II. ENVIRONMENT

A considerable amount of regional data on climate, geomorphology, soils, native vegetation and land use has been published.

Climate – The most detailed account of the climate of the region has been given by the Bureau of Meteorology (Anon 1952). The semi-arid climate increases in aridity from south to north because rainfall decreases and potential evaporation increases in this direction. Yearly potential evaporation averages 50 inches in the south and 60 inches in the north, compared with the mean annual rainfall of 14 inches in the south and 10 inches in the north. Approximately two-thirds of the rain falls during the six cooler months of May to October (Table 1) which form the growing season for the annual cereals and pastures on which agriculture is largely based.

Calculations of average potential evapotranspiration on a monthly basis show that, in the south, rainfall exceeds potential evapotranspiration only during June and July, and then only by a total of one inch (Rowan and Downes 1963). In the north, rainfall matches evapotranspiration only in the most favourable month of June, and barely at that.

Much of the salting within the region is associated with the seepage of rainwater, a considerable amount of which results from unusually heavy or prolonged rains. Heavy falls of three inches, or more, sometimes occur, particularly in late summer. A study of daily rainfall records at Woomelang showed that the heaviest falls between 1960 and 1966 totalled two or three inches, and three such falls had occurred over the seven-year period. Again, it can be deducted from Table 1 that in occasional years the seasonal excess of rainfall over potential evapotranspiration can be considerable, for example seven inches from May to October in the unusually wet year 1956.

Plate 1 - Mallee – the main native vegetation in north-western Victoria

Table 1 – Rainfall at Woomelang (points).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1943	110	33	15	61	50	140	97	167	127	96	37	22	950
1944	33	22	8	124	114	7	107	0	53	65	65	60	658
1945	66	29	9	2	48	250	85	159	54	112	69	51	934
1946	158	252	107	32	139	127	113	96	39	50	110	39	1,262
1947	0	117	160	40	38	135	188	119	64	190	206	110	1,367
1948	8	57	0	142	110	211	78	27	51	259	78	85	1,106
1949	9	242	39	3	215	16	91	31	111	270	60	12	1,099
1950	3	327	305	69	254	62	99	94	136	130	68	64	1,611
1951	33	47	9	45	190	174	166	165	26	135	22	49	1,061
1952	99	48	68	199	348	187	72	137	68	201	282	44	1,753
1953	128	63	0	61	34	147	165	187	157	102	121	38	1,203
1954	221	28	20	234	64	53	113	169	67	138	100	209	1,416
1955	0	224	92	15	180	310	135	179	316	109	104	89	1,753

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1956	77	0	288	136	401	142	231	120	144	496	42	7	2,084
1957	6	441	41	45	23	153	39	103	33	100	43	29	1,056
1958	127	56	11	24	132	19	206	259	101	321	229	14	1,499
1959	82	111	149	176	40	23	31	124	110	206	48	44	1,144
1960	225	183	48	133	301	113	149	224	245	28	282	118	2,049
1961	0	47	61	207	36	65	169	107	152	44	132	312	1,332
1962	154	17	15	0	161	120	56	199	157	107	17	154	1,157
1963	275	19	275	215	175	195	140	136	125	91	14	31	1,691
1964	28	18	0	142	64	93	148	208	428	297	103	36	1,565
1965	3	0	15	142	94	93	241	235	87	20	172	143	1,245
1966	58	91	82	24	70	18	164	130	204	197	76	262	1,376
1967	18	62	6	11	62	73	59	117	57	52	6	90	613
Av.*	64	109	72	87	129	134	128	134	131	140	99	88	1,315
Et. #	480	420	350	220	140	80	60	120	170	250	340	450	

* Average rainfall for 51 years ending 1966.
\# Average potential evapotranspiration (calculated in S. part of region).

Geomorphology – The most comprehensive papers on geology and physiography of the region are those of Hills (1939), Gloe (1947) and Lawrence (1966). The area is a vast depositional plain with superficial aeolian undulations distinguishing it from the Riverine Plain to the east. General levels are 300 to 350 feet above sea level in the south and 200 feet in the north, but there are several relatively large N.N.W – trending ridges some miles across, which maintain an elevation of approximately 300 feet in the north. The most notable ridge extends150 miles from just east of Hopetoun to the extreme north-west corner of the State. It is broken by two saddles south-west and north-west of Ouyen, and the resulting segments are known as the Dennying, Walpeup and Millewa Ridges. There are several broad basins below 200 feet. These contain large accumulations of salt and gypsum at or close to the surface and are known as the Tyrrell, Cow Plains and Raak Basins. Another occurs to the west of the Millewa ridge in the north-western corner of the State, extending into South Australia.

Throughout the Tertiary era a complex series of sediments was deposited in migrating seas and rivers over Mesozoic and Palaeozoic rocks. The basement rocks are mainly Ordovician slates and sandstones which outcrop in the hills to the south-east of the region. As the sea retreated westwards at the close of the Tertiary era Parilla Sand (Firman 1965) was laid down. Working in Victoria, Lawrence (1966) referred to this material as "Diapur Sandstone", and noted that it consisted almost entirely of fine to medium quartz sand with the upper 10 to 50 feet cemented by limonite as a result of laterisation. Coarse mottles, ironstone and clay frequently form a capping. A water table has been encountered 50 to 200 feet below the surface of the sand, but no records of its salinity have been published. N-S ridges up to 200 feet high occur on the surface, usually trending N.N.W – S.S.E, and possibly built up as coastal dunes as the sea retreated to its present position. These ridges are a dominant feature of the present landscape (Fig.1).

In the Big Desert and Berrook land systems (see map) the surface of the Parilla Sand has been worked by the wind to form Lowan Sand (Lawrence 1966). E-W dunes, jumbled dunes and sandplains have been formed.

Away from these so-called deserts the Parilla Sand is covered largely by aeolian calcareous clays and sands, the assemblage being known as the "Woorinen Formation" (Lawrence 1966). Working near Swan Hill, Churchward (1960) concluded that the older aeolian deposits arose as regional dust (see next section). On the other hand Blackburn *et al* (1967) concluded from studies in the Wimmera that the clays in the swales between N-S ridges are lacustrine and estuarine and that deflation of these by the wind has given rise to the calcareous clays on the ridges, that is wind deposits were local, not regional. It seems likely that there has been a graduation in aeolian redistribution on passing to the more arid north.

Within the Woorinen Formation the main modification of the N-S ridge swale topography has been the development of E-W dunes, mainly on the ridges in the south but more evenly spread further north. Weakly elongated aeolian land forms known as "hummocks" have also been formed, and these extend further to the south-east than the E-W dunes.

Soils – There have been several detailed soil surveys in irrigated districts along the Murray River – at Woorinen (Taylor and Penman 1930, Churchward 1960), Nyah (Taylor *et al* 1933), Merbein (Penman *et al* 1933), Mildura (Penman *et al* 1940), Robinvale (Skene 1940), Redcliffs (Hubble and Crocker 1941), and Swan Hill (Skene and Sargeant 1966). A detailed survey has also been done on a dryland farm at Walpeup (Newell 1961). The soils of the region have also been mapped at a reconnaissance scale by Northcote (1960) and by Rowan and Downes (1963).

In the Woorinen Formation the texture of the soils usually depends on the proportion of sandy saltation material and clayey dust known as "parna" (Butler 1956, Butler and Hutton 1956). In general the surfaces are sands on the E-W dunes and on crests of steeper ridges and hummocks, becoming clays and sandy clay loams in the lower positions.

The soils are known most widely as "solonised brown soils", characterised by a large accumulation of lime and by weak eluviation of clay) Stephens 1962). Eluviation is such a dry climate is thought to be assisted by the presence of salts which tend to mobilise the clay. The heaviest soils contain relatively little lime, are gilgaied and found most widely on broad plains; these are probably best classified as "grey and brown soils of heavy texture" (Stephens 1962). Some of the soils with sandy surfaces have solonetzic features, that is there is an abrupt change to a sandy clay with columnar structure. Soils saline to the surface occur in large basins and can be classified as "solonchaks".

On the Lowan Sands of the "deserts" the soils are deep sands, although in many swales there is a small accumulation of clay at depth. When not stripped by recent wind erosion, the upper horizons are pale and the subsoils yellow because of leaching of iron. These soils cannot be classified in conventional terms. Whilst they show evidence of podzolisation the reaction is frequently neutral to alkaline so that the term "podzol" cannot be used.

The Woorinen Formation is markedly layered. Churchward (1961, 1963 a, b, c) has examined the materials in great detail near Swan Hill and found that two or more buried soils or parts thereof underlie the upper profile. Apart from contemporary erosive deposits on farms (drift), soils have developed in aeolian materials deposited in four periods, presumably arid periods. Each of these is thought to have been followed by a more humid period when vegetation stabilised landscapes, enabling a soil to form. Because of stripping at the onset of each arid phase, the older soils are usually represented only by their B and C horizons. Churchward traced the distribution of the soils in a landscape of E-W dunes and associated swales near Swan Hill, and named the soil layers, in order of increasing age Piangil (drift), Kyalite, Speewa, Bymue and Tooleybuc. Each layer is more or less parallel to the present land surface and increases in clay content from dune crest to swale. He Kyalite layer forms the surface, with a maximal thickness of 6 feet on the southern and eastern slopes. It is markedly calcareous. The Bymue layer is also calcareous, and is always buried. The oldest layer (Tooleybuc) is usually of clay texture and it underlies the whole landscape. Churchward noted that the clays of the two oldest layers were of low visible porosity and thus of low permeability to water.

Salts in soils – The distribution of soluble salts in profiles has been discussed in the above-mentioned reports of soil surveys. The content of soluble salts was usually found to be moderate to high in subsoils of the heavier profiles, reaching a maximum between 4 and 6 feet and remaining high to at least 10 feet. The main salts were sodium chloride and sodium bicarbonate, with chloride predominating where values were high. The most comprehensive estimate of salinity was made in the Robinvale district (Skene 1951) where the soil survey was done before most of the area was laid out for irrigation. The land sampled was virgin or only sparingly cultivated. The proportion of sodium chloride was generally less than half where total soluble salts were low (less than 0.1 per cent), grading up to about two-thirds where salts were high (more than 0.3 per cent).

The contents of salts under native vegetation as indicated by percentage chloride in soils of various textures, topographic situations and localities are set out in Table 2. The samples were taken in 1956-57 during a reconnaissance survey of the region (Rowan and Downes 1963). On the sands of the E-W dunes the chloride values were low, except 2 or 3 feet on the lower slopes and on one of the two-mid slopes sampled. In the medium-textured soils values were moderate below 1 foot, with an increase from upper to lower slopes. The clay plains had higher values at all depths, and those below 1 foot were well within the range known to restrict severely the growth of most plants (0.2 per cent chloride). Values on the gilgai puffs were particularly high.

Origin of salts – In Pleistocene and Recent times salts have been deposited from the atmosphere (cyclic salts) and in alluvium, and have been redistributed by the wind during the development of the Woorinen Formation. Much of the alluvium was probably deposited under evaporative conditions far from its source in the highlands to the south and east. Macumber (1968) found that alluvium deposited under such conditions just to the east of the region by the Loddon River system is saline.

Churchward (1961) has established the relative ages of the several soil layers in the Woorinen Formation. Although absolute ages have not yet been determined, there can be little doubt that the two oldest, well-leached soils were deposited in Pleistocene times during which the climate is known to have fluctuated widely. Although the permeability of the oldest soils is low, there have been pluvial periods during which most of the salts have probably been leached to the regional groundwaters in the underlying Parilla Sand. It is likely than most of the salts now in the soils have been derived from the atmosphere since the last pluvial period.

In 1955-56 Hutton and Leslie (1958) collected salts at the rate of about 50 lb/acre/year in rain gauges set within the region but concluded from a study of ionic ratios that, away from the coast, the source of atmospheric salts is largely terrestrial. Thus the net gain would be considerably less than that collected in gauges. The main cations collected in 1955-56 were sodium and calcium, often in equal ionic concentrations. The main anions were bicarbonate and chloride, usually in the ratio of 2 or 4 to 1.

The regional water table contributed salts to soils before settlement in regionally low basins (Lawrence 1966).

Native vegetation – The dominant vegetation in most of the region before clearing was mallee which is usually a dense thicket of multistemmed eucalypts 10 to 20 feet high. The main species are as listed in Table 2, plus *E. behriana* F.v.M.Miq. Several variations in the structure of the formation can be recognised (Rowan and Downes 1963). Open stands with relatively large eucalypts (big mallee) occur on a wide range of soils in the more arid north and on clay plains in the centre and south where the relatively sparsity of timber may be caused by inherent salinity of subsoils. On the relatively infertile Lowan Sands, shrubs are often co-dominant with eucalypts. Most of the crests of E-W dunes in the Woorinen Formation have a prominent understorey of porcupine grass (*Triodia irritans* R.Br).

Patches of woodland occur throughout on a wide range of soils. The main trees are Murray pine (*Callitris preissii* Miq), belar (*Casuarina cristata* Miq) and buloke (*Casuarina Luehmannii* R. T. Baker). Woodlands of black box (*E. largiflorens* F. v. M) and red gum (*E. camaldulensis* Dehn) fringe the Murray River and occasional creek courses in the south.

Table 2 – Percentage chloride under native vegetation within 0-4 feet in various soils, topographic situations and localities.

Profile No, Parish and locality within region			Sample depth (ft) Surface *	1-2	2-3	3-4	Vegetation
E-W SAND DUNES							
Crest							
47	Tiega	Centre	0.007	0.003	0.003	0.010	*E. incrassata* Labill, *E. oleosa* F. Muell. Ex Miq, *Triodia irritans* R. Br
56	Timberoo	Centre	0.009	0.001	0.001	0.001	*Callitris preissii* Miq, *E. olesoa* F. Muell
100	Yaramba	N	0.002	0.001	0.003	0.002	*E. oleosa* F. Muell, *E. dumosa* A. Cunn, *E. foecunda* Schauer
109	Gunamalary	S.W.	0.003	0.001	0.002	n.d.	*E. incrassata, E. foecunda, Melaleuca uncinata* R. Br
Mid slope							
48	Tiega	Centre	0.006	n.d.	0.083	0.093	*E. dumosa, E. oleosa* F. Muell
57	Timberoo	Centre	0.001	0.001	0.001	0.001	*C. preissii, E. oleosa* F. Muell
Lower slope							
49	Tiega	Centre	0.003	0.003	0.089	0.118	*E. dumosa, E. oleosa* F. Muell
58	Timberoo	Centre	0.001	0.001	0.028	0.096	*C. preissii, E. dumosa*

Profile No, Parish and locality within region			Sample depth (ft)				Vegetation
			Surface *	1-2	2-3	3-4	
MEDIUM-TEXTURED SOILS ** *Upper slopes of hummocks and ridges*							
41	Boigbeat	S.E.	0.001	0.114	0.100	0.097	*E. dumosa, E. oleosa* var. *angustifolia* Maiden, *E. calycogona* Turez
45	Boigbeat	S.E.	0.001	0.081	0.083	0.079	*E. dumosa, E. oleosa* var. *angustifolia*
53	Tiega	Centre	0.001	0.040	0.051	0.061	*E. oleosa* var. *angustifolia, E. dumosa, E. gracilis* F. Muell
60	Timberoo	Centre	0.001	0.001	0.002	0.002	*C. preissii, Casuarina luehmannii* R. T. Baker
93	Woolwoola	N.W.	0.005	0.012	0.097	0.121	*C. preissii, Heterodendron oleifolium* Besf, *Stipa, Danthonia*
99	Kurnwill	N	0.006	0.056	0.084	0.079	*Casuarina cristata* Miq, *C. preissii*
103	Koleya	N	0.002	0.062	0.085	0.093	*E. oleosa* F. Muell, *E. dumosa*
		Av	0.002	0.052	0.072	0.076	
Lower slopes of hummocks and ridges (l.s), interdune flats (i.f) and other swales (s)							
50	Tiega	Centre (i.f)	0.001	0.004	0.005	0.013	*E. oleosa* F. Muell, *E. gracilis, E. calycogona*
51	Tiega	Centre (i.f)	0.009	0.010	0.021	0.024	*Stipa, Danthonia*
54	Tiega	Centre (l.s)	0.001	0.071	0.095	0.097	*E. oleosa, E. dumosa*
55	Tiega	Centre (l.s)	0.001	0.165	0.136	0.133	*E. oleosa* F. Muell
59	Timberoo	Centre (i.f)	0.002	0.089	0.136	0.130	*C. preissii, C. luehmannii, E. dumosa*
77	Gunamalary	S.W. (i.f)	0.001	0.023	0.059	0.069	*E. dumosa, E. foecunda*
82	Danyo	S.W. (l.s)	0.001	0.152	0.153	0.134	*E. dumosa, E. calycogona, E. gracilis*
90	Woolwoola	N.W. (s)	0.008	0.005	0.005	0.008	*C. preissii, H. oleifolium, Stipa, Danthonia*
95	Mallanbool	N (s)	0.006	0.087	0.088	0.091	*E. gracilis, E. dumosa*
96	Mallanbool	N (s)	0.006	0.111	0.123	0.124	*E. gracilis, E. dumosa*
102	Yaramba	N (i.f)	0.005	0.121	0.144	0.161	*E. oleosa* var. *angustifolia*
		Av	0.004	0.076	0.088	0.089	
CLAY PLAINS *Non-gilgaied*							
39	Bunguloke	S.E.	0.004	0.182	0.260	0.262	*Stipa, Danthonia*
101	Yaramba	N	0.008	0.268	0.252	0.244	*E. oleosa* var. *angustifolia, E. gracilis*
Gilgai depressions							
46	*(b)* Boigbeat	S.E.	0.016	0.133	0.170	0.177	*E. calycogona, E. dumosa, E. oleosa* var. *angustifolia*
108	*(b)* Carina	S.W.	0.011	0.074	0.107	0.134	*E. dumosa, E. calycogona*
Gilgai puffs							
46	*(a)* Boigbeat	S.E.	0.022	0.331	0.309	0.301	*E. calycogona, E. dumosa, E. oleosa* var. *angustifolia*
108	*(a)* Carina	S.W.	0.013	0.264	0.295	0.267	*E. dumosa, E. calycogona*

* Surface samples usually 0-1", 0-2" or 0-3".
** Medium-textured soils range from sandy loam to sandy clay loam at the surface and from sandy clay loam to sandy clay in subsoils.

In the north, savannahs are widespread and the main grasses before settlement appear to have been of the genera *Stipa* and *Danthonia.* In the basins with particularly high salinities at or near the surface the original vegetation is dominated by halophytic shrubs, notably samphire (*Arthrocnemum halocnemoides* Nees).

Land use – Clearing began in the south in the 1880's, and the last large-scale settlement occurred in the north in the 1920's (Holt 1946).

It is significant that, in E-W dune-swale landscapes in which problems of land management abound, no timbered reserves large enough to embrace a range of land forms have been left in the south-east as scientific reference areas. In the west, clearing is confined largely to the Ouyen-Murrayville and Redcliffs-Morkalla districts

In cleared areas land use is mixed farming, that is cropping alternating with grazing. A large body of experimental data has been built up by the Victorian Department of Agriculture concerning improvement of yields of crops and pastures. Much of this work is summarised in annual reports of the Mallee Research Station, Walpeup.

Wheat is the main crop, and it is sown in autumn, usually on a 2, 3 or 4-year rotation. Fallows for the conservation of moisture are usually prepared during the previous winter. Introduced pastures, mainly of annual medics such as barrel medic (*Medicago truncatula* Gaertn), are widely used for the production of wool and fat lambs. Lucerne is also sown, particularly on E-W dunes, but the proportion of dunes carrying this perennial is small. Yields of crops and pastures fluctuate widely from year to year because of variability of rainfall.

The stability of landscapes in this semi-arid region is precarious (see Reports on Mallee Soil Conservation Competitions conducted by the Soil Conservation Authority). The evidence of cyclic deposition of soil parent materials indicates that there had been widespread instability during particular periods in recent geological times, although immediately before settlement the landscape was in a period of stability maintained by the native vegetation. The replacement of this native cover by crops, pastures and bare fallows resulted in widescale wind erosion. In years of good or moderate rainfall, erosion is largely confined to fallows prepared on sandy rises, and it is during droughts that most of the erosion occurs, the flats as well as rises being attacked.

Fallows are prepared to maximise moisture in the soil for the ensuing crop. The land is usually ploughed about nine months before sowing, and rough tillage or stubble mulch is used on most farms, particularly on the dunes, to minimise erosion. However, ploughing is done in anticipation of enough rain falling in the following autumn. If a drought ensues erosion is widespread on bare fallows and where stubble degenerates under grazing. A preferable system would be to crop after short, mulched fallows prepared only when autumn rains are satisfactory.

By adding recent climatic data to that of Foley (1957) it can be seen that the longest drought-free run in the last 86 years was 21 years from 1945 to 1966. During this period the favourable climate, combined with improved skill and technology resulted in the regaining of stability lost in the early days of settlement. However it became evident during the 1967 drought that permanent general stability has by no means been attained.

Wind erosion has also been a significant factor in the gradual development of another form of deterioration, namely salting. Erosion has contributed by weakening growth both on dunes and on low sites prone to salting.