower slopes and depressions receiving run-on. Here, ironstone gravels and weakly indurated and reticulate ‘hardpans’ form from the yellow sandy matrix in profiles that are essentially well-drained despite the run on.

Shallower and sandier soil fringing rock outcrops are commonly vegetated by jam (Acacia acuminata) and she-oak (Allocasuarina heugliana) low woodland. The sandier soils vegetated by she-oak often merge to ironstone gravelly soil vegetated by tammar (Allocasuarina campestris and A. acutivalvis). The york gum/jam woodland with scattered wandoo on rocky soil (Rocky Red Loam) common in systems to the south and west, is rarely found in the Tandegin system although they do occur on deeper and more clayey soil receiving run-on from rock outcrops.

Other unlateritised country generally consists of sandy duplex soil vegetated by mallee-form eucalypts (commonly E. transcontinentalis and E. burracoppinensis) with varied understorey species generally lacking the tea-tree (Melaleuca sp.) component that is common further
south. Lower slopes to the south-east of major valleys are influenced by wind-borne clayey and calcareous deposits. Soils in these positions are usually red calcareous clays and loamy duplexes vegetated by open woodlands of salmon gum (Salmon Gum Red Soil) and gimlet (Gimlet Soil).

The **Kwolyin System**, between Quairading and Bruce Rock, is the undulating low granitic hills on the Kellerberrin batholith. The system conforms to the Mount Caroline vegetation system of Beard (1980b). There are many large ‘whale-back’ granite hills. The soil surrounding these are mostly sands, sandy duplexes and hardsetting loams vegetated by jam and sheoak where the soil are shallow and sandy (Rocky-Shoal Sand). York gum-jam and mallee-jam associations occur on the deeper sandy loams (Mallee/Jam Soil). The sandier soil vegetated by sheoak (*Allocasuarina heugiana*) often yield to tammar (*Allocasuarina campestris*) on ironstone gravelly soil (Shallow Tammar Gravel). Yellow sandplain vegetated by mixed kwongan including Acacia species often occurs further down slope (Grevillea/Wodjil Yellow Sands). This type of sequence occupies a minor part of the Kwolyin system but is common in many other systems in the central wheatbelt.

Smooth lower slopes have hardsetting loams, loamy duplexes and sandy duplexes vegetated by York gum woodland where subsoil pH trends towards neutral and by salmon gum woodland where the subsoil become calcareous (Salmon Gum Red Soil and occasionally Salmon Gum Grey Duplex). Wandoo woodland occupies small areas of poorly-drained sandy duplex soil, generally in lower slope positions (Wandoo/Shoal Sandy Duplex).

The **Wadderin System** occurs in the north-eastern part of the Corrigin survey area, within Beard (1980a)’s Muntadgin vegetation system. This system has gently undulating rises in mixed siliceous and mafic gneiss and granodiorite country. It sports numerous small rock outcrops. Rocky red/brown loamy gradational soil vegetated by mallee-form York gum and jam woodlands surround these outcrops (Rocky Red Loam). The soil on lower slopes often has loamy surfaces, with clayey, calcareous and sodic subsoil vegetated by salmon gum (Salmon Gum Red Soil) and gimlet woodland (Gimlet Soil). The limited areas of lateritic sandplain consist of duricrust and gravel (Deep Tammar Gravel) on crests and ridges vegetated by proteaceous heath and shrubland (mainly *Allocasuarina, Dryandra* and *Hakea* species). The long colluvial slopes of yellow sandplain, common in other Northern Zone of Ancient Drainage systems, are largely absent.

The **Walyerming System** lies south of the Kellerberrin Batholith in the far south of the Northern Zone of Ancient Drainage. It closely approximates the Pikaring vegetation system of Beard (1980a) and has undulating rises sporting a mix of sandplain, granite and colluvium dominated by duplex soils. This is the northern equivalent of the Kweda System found in the South-western Zone of Ancient Drainage. The Walyerming System has extensive areas of sandy aeolian deposits, most commonly on the north-west slopes facing the Salt River. Productive land adjacent to the salt-lake chain in the Salt River valley may have been subjected to repeated cycles of denudation following episodic salinisation after flooding and/or groundwater rise. Sands blown from these denuded areas have deposited locally. These deposits are now vegetated by banksia woodlands (*B. prionotes, B. attentuata* and *Xylomelum angustifolium*) and are becoming lateritised, with semi indurated rough faced gravel and reticulated “B” horizons forming at depth (Banksia Yellow Sand).

Outcrops of siliceous granites and gneisses are common, particularly in a band trending north-south along the Corrigin Hills at the eastern margin of the system. The west of the system also contains numerous rocky outcrops that have a generally more mafic nature, with more dolerite dykes evident and several enclaves of ultra-mafic bedrock. The granite outcrops are
patchily vegetated with *Dodonea attentuata*, *Kunzea pulchella* and *Stypandra imbricata*. Shallow and deep gritty sands at outcrop margins are usually vegetated by *Allocasuarina heugliana* and the sandy and loamy earths near rock outcrops support *Acacia acuminata* and *E. loxophleba* (York gum).

Smooth uniform lower slopes and slopes remote from rock outcrops commonly contain sandy and loamy duplex soil with mixed woodland of *E. loxophleba* (York gum), *E. wando* (wando), *E. salmonophloia* (salmon gum) and *E. salubris* (gimlet) (Gimlet Soil and Wandoo Brown Duplex).

The sandplain of the Walyerming System comprises yellow sands and sandy earths overlying ironstone gravels and reticulite (Shallow Tammar Gravel). The range of soils in these landscapes support several distinct vegetation communities. Well-developed ironstone gravels in a yellow sandy matrix underlain by well-developed reticulite (Deep Tammar Gravel) is vegetated by a highly diverse mixed ‘Kwongan’-type heath, with several species of *Allocasuarina (A. campestris* and *A. humilis*) intermixed with numerous species from the Proteaceae family (eg: numerous species from the genera *Banksia, Dryandra, Hakea, Persoonia* and *Petrophile*) and various other species. In other places, discreet stands of tammar-dominated tall scrub (*Allocasuarina campestris*) occupy less well-developed ironstone gravels with a brown to yellow sandy loam matrix, which often overlies granite basement at relatively shallow depth (<2m).

Small areas of sandy and gravelly duplex soil with sodic subsoils, vegetated by mallee-form eucalypts, are found between the lateritic terrain and the duplexes and woodlands of the lower slopes.

The **Kellerberrin System** consists of broad valley floors in the Northern Zone of Ancient Drainage. The dominant soils are red and grey loamy duplexes with some clay soil where water flows stagnate. Vegetation is dominantly salmon gum with some gimlet on heavier textured soil. Heavier reddish clay soils under gimlet increase towards the north-east and where clays are inherited from surrounding mafic uplands. Some of these heavy gimlet soils have gilgai micro-relief. Small areas within the Kellerberrin System are dominated by duplex soil vegetated by York gum/wandoo woodland.

The **Wallambin System** consists of salt lakes, salt lake chains and associated aeolian soils within the broad valley floors of the Northern Zone of Ancient Drainage. The dominant soils are salt lake soil and saline wet soil in low-lying positions, with calcareous loamy earths on dunes vegetated by morrel. Vegetation fringing bare saline ground is limited to salt tolerant succulents such as samphire, whilst saltbush shrub species (eg *Atriplex* spp.) and *Allocasuarina obesa* and *Melaleuca* spp. inhabit better drained locations.
Pure stands of Allocasuarina campestris (tammar) on loamy gravel soils

Mixed heath dominated by grevillea on Yellow sandy earth
South-western Zone of Ancient Drainage (259)

The South-western Zone of Ancient Drainage is an ancient peneplain of low relief with drainage connection improving towards its western margin. It extends from the Yenyening Lakes, east to Corrigin and south to the border between Katanning and Broomehill Shires. It is bounded by the Meckering line to the west and the salt-lake chains of the valleys of the Lockhart and Camm River to the east. This zone is characterised by the widespread occurrence of ‘grey’ lateritic gravelly sandplain under Proteaceous heath. It approximates the southern portion of the Avon Botanical District of Beard (1980a) and the south-western portion of his Roe Botanical District.

In the survey area, it encompasses the upper reaches of the main branch of the Avon River and a small portion of the Upper Blackwood catchment. Both of these upper catchments have sluggish drainage, but salinity in the Blackwood (Grein 1995) and Avon Rivers has, mostly, only become apparent since the 1940s. The majority of lakes in this zone were fresh prior to clearing, in contrast to the primary salt lakes to the east and north (see Appendix B “Salinity in the Central Wheatbelt”). These different situations may relate to the fact that the lower reaches of this zone have been weakly rejuvenated by the Avon River. The extent of this rejuvenation is reflected in the soil-landscape systems of the valleys, with recent lateritisation occurring in the most rejuvenated and better drained systems of the north-west valleys.

Examples of main soil types are located on a relief photograph Figure 14. Local names and Soil groups are tabulated in Table 7. Five upland soil-landscape systems and three valley systems have been defined from this zone in the survey area.

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0211</td>
<td>Kwongan Cap Rock</td>
<td>Yellow/brown shallow sand, Shallow gravel</td>
</tr>
<tr>
<td>0212</td>
<td>Good yellow Sand</td>
<td>Yellow or brown sandy earth</td>
</tr>
<tr>
<td>NYA 0493</td>
<td>Banksia Yellow Sand</td>
<td>Yellow or Brown deep sand</td>
</tr>
<tr>
<td>0215</td>
<td>Kwongan Sandy Gravel</td>
<td>Gravelly pale deep sand, Pale deep sand</td>
</tr>
<tr>
<td>0090</td>
<td>Wandoo Brown Duplex</td>
<td>Yellow/brown deep sandy duplex</td>
</tr>
<tr>
<td>0091</td>
<td>York gum Valley Duplex</td>
<td>Grey deep sandy duplex</td>
</tr>
<tr>
<td>0099</td>
<td>Salmon Gum Grey Duplex</td>
<td>Alkaline grey shallow loamy duplex</td>
</tr>
</tbody>
</table>

The Alderside System consists of broad valley floors (1-3 km wide) that are being weakly incised by headward incision of the Avon River. These areas have river terraces. Minor sandy deposits vegetated by *Banksia* (*Banksia Yellow Sand*) and *Allocasuarina* species have formed on the margins of the Avon River channel. The better drained soil near the channel of the Avon River are formed in older sediments of the ancestral river, and are vegetated by proteaceous heath. Weakly developed laterites are forming in these areas. Duplex soils with neutral to alkaline subsoil are present in less well-drained areas and are commonly vegetated by wandoo (*Wandoo Brown Duplex*) and occasionally by salmon gum woodlands (*Salmon Gum Grey Duplex*). Salinity generally increases upstream away from the rejuvenated areas. The Alderside System represents an intermediate stage of rejuvenation evidenced by increasing lateritisation and colonisation by Proteaceae, with a progressive change from normal flat valley relief upstream to the inverted Kokeby System.

The Coblinine System is a valley system unaffected by headward incision. It was first identified and described by Percy (2000) and in that publication a detailed description is available. Its soils are often poorly drained and saline. Sandy and loamy duplexes with impermeable and sodic ‘B’ horizons and vegetated by woodlands of salmon gum and wandoo are common.
Figure 14. Relief air photograph of a portion of the South-Western Zone of Ancient Drainage showing locations of representative soil profiles. Red points locate actual pit sites, the yellow points simulate likely position of type profiles drawn from nearby areas.

Mixed heath with flowering dryandra growing on Shallow gravel and Sandy gravel within lateritic terrain near Yelering
The **Kondinin System** describes broad flat valleys with fine textured alluvial soil derived mainly from mafic parent material coming in from the surrounding Corrigin System with some influence from siliceous parent materials deriving from the Kukerin System in the south. Salt lakes and saline land are common and the system drains in a north-easterly direction to the large salt lake chains of the Lagan System in the adjoining South-eastern Zone of Ancient Drainage. The soils are mainly calcareous red and brown loamy duplexes, and calcareous red clays (*Salmon Gum Red Soil* and *Gimlet Soil*) vegetated by salmon gum and gimlet woodlands. Saline red calcareous phases (*Morrel Soil*) occur under morrel with salt bush understorey.

The **Kweda System** is a smoothly undulating upland overlying granitic and gneissic basement and is located east of the Alderside System, wholly within the Corrigin survey area. This system is the southern equivalent of the Walyerming System, and it differs from its northern counterpart mainly in the plant composition of the sandplain element. The sandplain in Kweda is dominated by pale and grey sandy gravels (*Kwongan Sandy Gravel*) vegetated by proteaceous vegetation, whereas, as previously described, the sandplain of Walyerming has a much wider occurrence of gravelly yellow sandy loams (*Deep Tammar Gravel*) under *Allocasuarina* communities.

The **Kukerin System** was first described by Percy (2003). It extends into the southern half of the Corrigin survey area and is characterised by expanses of lateritic sandplain with grey to pale sands overlying ironstone gravels and reticulite horizons (*Kwongan Sandy Gravel*) over a siliceous granitic and gneissic basement. Exposed ironstone gravels and duricrusts (*Kwongan Cap Rock*) persist on the subdued breakaways and crests. The native vegetation is typically proteaceous ‘Kwongan’ type heath with *Banksia*, *Dryandra*, *Hakea* and *Allocasuarina* species dominant. Whilst shallow and deep pale sands overlying ironstone gravels are not unique to this area, they are particularly common and may follow fracture zones within the bedrock. Deep pale sands are also located in depressions within lateritic terrain. In both cases they are vegetated by a mix of proteaceous species and tea-tree thicket – *Melaleuca seriata* and *Leptospermum erubescens*.

The lateritic mantle is partially stripped in places, revealing a deeply weathered kaolinitic and quartz-rich regolith that often has some degree of silicification. The soils on these substrates, mostly sandy duplexes with inhospitable subsoils, tend to be vegetated by mallee-form eucalypts, Brown mallets and wandoo.

Outcrops of consolidated rock are uncommon and the principle occurrence of York gums is in association with salmon gums on sandy and loamy duplex soils of the lower slopes and valleys.

The **Corrigin System** straddles the Corrigin Hills in the east of the South-western Zone of Ancient Drainage. It embraces the undulating low hills, on mafic bedrock, that form the divide between the catchment draining to the main Avon River valley to the west and the slopes draining to the salt-lakes of the Camm and Lockhardt Rivers to the east. Lateritic landscapes are common and are typified by subdued breakaways and crests of duricrust, merging to long slopes of sandy and loamy gravels (*Deep Tammar Gravel*). These areas are typically vegetated by ‘Kwongan’ type heath with *Banksia*, *Hakea*, *Dryandra* and *Allocasuarina* species dominant. The eastern portion of the Corrigin System has common gneissic rock outcrops, with red to brown loamy earths and loamy duplex soil supporting York gum woodland with salmon gums emerging on lower slopes. Unlateritised slopes remote from rock outcrops usually have sandy (with some loamy) duplex soil (*Wandoo*
Brown Duplex), vegetated by wandoo in the west. Mallee-form vegetation, principally *E. phaenophylla* and *E. incrassata* becomes increasingly dominant further east.

The **Dongolocking System** (Percy 2000) occupies the gently undulating rises and low hills in the lower south-west of the survey area. The main soil are grey deep sandy duplexes with sodic subsoil, shallow sandy duplexes with hardsetting surfaces and shallow and deep sandy gravels. The vegetation comprises mostly wandoo woodland with *Gastrolobium* and *Dryandra* understorey and some York gum woodland on the duplex soils and proteaceous heath on the gravels.

The **Yealering System** occupies the slopes next to the Coblinine System in the upper Avon, between the Avon River and the Zone of Rejuvenated Drainage. It is somewhat similar to the Kweda System to the north-east, the Dongolocking System in the Blackwood catchment and, to a lesser extent, the Greenhills System to the north. It differs from the Kweda System in the extent of well-developed grey gravelly lateritic sandplain. The Yealering System is dominated by sandy duplex soil vegetated by wandoo, with recent lateritisation occurring and expressing as gravelly duplex soils where *Allocasuarina campestris* and *A. humilis* become dominant components of the vegetation. Rock outcrop and fresh rocky soil are relatively rare, compared to the more dissected Pingelly System to the west.
South Eastern Zone of Ancient Drainage (250)

The South Eastern Zone of Ancient Drainage extends from Corrigin east through Hyden to the edge of the intensive agricultural zone (clearing line), and south to the north-eastern part of the Shire of Gnowangerup. The north-western margin of this zone occupies the south-eastern part of the Corrigin survey area, between Corrigin and Lake Grace, and embraces part of the mallee soil zone described by Teakle (1938). The South Eastern Zone of Ancient Drainage defines an ancient peneplain of smoothly and irregularly undulating country characterized by salt lake chains in the lowest parts of the valley floors with widespread duplex soil and laterite duplex intergrades, both on the valley flats and interfluves. Mallee-form eucalyptus species are ubiquitous and specific soil type is usually indicated by understorey species. Proteaceous species tend to dominate on well-developed laterites and persist as a mallee understorey on gravelly duplexes (Mallee Gravel Soil). Mallee on calcareous duplex soil tends to have a Melaleuca species understorey (Mallee Broombush Soil). The zone closely approximates the extent of the Hyden vegetation system (Beard 1972a, 1972b, 1980c). Examples of main soil types in the South Eastern Zone of Ancient Drainage are located on a relief photograph (Figure 15). Local names and Soil groups are tabulated in Table 8.

Figure 15. Relief air photograph of a portion of the South Eastern Zone of Ancient Drainage showing locations of representative soil profiles. Red points locate actual pit sites. Yellow points simulate likely position of type profiles from other areas.
Table 8. Typical soil profiles in the South Eastern Zone of Ancient Drainage

<table>
<thead>
<tr>
<th>Site No</th>
<th>Local Soil Name</th>
<th>WA Soil Group(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1776</td>
<td>Heavy Eastern York gum Soil</td>
<td>Red shallow loamy duplex</td>
</tr>
<tr>
<td>1770</td>
<td>Light Eastern York gum Soil</td>
<td>Brown deep loamy duplex</td>
</tr>
<tr>
<td>1772</td>
<td>Mallee White Gum Soil</td>
<td>Yellow/brown shallow loamy duplex</td>
</tr>
<tr>
<td>SC2 NDS4</td>
<td>Mallee Gravel Soil</td>
<td>Grey deep sandy duplex, gravelly</td>
</tr>
<tr>
<td>1773</td>
<td>Mallee Broombush Soil</td>
<td>Grey deep sandy duplex</td>
</tr>
<tr>
<td>1774</td>
<td>Saline Wet Grey Loam</td>
<td>Saline wet soil</td>
</tr>
</tbody>
</table>

The South Eastern Zone of Ancient Drainage is represented in the Corrigin survey area by three upland soil-landscape systems and four valley systems. All of these have been extended into Corrigin from surrounding surveys to the east and south. Whilst these systems have been previously identified, several have not yet been described in published reports.

The **Lagan System** was first identified during initial fieldwork for the Southern Cross- Hyden survey. It is the southern equivalent of the Wallambin System in the north. It consists of salt lakes, salt lake chains and associated aeolian soil within the broad valley floors of the South-eastern Zone of Ancient Drainage. The dominant soils are salt lake soils (*Salt Lake Soil*) and saline wet soils (*Saline Wet Grey Loam*) in low-lying positions, with calcareous loamy earths on dunes vegetated by morrel. Vegetation fringing bare saline ground is limited to salt tolerant succulents such as samphire, whilst saltbush shrub species (eg *Atriplex* spp.) and *Allocasuarina obesa* and *Melaleuca* sp. inhabit better drained locations. The Lagan System drains sluggishly towards the north and ultimately flows into the Wallambin System south of Lake Kondinin.

The **Hope South System** defines the broad valley floors in granitic and siliceous gneiss country in the South-eastern Zone of Ancient Drainage. Salt lakes are common in the main trunk valleys. Soils comprise red and brown loamy earths (usually calcareous), grey sandy duplices (often alkaline and sodic) and various saline soils around the salt lakes.

The **Conraking System** are areas of gently undulating rises to undulating low hills in the southern wheatbelt. Pale yellow sandplain dominated by gravel and interspersed with pale surfaced duplexes, red rocky soil and numerous siliceous and mafic outcrops.

The **Karlgarin Hill System** expresses as low hills on the Widgiemooltha Dyke suite, striking east-north-east across the south eastern wheatbelt. Most common soils are red rocky loams (*Heavy Eastern York gum Soil*) under gimlets and York gums with *Allocasuarina* sp. on red loamy gravels (*Shallow Tammar Gravel*) and mallee on grey alkaline duplices (*Mallee Broombush Soil*).

The **Newdegate System** and the **Sharpe System** together occupy less than six hectares in the far south-east of the Corrigin survey area. The Newdegate System is a gently undulating peneplain and the Sharpe System represents broad valley floors. Both are described in detail in other land resources series publications (Percy 2003; Overheu in prep).
**Land units**

Most farmers and surveyors can recognise land management units in the field without too much difficulty. Soils within each unit have inherent clustering of properties, tend to associate with particular types of native vegetation, and can be managed as a single unit. These are the units that the surveyor would most like to map. Unfortunately, the resources needed to prepare such mapping were not available for this survey.

To partially overcome this problem, unmapped land units are identified, in terms of a unique combination of soil and landform comprising a Western Australian Soil Group, a soil qualifier (Schoknecht, 2002) and a coded landscape position. The proportion of land units within each map unit is estimated from the soil profile database that holds the survey area’s auger and pit data, and from expert understanding and experience in the area.

An example of a land unit in the Corrigin survey is:

- **WA Soil Group**: Duplex sandy gravel
- **Qualifier**: clay loam to clay subsoil at <80 cm is neutral (pHw 6.0 – 8.0),
- **Landscape position**: crests and slopes <3%.

From interpreted properties (eg texture, surface condition) the land units are then assigned a series of qualities (for example risk of wind erosion). These are used to determine risks associated with the unmapped land unit. Since the land units are proportionally assigned to the mapped unit, so too are the risks. In a similar way the land units can be used for a variety of interpretations including land use potential.

The proportional allocation of land units to maps units, the characteristics and qualities or the land unit, and selected interpretations of the land units are available on the CD-ROM.
Interpretation of land resource survey results

Land managers like to know how well a particular soil is going to perform under a particular land use or how susceptible it might be to a specific land degradation hazard. This requires an interpretation of a site’s capability for a specified use based on knowledge of soil properties, distribution and behaviour (land quality). Some soil characteristics such as water repellence or susceptibility to subsoil acidification can be attributed directly to soil and its management history. Others, such as flood risk, relate directly to the landscape and are largely independent of the soils present. Most land qualities are derived from a combination of soil and landscape characteristics.

Potential degradation risk maps of subsoil compaction, surface structure decline, water erosion, wind erosion, water repellence (non-wetting soils) and acidification are provided, together with the extent of surface salinity seen in 1992 air photographs. Such risk maps are created by assessing the soil and landscape characteristics, which are based on surveyor’s judgement, according to the provisional methodology of van Gool et al. (in prep.).

No land capability maps have been included in this report (or CD-ROM) because the results of the current methodology are still being evaluated. Such interpretations are not static and will change over time in response to changes in land use practices and crop requirements. Current land capability maps may be available on request, subject to discussion with land assessment professionals within the Department of Agriculture.

The following section outlines major degradation issues that are currently recognised in the survey area.

Soil salinity

Salinity can be classified into primary and secondary types. Primary soil salinity is not induced by land clearing. It occurs throughout the world in arid climates. It is prevalent towards the eastern margin of the south-western agricultural region and includes salt lakes and salt marshes in valleys with low down-stream gradient.

Most salinity within the survey area comes from the concentration of rain-borne salts by evapo-transpiration (see Hingston and Gailitis, 1976). The Lagan and Wallambin Systems map the bulk of the salt lakes and salt marshes. Salt lake soils also occur within the Coblinine, Kellerberrin, Kondinin and Alderside Systems. These ‘western-most’ valley systems, the Coblinine and Alderside, may also include fresh lakes and swamps that have salinised since clearing.

Other types of naturally salty soil include Calcareous loamy earths blown in from nearby saline playas, some morrel soils, pallid clays under ferricrete layers and poorly permeable hard cracking clays in flat valleys.

Secondary soil salinity occurs due to changes in land use and management and mainly arises after clearing of perennial vegetation. It develops when saline groundwater rises or when slightly salty water evaporates from the surface leaving the salts behind. The accumulated
salts, particularly in combination with water logging, are toxic to plants, resulting in bare soil. Overall about 6% of the Corrigin survey has moderate to extreme surface soil salinity comprising Saline wet soils (5%) and Salt lake soils 1%.

Secondary salinity is most obvious in flat valleys on the western margin of the South-western Zone of Ancient Drainage (see Appendix B “Salinity in the Central Wheatbelt” for more information). Systems most affected are Alderside, Coblinine and Arthur River. Both Kellerberrin and Kondinin Systems are experiencing increases in secondary salinity with rates of increase most obvious in the west, upstream of Yenyenning Lakes. Other drainage constrictions further east also exhibit this behaviour. Small areas of Saline wet soils (sometimes sulphidic) also occur as saline hillside seeps where bedrock is shallow. Systems where this can be seen include the Clackline, Dellyanine, Greenhills, Morbinning, Narrogin and Pingelly Systems.

Soil acidification

Acid soils can be a serious limitation to crop and pasture production. In the Corrigin survey area there are soils with both naturally acid subsoil and soils which have become acidified through agricultural practices.

Yellow sandy earths with naturally acidic surface and subsoil horizons (under wodjil vegetation) occur within lateritic subsystems of the Tandegin System, in the far north east of the survey area.

Accelerated acidification depends on a number of factors including leaching rate, soil susceptibility (the pH buffering capacity of the soil), the rate of the product (and cation) export, the type of crops and pastures grown and the length of time since clearing. Localities most susceptible to accelerated acidification associate with higher rainfall, various sandy surfaced soils and high productivity.

The susceptibility of the subsurface soil layer to acidification was assessed using the method outlined in van Gool, et al. (in prep). However, the results are still being evaluated.

Subsurface compaction

Subsurface compaction of soils can result in plough and traffic pans which act as barriers to root growth and water penetration. Plough pans result from repeated tillage and are found in medium and fine textured soils just below the tilled layer. Traffic pans, which occur deeper in the soil, are caused by compression due to traffic. They are more common on light to medium textured soils. Susceptibility to subsurface compaction was assessed using the method outlined in van Gool et al. (in prep).
**Surface soil structure decline**

Soil structure decline refers to the changes in the structure and surface condition of the top layers of the soil since clearing and cultivation. This decline makes the topsoil hard and more compact, effectively reducing the amount of water infiltration while increasing the amount of run-off. Topsoil textures of sandy loam to clay are generally moderately or highly susceptible to soil structural decline and most become hardsetting after repeated cultivation. Most of these problems occur in flat valleys, particularly at confluences of main trunk valleys. Susceptible soils include Alkaline loamy duplexes, Brown loamy earths, Calcareous loamy earths Grey non-cracking clays, Hard cracking clays and Red/brown non-cracking clays.

**Water erosion**

Water erosion removes soil nutrients, causes siltation and contributes to eutrophication. Major contributing factors are high intensity rainfall events and management practices, such as cultivation, overgrazing and burning of plant residues, that expose the soil surface to rain. Landscape features such as slope gradient and length, as well as soil properties combine to determine the susceptibility of a land unit to water erosion.

Properties that increase a soil's inherent erodibility include:
- low organic matter content (<1% organic carbon),
- high silt or fine sand content (>65%),
- unstable soil structure, particularly dispersive soils,
- susceptibility to waterlogging, and
- water repellence.

All these features enhance runoff.

About 5% of the survey area has high to extreme water erosion hazard and another 13% has moderate water erosion hazard. Soil-landscapes with moderate to extreme water erosion hazard are displayed on the distribution map included on the CD-ROM.

**Water logging**

Waterlogging is an excess of water in the root zone causing anaerobic conditions. It is widespread and problematic in wet years on valley duplexes on lower slopes in the Eastern Darling Range Zone and the Southern Zone of Rejuvenated Drainage.

**Wind erosion**

Wind erosion is an on-going process, however, major wind erosion events in the survey area appear to be infrequent. Wind erosion can have many effects including sand blasting of
crops, loss of soil nutrients and associated losses in productivity, and air pollution. In extreme events, soil can bury fences and roads, and fill dams.

Susceptibility to wind erosion can be assessed from soil texture and surface condition. The most susceptible soils are bare of plant cover, with loose topsoil having detachable fine sand silt and clay. Bare sandy soils blow frequently on winds as low as 8 m/s or 28 km/hr (Moore et al 1998) during late summer and autumn. Hardsetting soils with sandy loam or clayier surface textures are the least susceptible to wind erosion. More than 50% surface cover of stones or gravels partially protects the bare soil from wind erosion. Highly susceptible soils include Pale deep sands, Gravelly pale deep sands, Pale shallow sands, Yellow deep sands, Brown deep sands, Grey deep sandy duplex soils and Alkaline grey deep sandy duplex soils. Gravelly soils such as Deep sandy gravels and Duplex sandy gravels are also highly susceptible to wind erosion if their surface gravel cover is less than 50%.

Practices that disturb and expose the surfaces of these soils, such as cultivation or overgrazing in dry seasons, will increase the hazard on these soils.

Methodologies developed (van Gool, et al, in prep) attempt to determine the susceptibility to wind erosion. Areas of high to extreme wind erosion hazard are indicated on the map included on the CD-ROM.

**Water repellence**

Water repellence causes uneven topsoil wetting resulting in patchy germination of crops and pastures. It can also result in sheet erosion on sandy topsoils.

A soil's susceptibility to water repellence is inversely related to the surface area of its fabric and directly related to the supply of water repellent compounds, which varies with land use and the productivity of the agricultural system. The most susceptible soils have the sandiest topsoils with less than 2% clay. These include Pale deep sands, Pale shallow sands, Gravelly pale deep sands and Brown deep sands. Acid shallow duplex soils vegetated by mallet are inherently water repellent. Oils and waxes produced by these mallets may create this situation.

Alkaline grey deep sandy duplex soils, Grey deep sandy duplex soils, Acid shallow sandy duplexes, Yellow deep sands, Duplex sandy gravels, Shallow gravels and Deep sandy gravels are moderately susceptible to water repellence. They are more likely to develop water repellence as organic matter levels build up under long-term clover-dominant pasture or on sheep camps.
Glossary

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

Aeolian deposit: Material transported and/or arranged by wind.

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 2,700 million years ago.

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

CEC (Cation exchange capacity): The total amount of exchangeable cations that a soil can absorb being made up of calcium, magnesium, potassium, sodium, aluminum and hydrogen. CEC affects soil properties and behaviour, stability of structure, the availability of some nutrients for plant growth and soil pH.

Colluvium: Materials transported and deposited by gravity.

Conglomerate: A group of sedimentary rocks consisting of rounded and sub-rounded particles, many greater than 2 mm in diameter.

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.

Diorite: A granular igneous rock consisting essentially of felspar and hornblende.

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. They typically appear on the surface as relatively narrow, linear features.

Earthy fabric: The soil material is coherent and characterised by the presence of pores and few if any peds.

Fault: A fracture or fracture zone of the Earth’s crust with displacement along one side in respect to the other.

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 to 40%), feldspar and very commonly a mica.

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.

Indurated layer: A layer of material hardened by cementation or pressure.

Interfluve: Raised area of land between drainage lines.

Laterite: Regolith, once thought to be formed in past tropical environments under climatic extremes of wet and dry seasons throughout the year. ‘Leaching’ of the profile removes
sodium, potassium, calcium and magnesium ions. Iron and aluminium oxides remain to form a hardened and cemented layer. The lateritic profile typically consists of sand or gravel on top of a ferruginous duricrust where the iron oxides have accumulated. This often overlies a mottled clay and then a ‘depleted’ pallid zone (white clay) from which the leaching has occurred.

**Loam:** A medium-textured soil of approximate composition 10 to 25% clay, 25 to 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 forefinger.

**Lunette:** An elongated, gently curved, low ridge built up by wind on the margin of a lake or playa.

**Mafic:** Igneous rocks such as dolerite and gabbro with high proportion of dark coloured minerals containing magnesium and/or iron

**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.

**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 agricultural plants grow best when the soil pH is in the range of 5.5 to 8.0.

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

**Playa:** A large, shallow, level floored closed depression, intermittently water-filled but mainly dry due to evaporation.

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

*Blocky peds* are cube-shaped with six relatively flat, roughly equal faces.

*Crumb peds* are small (1 to 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.

**Quartz:** Mineral composed of silicon dioxide (SiO₂).

**Quartzite:** A metamorphic rock consisting of interlocking quartz crystals.

**Reticulate:** A reddish, yellowish, grey and white mottled horizon common in the wheatbelt below surface gravels. The mottling has a reticulate (net-like) pattern. It has a ‘gritty’ field texture of sandy loam to sandy clay loam, but until textured often looks like a clayey horizon. Clay content usually increases with depth. When moist it is usually hard and brittle and can be augered or hand cut with a spade, however it often hardens further on drying. Some ironstone gravel may be present but this is not diagnostic.

**Salinity:** Usually refers to condition of 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 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.
Shear zone: A tabular geological zone where rocks have been deformed due to shear stress (i.e. stress causing fracturing and compression along parallel planes).

Silcrete: Strongly indurated siliceous material.

Siliceous: Igneous rocks such as granite with high proportion of light-coloured minerals such as quartz and feldspars

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 which 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 profile.

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

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.
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References


Bettenay, E. and Hingston, F.J. (1961) The soils and land use of the Merredin area, Western Australia. CSIRO Division of Soils. Soils and Land Use Series No. 41


Beard, J.S. (1979) The Vegetation of the Pinjarra Area, Western Australia. Explanatory memoir -1:250,000 map series. Vegmap Publications, Perth, Australia


Chin, R.J. (1986a) Corrigin, Western Australia: 1: 250,000 Geological series, map and explanatory notes, Geological Survey of Western Australia. Perth, Australia.

Chin, R.J. (1986b) Kellerberrin, Western Australia: 1: 250,000 Geological series, map and explanatory notes, Geological Survey of Western Australia. Perth, Australia.


Lantzke, N. and Fulton, I. (1993). Land Resources of the Northam Region, Land Resources Series No.11, Department of Agriculture Western Australia.


Percy, H.M. (2003) Nyabing-Kukerin area land resource survey. Land Resources Series No.18, Department of Agriculture Western Australia


Prescott, J.A. (1952). The soils of Australia in relation to vegetation and climate. CSIRO Bulletin No. 52. Australia


Appendix

A. Standard analytical procedures applied to profile samples.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Size Distribution</td>
<td>Hydrometer Method (Bouyoucos) and sieve</td>
</tr>
<tr>
<td>pH (CaCl₂)</td>
<td>in 1:2.5 0.01M calcium chloride solution</td>
</tr>
<tr>
<td>pH (H₂O)</td>
<td>in 1:5 water</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>K₂Cr₂O₇ digestion (Walkely and Black)</td>
</tr>
<tr>
<td>Free Iron</td>
<td>citrate-dithionite-extractable iron</td>
</tr>
<tr>
<td>CEC and exchangeable cations method (1)</td>
<td>1M NH₄Cl pH 7.0</td>
</tr>
<tr>
<td>CEC and exchangeable cations method (2)</td>
<td>0.1M BaCl₂ (unbuffered)</td>
</tr>
<tr>
<td>CEC and exchangeable cations method (3)</td>
<td>1M NH₄Cl pH 8.5</td>
</tr>
<tr>
<td>CEC and exchangeable cations -default</td>
<td>1M NH₄OAc pH 7.0</td>
</tr>
</tbody>
</table>

B. Additional reading on landscape development

Several documents explaining some landscape and soil development theories being investigated are available on the CD-ROM.


During the Corrigin Survey we found evidence linking cluster-root bearing taxa and microbes to formation of ferric layers (Pate et. al., 2001). We suggest that this partly relates to phosphorous acquisition strategies. Further work on climax communities indicates that different niche building activities occur in different groupings of plants. These activities result in different soil-landscape patterns indicative of inter-community competition (Verboom and Pate, 2003).


A regional overview emerged during the Corrigin Survey when the detailed spatial information was integrated with field experience and knowledge of processes. The resulting map reveals geomorphic controls on salinity, and areas affected by rises in saline waters during wetter times.


This document briefly discusses association between landscape rejuvenation, breakaway structures and soil distribution in sections of the Avon valley straddling the western margin of the Yilgarn block.