## II Physical Environment

N.J. Hall and K.R. Newbey

### Climate

The Norseman-Balladonia Study Area has hot, dry summers and cool winters. Rain falls during both winter and summer (Figure 3). A bioclimatic map of the region has been compiled by Beard (1975) based on the system of Bagnouls & Gaussen (1957). The Study Area contains three different climatic types varying from Dry Warm Mediterranean in the south-west to Desert (non-seasonal) in the north-east. The climate over most of the Study Area has been classified as semi-desert (Mediterranean). Average monthly recordings of rainfall and temperature and the long-term mean are presented in Figure 3. Climatic data are summarised from Norseman, Balladonia and Salmon Gums.

### Temperature

Average maximum temperatures for each month range from 31.3°C (January) to 16.5°C (July). Average minimum temperatures range from 14.2°C (January-February) to 4°C (July). Numerous frosts are experienced during winter. Extremes recorded are: Norseman (44.9°C and -2.8°C), Balladonia (48.0°C and -3.3°C) and Salmon Gums (44.3°C and -8.6°C). Mean annual evaporation decreases from 2450 mm on the northern boundary of the Study Area to 2200 on the southern boundary (Anon. 1981).

### Rainfall

Average annual rainfall in the Norseman-Balladonia Study Area varies from 325 mm in the south-west (Salmon Gums) to 292 mm in the north-west (Norseman) and 272 mm in the north-east (Balladonia). The mean rainfall tends to be evenly distributed throughout the year, being slightly higher in winter than summer. Annual rainfall is unreliable with extremes recorded being: Norseman (152-613 mm), Salmon Gums (159-568 mm) and Balladonia (169-449 mm).

Light winter rains are mainly from the passage of cold fronts associated with sub-Antarctic lows. Unreliable and sporadic rainfall is associated with thunderstorms during the summer. Heavy falls (50-150 mm) occur from tropical cyclones which have degenerated into rainbearing depressions. Associated with rainfall is the growing period which grades from 0.4 months in the south-west to 0.1 months in the north-east (Anon. 1981).

An examination of monthly rainfall totals for the Norseman-Balladonia Study Area during 1976-1981 show that rainfall was below average for the majority of the present survey and the year preceding it (Figure 3). In comparison with the long-term mean of 296 mm, about average rainfall was only recorded during 1978 (306 mm) and 1979 (292 mm). Below average rainfall was recorded during 1976 (227 mm), 1977 (202 mm), 1980 (225 mm) and 1981 (250 mm). Most winter rain fell in May and June during the survey, which is consistent with the long-term pattern.

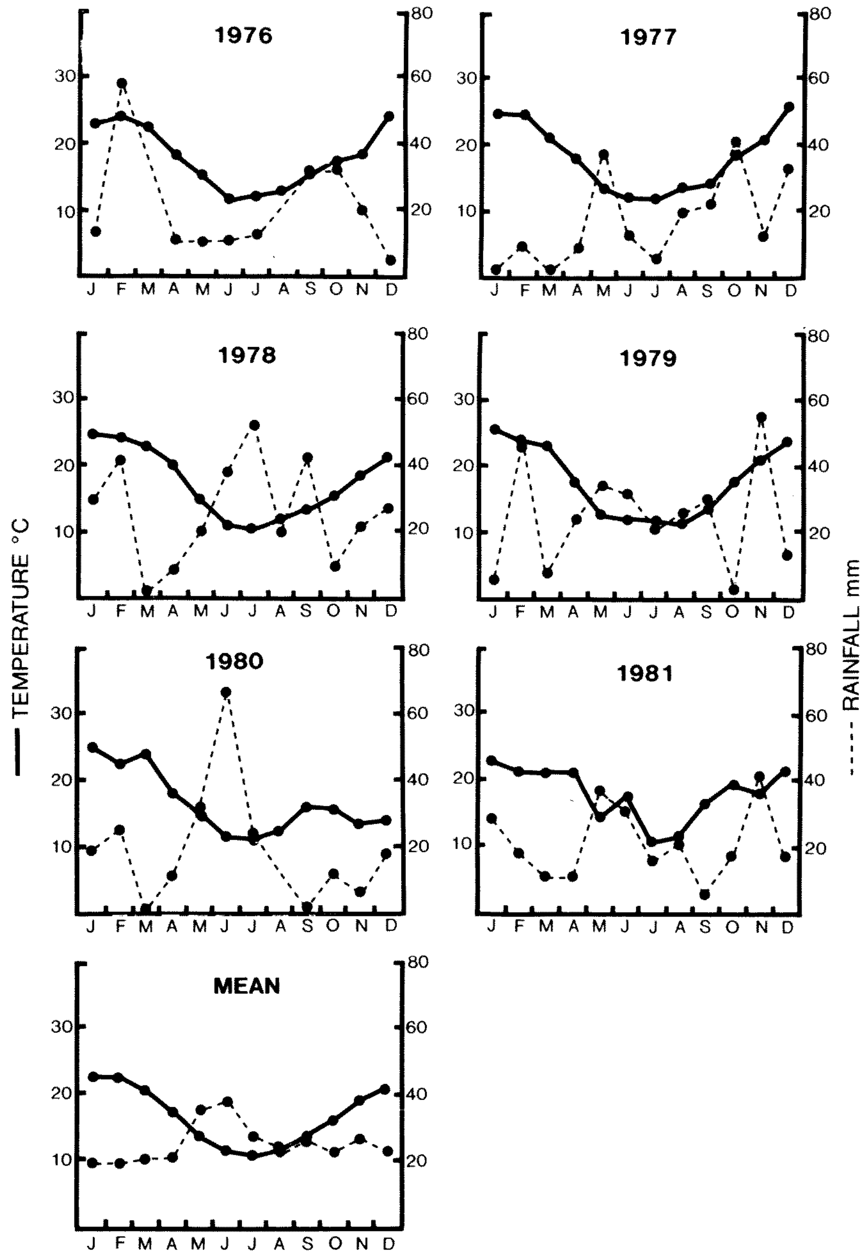


**Figure 3** Ombrothermic diagrams showing the mean monthly rainfall and average monthly temperatures for the years 1976-1981 and the long term mean (Australian Bureau of Meteorology data).

**Winds**

Wind speed summaries are available for Norseman and Balladonia. At 0900 hr and 1500 hr, the most frequent wind speeds recorded at Norseman were similar: summer and autumn (6-20 km/hour) and winter and spring (11-20 km/hour). Wind directions were variable at both 0900 hr and 1500 hr, with the most frequently recorded directions being NE (summer and spring) and NW (autumn and winter). At Balladonia, wind speeds averaged 1-5 km/hour throughout the year. At both 0900 hr and 1500 hr the most frequently recorded wind directions varied: summer (NE), autumn (NE, W), winter (W) and spring (SW, W, NE).

No data on maximum wind speeds are available for the Norseman-Balladonia Study Area. Kalgoorlie, to the north-west of the study area, has maximum monthly wind speeds of 60-80 km/hour with a highest recorded wind speed of 138 km/hour (November 1979). Esperance, to the south-west, has recorded wind gusts of 129 km/hour (July 1979) and 127 km/hour (August 1981). Squalls associated with thunderstorms may be capable of damaging the vegetation. There were no sightings during the survey however, of physical damage caused by strong winds.

**Radiation**

The average daily solar radiation during January grades from south (750 $mWh.cm^{-2}$) to north (800 $mWh.cm^{-2}$). The gradient is similar in direction during April (400-450 $mWh.cm^{-2}$) and July (300-350 $mWh.cm^{-2}$) (Anon. 1975).

**Geology**

The geology of the Study Area has been mapped at a scale of 1:40 000 and described regionally at a scale of 1:250 000: Norseman sheet (Doepel 1973) and Balladonia (Doepel & Lowry 1970). The area, tectonically stable since the Proterozoic, consists of several elements important to both the development of its landscape and vegetation:

a) most of the Study Area is underlain by Archaean or Proterozoic gneisses and granites eroded into a flat plain, largely by the transgression of the Eocene sea (Lowry 1970), and covered with Tertiary sediments, with scattered exposures of bedrock;

b) near the western margin of the Study Area, in the vicinity of Lake Dundas and Lake Cowan, is an Archaean greenstone belt, consisting of a number of distinct formations (Doepel 1973), eroded into low hills and ridges with colluvial flats;

c) a series of unmetamorphosed basic dykes of the Widgiemooltha Dyke Suite (Sofoulis 1966), striking predominantly east-west for 60 km, intrude Archaean rocks in the vicinity of Norseman and include the outcrops Mt Norcott and Jimberlana Hill;

d) running south-west for 50 km from the Study Areas' northern boundary is the Fraser Range, an eroded horst of Proterozoic basic granulite (Wilson 1969), which also extends north towards Zanthus (see Newbey 1984);

e) east of the Study Area are Eocene to Miocene limestones of the Nullarbor Plain within the Eucla Basin (Doepel & Lowry 1970);

f) a series of salt lakes including Lake Dundas and Lake Cowan, along the western margin of the Study Area, represent remnants of a major Palaeodrainage channel (van de Graaff *et al.* 1977).

The term granite, as used in this report, refers to all granitoid rocks, which weather into similar soils and support vegetation of similar structure and species composition.

The Norseman-Balladonia Study Area, falling within Salinaland of Jutson (1950), is gently undulating with a regional slope from north-west to south-east. Altitude varies from 250-350 m above sea level on the western boundary sloping gradually to 150 m in the south-eastern corner. Prominent chains of hills in the Study Area are the Dundas Hills, in the north-west near Norseman, and Fraser Range along the northern boundary. High points within the greenstone Dundas Hills include Woolyeenyer Hill (486 m) and Mt Deans (441 m) while Wyralinu Hill (569 m) is part of the basic granulite Fraser Range. Granite bedrock exposures are prominent above the subdued terrain of the Study Area's central and eastern portions. Granite outcrops include Jyndabinbin Rocks (341 m), Mt Andrew (306 m) and Mt Willgonarinya (236 m). In the vicinity of salt lakes, granite exposures sometimes rise markedly above the lake bed floor.

Surface drainage in the Norseman-Balladonia Study Area consists of two types, distinguished by the presence of salinity and their distinctive vegetation associations. Drainage lines within Palaeodrainage channels have largely filled with colluvium and alluvium, and are now reduced to strings of flat-floored salt lakes (van de Graaff *et al.* 1977). Higher in the landscape are indistinct linear valley features characterised by a lack of salinity and ephemeral water flows. These seasonally active features are not prominent in the landscape and have been included within the extensive Calcareous Plains landform east of Lake Dundas. To the west, broad valleys contain drainage lines that flow into the larger salt lakes. In the Study Area, salt lakes vary in size from strings of small lakes to the extensive Lake Cowan and Lake Dundas. Some of the aeolian features of the calcareous plains, valleys and salt lakes — formed during the last major arid period, which ended just before or early in the Holocene (Bowler 1976) — are still developing today.

During the present survey, geological surface types following Doepel (1973) and Doepel & Lowry (1970) were recorded for each vegetation site and vertebrate fauna survey site. The geological surfaces are listed in Appendix I with the detailed descriptions of vegetation.

**Soils**

The soils of the Norseman-Balladonia Study Area have been mapped by Northcote *et al.* (1968). The soil groups of the extensive Calcareous Plains are dominated by Deep and Shallow Calcareous Earths. These widespread calcareous soils, high in calcium (Ca) and magnesium (Mg), have a pH that varies from 7.5 - 8.75 with carbonate nodules present in either A or B horizons. Aeolian Sands are sometimes present as extensive sheets on Calcareous Plains. Soils of the Undulating Plains, over greenstone, are also high in Ca and Mg. Shallow Calcareous Earths occur on slopes, low ridges and hills within the greenstone belt near Norseman.

Neutral soils are skeletal to shallow over bedrock of granite throughout the Study Area, and over granulite in the Fraser Range. Granitic soils are present on or peripheral to exposures of granite bedrock. Some soils have formed from *in situ* weathering over granite. Also important is the laterite profile which develops over granitic and greenstone lithologies. The upper layer consists of unconsolidated sands and silts, followed by a ferruginous mottled zone, over indurated pisolites (Ollier 1988).

Associated with salt lakes are Saline and Sub-saline Soils. The floors of salt lakes consist of Saline Soils, with surrounding damp flats of Sub-Saline soils. Peripheral to most salt lakes are dunes and broad flats of Aeolian Sands. A net accumulation of aeolian deposits occurs on the eastern margin of salt lakes. Saline Soils in the Study Area include sands, clays and loams. There appears to be a westward migration of salt lakes in the Study Area (S. Kent, pers. comm.).

Deep Calcareous Earths are common on well-drained colluvial flats of Broad Valleys in the western section of the Study Area. Evidence of a colluvial origin however, often appears lacking. These soils may be highly calcareous with a pH exceeding 8.0 and carbonate nodules present in either horizon. Calcareous Earths occur within alluvial valley fills and also on relatively flat surfaces. Thin sheet deposits of Aeolian Sands are sometimes present on Broad Valleys.

During the present survey, soil data were recorded at each vegetation site. A summary profile for each soil group is presented with the detailed descriptions of vegetation in Appendix I. The correlations between geology, landforms, soils and vegetation are shown in Table 1.

**Landform Units**

Newbey and Milewski developed a classification of 10 units to describe the landscapes of the Eastern Goldfields (unpublished). Descriptions of relevant landform units are provided in previous reports in this series. Seven of these were present in the Norseman-Balladonia Study Area and their distribution is shown in Figure 2. Two of these (Undulating Plain and Hill) are divided into four sub-units on the basis of bedrock type. In Figure 2 these are shown as follows: Undulating Plain, Greenstone (U); Undulating Plain, Basic Granulite (UR); Hill, Greenstone (HN) and Hill, Basic Granulite (HR). The landform units and sub-units recorded in the Study Area are briefly described below.

Within the Study Area, the landforms Drainage Line (C), Dunefield (D) and Breakaway (B) do not occupy areas of sufficient size to be defined as units. A few, single dunes were present in the Study Area while Drainage Lines and Breakaways were rarely seen during field work.

*Granite Exposure* (G): Exposures of bedrock, flat to low-domed, vary in size from a few square metres to 0.5 $km^2$. Granite Exposures are mainly bare with scattered small pieces of exfoliated flat rock. Skeletal sheets of soil develop in slight depressions and low-lying areas of the exposure surface. Soils present on the rock and forming the peripheral apron are Granitic Soils. The apron consists of soil profiles up to 2 m thick weathered *in situ* from the underlying granite. In some areas the subsurface granite is not exposed.

Overlying this bedrock are soils similar to those of the peripheral apron. As the soil profile thickness decreases from the apron to the exposure, the frequency of waterlogging and the rate of drying increases. Run-off, directed along faint drainage lines or shed around the perimeter, also influences the rate of waterlogging.

Granite Exposures are scattered throughout the Norseman-Balladonia Study Area with the highest concentration in the south-eastern section. Scattered exposures include Theatre, Boojerbeenyer, Carranning and Buldania Rocks (north-west); Jyndabinbin Rock and Cowalinya Pool (east of Lake Dundas); Boingaring, Ten Mile, Newman and Afghan Rocks (north-east). A large number of Granite Exposures are concentrated in the south-east including Mt Newmont, Mt Willgonarinya, Booanya, Ponier and Coragina Rocks.

*Hill* (H): Hills rise more than 30 m above the surrounding plains and have slopes ranging from 5° to 15°. Soils are skeletal and excessively drained with numerous small areas of bare rock. Hills are divided into sub-units based on their bedrock type. Two of these (basic granulite and greenstone) were recognised within the Study Area. A number of Granite Exposures, including the large domed Mt Andrew, border on being classed as Hill (granite). The main differences between granite exposures and hills are the contrast in size and vegetation cover.

*Hill, basic granulite* (HR): A few low hills are present on a small southern section of the basic granulite Fraser Range. High points within the range include Wyralinu Hill, Mt Pleasant and Mt Malcolm. An un-named hill on the Eyre Highway, with slopes of 15-20°, was the only outcrop surveyed within the Fraser Range. Granitic Soils cover most of the slopes.

*Hill, greenstone* (HN): Hills and ridges within Undulating Plains (greenstone) are defined as features rising more than 30 m with slopes of 5-15°. Most prominent are the Dundas Hills, a series of hills separated by narrow colluvial flats and alluvial valleys, in the north-western section of the Study Area. This range extends west and south from 35 km north-east of Norseman to the northern flank of Lake Dundas, and includes the high points of Mt Norcott, Woolyeenyer Hill and Mt Deans. Jimberlana Hill, also within the range, is a Proterozoic norite, dolerite and gabbro dyke. The slopes and summits of several greenstone hills surveyed within the Dundas Hills are characterised by Shallow Calcareous Earths. A low foothill near Mt Thirsty on the western shore of Lake Cowan had similar soils.

*Salt Lake Feature* (L): Salt lakes are flat-floored with ephemeral water up to 30 cm deep following rain. Peripheral dunes, 1-5 m high and typically composed of gypsum, occur mainly on the southern and eastern margins. Lunettes, low sand ridges or dunes built up by wind and characterised by gentle outer slopes and wave-modified slopes towards the playa, form on the eastern margin of some salt lakes. Peripheral lake dunes and lunettes are usually stabilised by vegetation. The remainder of most lake margins consist of a gentle slope.

**Table 1.** Relationship between landforms, lithology, soils, vegetation structure and floristic composition at sites sampled or visited in the Norseman-Balladonia Study Area. Lithological surfaces follow Doepel (1973) and Doepel and Lowry (1970).

| Landform | Lithological Surface Norseman | Lithological Surface Balladonia | Soil | Vegetation Type | Vegetation Sites (Appendix I)[a] |
|---|---|---|---|---|---|
| GRANITE EXPOSURE (G) | | | | | |
| Skeletal soil sheets and inner aprons | Ag, Pag | Pl, Pc, Pm, Py | Granitic Soils | *Thryptomene australis* Tall Shrubland | NB59 |
| | | | | Granite Complex | NB33, NB37, NB51, NB118 |
| Outer aprons | Ag, Pa, Pag, Tft | Pl, Pm | Granitic Soils | *Acacia acuminata* Low Woodland | NB119 |
| | | | | *Acacia* Tall Shrubland | NB117 |
| | | | | *Allocasuarina huegeliana* Low Woodland | |
| | | | | *Eucalyptus loxophleba* Mallee | |
| | | | | *Melaleuca elliptica* Tall Shrubland | |
| | | | | *Lepidosperma drummondii* Hummock Grassland | NB43 |
| Surrounding plains | -[b] | Py, Qpl[c] | Shallow Sands | *Eucalyptus histophylla* Mallee | |
| HILL, GREENSTONE (HN) | | | | | |
| Slopes and summits | Aeo, Awb, | - | Shallow Calcareous Earths | *Eucalyptus brockwayi* Woodland | |
| | Abd, Pd | - | | *E. lesouefii* Low Woodland | |
| | Tec, | - | | *Eucalyptus* Mixed Low Woodland | |
| | Apz | - | | *E. oleosa* Low Woodland | NB23 |
| | | - | | *E. torquata* Low Woodland | |
| HILL, BASIC GRANULITE (HR) | | | | | |
| Slopes and summits | Px | - | Granitic Soils | Granite Complex | NB80 |
| SALT LAKE FEATURES (L) | | | | | |
| Lake floors | Qra, Qrm | Qre[d] | Saline Soils | *Halosarcia* Low Shrubland | NB42, NB152, NB154, NB162 |
| Lake slopes | Qra | - | Saline Soils | *Melaleuca* aff. *cuticularis* Tall Shrubland | |
| | Qps[e] | - | Aeolian Sands | Lake Margin Complex | |
| | Qps | Qo[f] | | Lake Margin Complex | |
| | - | Qo | | *Eucalyptus* Mixed Mallee | NB35 |

[a] A total of 162 vegetation sites were sampled, of which a representative set of 49 are presented in detail as Appendix I. The balance of the sampled sites are held as data sheets at the W.A. Wildlife Research Centre, Perth.
[b] - = not encountered during the survey.
[c] "Qqs" + "Qpl" on the Norseman Geological Map are equivalent to "Qpl" on the Balladonia Map.
[d] Mostly, parts of "Qre" on the Balladonia Geological Map are equivalent to "Qra" on the Norseman Map.
[e] Mostly, parts of "Qpl" + "Qre" on the Balladonia Geological Map are equivalent to "Qps" on the Norseman Map.
[f] "Qo" on the Balladonia Geological Map is equivalent to "Qps" on the Norseman Map.

**Table 1. (cont).**

| Landform | Lithological Surface Norseman | Lithological Surface Balladonia | Soil | Vegetation Type | Vegetation Sites (Appendix I)[a] |
|---|---|---|---|---|---|
| | Qpf | - | Calcareous Earths | *Melaleuca quadrifaria* Tall Shrubland | |
| | Qpf | - | | *Eucalyptus oleosa* Low Woodland | NB128 |
| | Qps | Qpl, Pl | Loamy Sands | *Callitris canescens* Tall Shrubland | NB45 |
| | - | Qpl, Qre, TQo | Shallow Calcareous Earths | *Eucalyptus fraseri* Low Woodland | NB36 |
| Sub-saline flats | Qrm | - | Sub-saline Soils | *Atriplex* Low Shrubland | |
| Lunettes | Qps | - | Deep Calcareous Earths | *Eucalyptus transcontinentalis* Mallee | |
| | Qps | - | Aeolian Sands | *E. salicola* Low Woodland | |
| | - | Qo | | *E. leptophylla* Mallee | |
| Raised Aeolian flats | Qps | - | Calcareous Earths | *Atriplex* Low Shrubland | |
| | Qpf | - | | *Eucalyptus oleosa* Low Woodland | NB153 |
| Peripheral lake dunes | - | Qo | Aeolian Sands | *Eucalyptus gracilis* Mallee | NB38 |
| | Qps | | | *E. falcata* Mallee | NB161 |
| | Qps | - | | *E. flocktoniae* Low Woodland | |
| | Qps | - | | *E. leptophylla* Mallee | |
| | Qps | Qpl | | *E. eremophila* Low Woodland | NB46 |
| | - | Qro | Gypsum Soils | *E. fraseri* Low Woodland | NB157 |
| Aeolian sheet deposits | Qpf | - | Aeolian Sands | *Eucalyptus leptophylla* Mallee | |
| | Qps | - | | *E. gracilis* Mallee/ *Callitris* | |
| | Qqs | - | Calcareous Earths | *Eucalyptus* Mixed Low Woodland/ *Atriplex* | |
| | Qqs | - | | *E. cylindrocarpa* Mallee/ *Triodia* | |
| | Qqs | - | | *E. kessellii* Mallee | |
| CALCAREOUS PLAIN (P) | | | | | |
| Flat & gentle undulating plains | Qqs | - | Shallow Loamy Sands | *Eucalyptus oleosa* Low Woodland | NB126 |
| | Qqs | - | | *E.transcontinentalis* Woodland | NB28 |
| | Qpv | - | | *E. salmonophloia* Woodland | |
| | Qqs | - | Calcareous Earths | *E. cylindrocarpa* Mallee | NB104 |
| | Qqs | - | | *Eucalyptus* . Mixed Low Woodland | NB160 |
| | Qpl | - | | *E. diptera* Low Woodland | |
| | Qpl | - | | *E. dundasii* Woodland | NB151 |
| | Qpl | - | | *E. dundasii* Low Woodland | NB127 |
| | Qpl | - | | *E. flocktoniae* Low Woodland | |
| | Qpl | - | | *E. oleosa* Low Woodland | NB150 |

**Table 1. (cont).**

| Landform | Lithological Surface Norseman | Balladonia | Soil | Vegetation Type | Vegetation Sites (Appendix I)[a] |
|---|---|---|---|---|---|
| | Qpl | - | | *Eucalyptus* Mixed Mallee/ *Melaleuca* | NB158 |
| | Qpl | - | Loamy Clays | *E. creta* Low Woodland | NB159 |
| | Qpv | - | Calcareous Earths | *E. campaspe* Low Woodland | |
| | Qpv | - | | *E. salubris* Low Woodland | |
| | Qqs | - | | *E. diptera* Low Woodland | |
| | Qqs | - | | *E. salubris* Low Woodland | |
| | - | Qpc | | *E. transcontinentalis* Low Woodland | |
| | - | Qpc | Fine Sandy Clays | *E. diptera* Mixed Mallee | NB155 |
| | - | Qpl | Calcareous Earths | *E. flocktoniae* Low Woodland | |
| | - | Qpl | | *E. flocktoniae* Low Woodland/ *Melaleuca* | |
| | - | Qpl | | *E. oleosa* Low Woodland | NB50, NB65, NB156 |
| (Adjacent to exposed granite) | Qpl, Pa | - | Calcareous Earths | *Eucalyptus cylindrocarpa* Mallee | NB105, NB114 |
| | - | Qpl, ?Py | | *E. cylindrocarpa* Mallee | NB61 |
| | - | Qpl, Pc | Loamy Sands | *Melaleuca uncinata* Tall Shrubland | NB48 |
| | - | Qpl, Pc | | *M. uncinata* Tall Shrubland | NB58 |
| | - | Qpl, Pm | | *Eucalyptus melanoxylon* Low Woodland | NB54 |
| | Qpl, Ag | - | | *E. gracilis* Mallee | |
| (Superficial to Tertiary strata) | - | Qro | Calcareous Earths | *Cratystylis conocephala* Low Shrubland | NB41 |
| | - | Qro | | *Eucalyptus oleosa* Low Woodland | |
| | Tox | - | | *E. oleosa* Low Woodland | |
| | Ttl | - | Shallow Loamy Sands | *E. oleosa* Low Woodland | |
| | Ttf | - | Clay Sands | *E. calycogona* Mallee/ *Triodia* | |
| | Ttf | - | Fine Loamy Sands | *E. transcontinentalis* Mallee | NB93 |
| | Qqs, ?Ttf | - | | *Eucalyptus* Mixed Mallee | |
| | Tog | Tep, TQr, Tmn | Calcareous Earths | *E. oleosa* Low Woodland | |
| Aeolian dunes | Qpl | - | Shallow Loamy Sands | *Eucalyptus oleosa* Mallee | NB29 |
| | Qqs | - | | *E. flocktoniae* Low Woodland | |
| | Qqs | - | Aeolian Sands | *E. transcontinentalis* Low Woodland | |
| Aeolian sheet deposits | Qqs | Qpl | Aeolian Sands | *Eucalyptus flocktoniae* Low Woodland | |
| | Qps | - | | *E. oleosa* Mallee | NB31 |

**Table 1. (cont).**

| Landform | Lithological Surface | | Soil | Vegetation Type | Vegetation Sites (Appendix I)[a] |
|---|---|---|---|---|---|
| | Norseman | Balladonia | | | |
| | - | Qpl | Calcareous Earths | *E. transcontinentalis* Low Woodland | |
| | - | Qpl | | *E. flocktoniae* Low Woodland | |
| Colluvial flats | Qpl | - | Calcareous Earths | *Eucalyptus oleosa* Low Woodland/ *Atriplex* | |
| | Qpl | - | | *E. salubris* Low Woodland | |
| | - | Qro | | *Atriplex-Cratystylis* Low Shrubland | |
| | - | Qro | | *Atriplex-Maireana* Low Shrubland | |
| SANDPLAIN (S) | | | | | |
| Plains | Ttf | - | Deep Gravelly Loams | *Allocasuarina acutivalvis* Tall Shrubland | |
| | Ttf | - | Gravelly Sands | *Eucalyptus transcontinentalis* Mallee | |
| | Ttf | - | | *Melaleuca uncinata* Tall Shrubland | |
| UNDULATING PLAIN, GREENSTONE (UN) | | | | | |
| Raised colluvial flats | Pd | - | Shallow Loamy Sands | *Allocasuarina helmsii* Tall Shrubland | |
| | Pd | - | Shallow Calcareous Earths | *Eucalyptus griffithsii* Mallee | NB26 |
| Slight ridges | Qqs | - | Shallow Calcareous Earths | *Eucalyptus* Mixed Low Woodland | |
| | Qqs | - | | *E. lesouefii* Low Woodland | |
| UNDULATING PLAIN, BASIC GRANULITE (UR) | | | | | |
| Colluvial flats | Qpl | - | Loamy Clay Sands | *Eucalyptus effusa* Mallee | NB131 |
| Undulating plains | Pxa | - | Shallow Loamy Sands | *Acacia acuminata* Tall Shrubland | |
| BROAD VALLEY (V) | | | | | |
| Flat and gentle undulating plains | Qqs | - | Deep Calcareous Earths | *Eucalyptus* Mixed Low Woodland | |
| | Qqs | - | | *E. dundasii* Low Woodland | |
| | Qqs | - | | *E. flocktoniae* Low Woodland | |
| | Qqs | - | | *E. longicornis* Low Woodland | |
| | Qpl | - | | *E. cylindriflora* Mallee | |
| | Qpl | - | | *E. salubris* Low Woodland | |
| | Ttf | - | | *E. diptera* Low Woodland | |
| | Ttf | - | | *E. dundasii* Low Woodland | |
| | Ttf | - | | *E. ovularis* Low Woodland | |
| | Ttf | - | | *E. salmonophloia* Woodland | NB6 |
| | Ttf | - | | *E. transcontinentalis* Low Woodland | |

Most salt lakes in the Study Area represent former, major drainage lines reduced to a scattered string of lakes, associated with extensive areas of flats. These marginal areas usually consist of alluvial or aeolian material forming sub-saline and well-drained flats. Sheet deposits and raised flats in the vicinity of salt lakes are primarily of aeolian origin.

The soils of Salt Lake Features have a complex history which includes colluvial, alluvial and aeolian actions and intermittent reworking, especially by wind during recent arid periods (Bowler 1976). The development of salt lakes in the Study Area, also influenced by groundwater and evaporation, is an ongoing process. Lake floors and slopes are characterised by Saline soils while Calcareous Earths form lake slopes, raised flats and undulating sheet deposits. Peripheral dunes, lunettes and some lake slopes consist of Aeolian Sands, typically comprised of gypsum.

The main salt lakes (Lake Cowan, Lake Dundas) are confined to the western section of the Norseman-Balladonia Study Area. Smaller un-named salt lakes, some forming chains, are scattered throughout the Study Area. Granite Exposures are often associated with the margins of salt lakes.

*Calcareous Plain* (P): Extensive flat plains dominate the Norseman-Balladonia Study Area. Well-drained Calcareous Earths of colluvial and alluvial origin constitute the main soil group present. The other important soil group is Aeolian Sands, forming extensive sheet deposits over deep calcareous soils, and occasional low dunes stabilized by vegetation. Calcareous Earths are shared with Undulating Plain over greenstone (UN) and Broad Valleys (V). Local relief of Calcareous Plains rarely exceeds 4 m, which contrasts with the topography of Undulating Plain.

Broad Valleys and Calcareous Plains are distinguished with difficulty in the Norseman-Balladonia Study Area. Size and origin are the major differences between the two landforms. Calcareous Plains are in the order of 70-100 km wide and their level surface appears to have resulted from transgression by the Eocene Sea about 45 million years ago (Lowry 1970). Broad Valleys, in contrast, are narrower and follow Palaeodrainage systems. Although many of the soils are similar, the limits of the Eocene Sea arbitrarily define the extent of Calcareous Plains within the Study Area. The surface morphology of the Study Area was developed by Eocene transgression, however the limits are not necessarily represented by rocks as exposed today (S. Kent, pers. comm.). Broad Valleys are confined to the western portion while Calcareous Plains dominate the rest of the Study Area, east of Lake Dundas.

*Sandplain* (S): Sandplains, undulating uplands with thick laterized soil profiles that have been reworked relatively little since the Tertiary, are usually associated with granite bedrock and grade into Granite Exposures (G) and Broad Valleys (V). Laterite profiles in many cases have developed in situ over granite and Archaean greenstones. Sheets or dunes, primarily of Aeolian sands and of recent origin (Quaternary), associated with salt lake playas are not considered part of the sandplains landform.

Sandplains are common in the western portion of the Norseman-Balladonia Study Area with small sandplain areas also scattered throughout the extensive Calcareous

Plains (P), usually associated with Granite Exposures. Although absent from the Widgiemooltha-Zanthus Study Area immediately to the north (Newbey 1984), Sandplains are a dominant landform in the western and northern regions of the Eastern Goldfields.

*Undulating Plain* (U): Differential weathering of the bedrock has resulted in series of low hills, ridges and rises with local relief of 2-30 m and slopes of 5° to 15° separated by narrow colluvial flats and alluvial valleys. The landform unit was subdivided on the basis of bedrock type with two sub-units (greenstone and basic granulite) recognised within the Study Area.

*Undulating Plain, greenstone* (UN): The greenstone belt, extending north-south between Lake Dundas and Lake Cowan, consists of Undulating Plains with hills of mainly basic basalt and ultra-basic sections underlying colluvial flats and slopes. The rises of metabasalt are more resistant to weathering than the intervening flats. Bedrock exposures are present on steeper slopes, along the margins of salt lakes and exposed hill tops.

Greenstone lithologies refer to Archaean Age units of specific affinities, however, lithology alone does not explain the landform developments. Modern day exposure of ancient lithologies may also be a function of deformational elements, such as faulting and shearing, that are more prone to physio-chemical weathering processes.

Shallow Calcareous Earths and Shallow Loamy Sands are present on the hills and rises while colluvial flats consist of Deep Calcareous Earths. Undulating Plain over greenstone is confined to the western portion of the Norseman-Balladonia Study Area.

*Undulating Plain, basic granulite* (UR): The Fraser Range is a landform unique within the Eastern Goldfields. The southern one-third of the range occurs within the Study Area, with the remainder within the adjacent Widgiemooltha-Zanthus Study Area (see Newbey 1984). The Fraser Range is a horst that appears to have experienced uplift that is greatest in the south-west, on the northern boundary of the Norseman-Balladonia Study Area (Newbey 1984). A few low hills (Wyralinu Hill, Mt Pleasant, Mt Malcolm) are present within this southern section of the range. Differential weathering of the complex bedrock (Wilson 1969) has resulted in a crude and well-spaced lattice of low and rounded ridges. The ridges within the Study Area reach 3-5 m and decrease in height as the Fraser Range extends north-east.

*Broad Valley* (V): Broad Valleys are broad, saucer-shaped valleys 2-15 km in width with internal relief usually less than 20 m and slopes rarely exceeding 2°. The valleys consist of colluvial, alluvial and aeolian fills of Palaeodrainage systems. Broad Valleys are well-drained by sheet movement of water or indistinct drainage lines that flow after heavy rainfall. Broad Valleys are dominated by Deep Calcareous Earths with sheet deposits of Aeolian sands in some areas.

Broad Valley and Calcareous Plain landforms are difficult to distinguish in the Norseman-Balladonia Study Area. Many of the soils are similar but those of Broad

Valleys tend to be less calcareous indicating development over or proximal to granite bedrock. Within the Study Area, Broad Valleys are only found west of the greenstone belt.

### Freshwater

Permanent areas of freshwater consist mainly of scattered dams constructed on pastoral leases mainly in the western and eastern sections of the Study Area and near Fraser Range. Salt lakes are veneered with freshwater for short periods following heavy rainfall. Natural areas of freshwater are also present as ephemeral pools associated with granite exposures. Rarely exceeding 30-60 cm in depth these pools, up to a few metres wide, persist only for short periods. Granite rock-holes are scattered throughout the Study Area.

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