A Soil Survey of part of the Kerang Irrigation District, Victoria

Bulletin No. 125

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Melbourne 1939

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SUMMARY

The Bulletin describes the results of a soil survey of 54,000 acres of the Kerang Irrigation District, in the Murray Valley in northern Victoria. Since this area was opened for irrigation, an increasing soil salinity has caused considerable loss of productivity, and the survey was designed to form the basis of future rehabilitation.

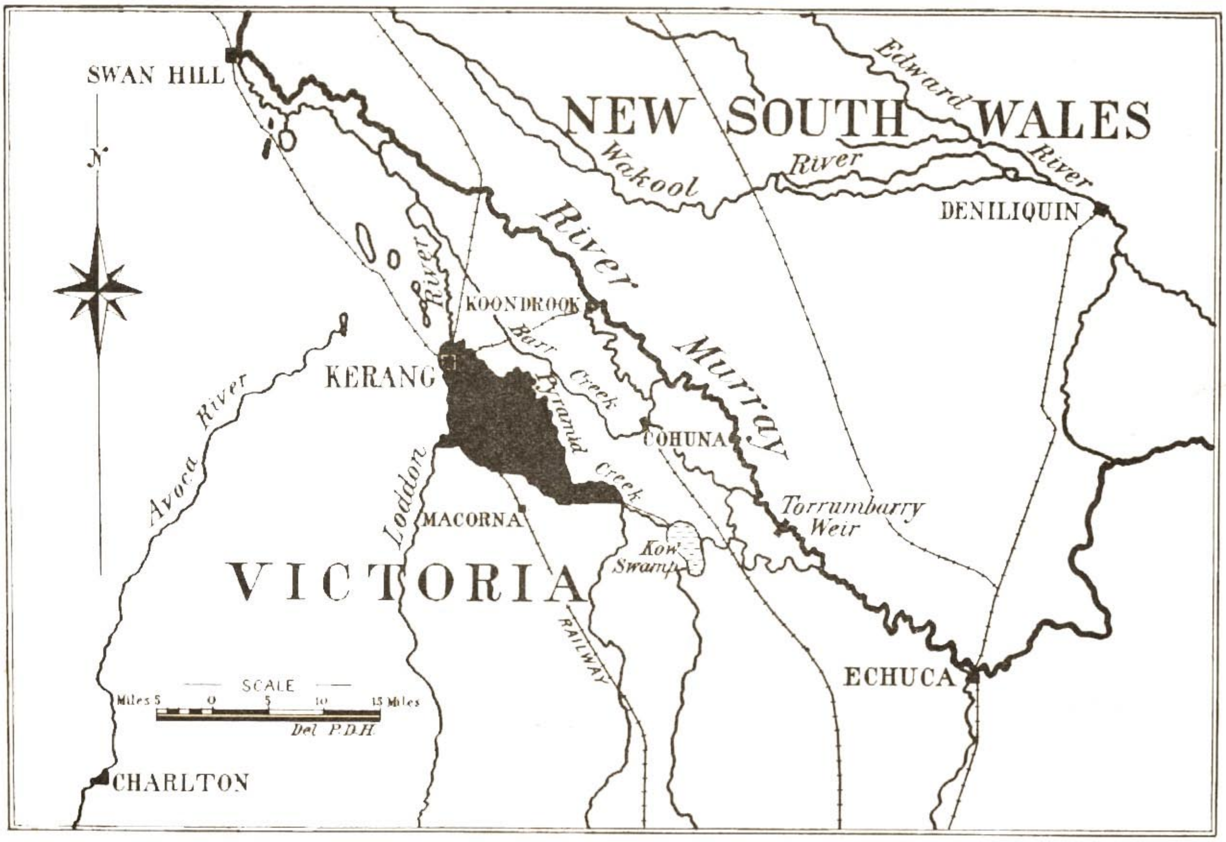
An account of the district's climate, physiography, and vegetation is given, and then the soils of the area are described in detail. They are divided into three major types – Macorna clay, Kerang clay, and Tragowel clay, each with several phases – and four minor types, three of which are grouped together as the Pyramid Creek suite. The major types, covering 95 per cent of the area, are heavy crabholey soils, with shallow surfaces; the minor types are much lighter. Their distribution is shown on a soil map.

Mechanical and chemical analyses are discussed in their relation to soil type, the full analytical data being included in an appendix. Chemical analyses of the soluble salts in soils and ground waters and of saline surface incrustations are given.

The salt status of the soils was examined throughout the survey, and its relation to irrigation and vegetation is shown. The salt tolerance of many species of plants was studied in some detail, and the range of their tolerance is defined.

The present agricultural state of the district is described, and the course of its deterioration traced. The high concentrations of salt near the surface are due to a high and saline water-table, the causes of which are enumerated. It is concluded that reclamation is thoroughly practicable, and the means of improvement are outlined.

Fig. 1 – Locality plan showing the situation of the Soil Survey.



A Soil Survey of Part of the Kerang Irrigation District, Victoria*

I. GENERAL DESCRIPTION OF THE AREA

1. Introductory

In northern Victoria, east of the Mallee zone, there occurs an extensive tract of plain country, of very low relief, and treeless except for strips along the rivers and other drainage lines. It is continuous with the great plains of the Riverina of New South Wales. The Kerang Irrigation District lies towards the western limit of these Victorian plains, and centres round the township of Kerang, which is situated on the Loddon River, about 20 miles from its junction with the Murray River.

The country was originally used for large scale grazing by squatters, but in 1877 it was opened for selection in 320-acre allotments. The rainfall was rather low for development, but with the introduction of irrigation the district gained a good reputation, over a long period, both for cereal cropping and for the grazing of cattle and sheep.

The earliest irrigation schemes, about 1884, only made available small amounts of water from the Nine Mile Creek and the Loddon River. With the construction of the Macorna Channel about 1890, the water from Kow Swamp was brought to the area, but supplies were still limited by seasonal conditions. An adequate supply was assured by the completion, in 1923, of the Torrumbarry Weir, about 40 miles from Kerang on the Murray, making possible a diversion to Kow Swamp to maintain it at the necessary level.

Deterioration of the land through salt accumulation in the surface layers probably commenced about 30 years ago, and has been intimately associated with a rise in ground water level. Many reasons have been advanced for this rise, and several of them will be discussed more fully in later sections of this report. All factors which have increased the amount of water in the soil, including irrigation, seepage, and leakage from channels, restrictions to drainage, increased flooding, and depletion of herbage, must be considered as contributory causes.

In an endeavour to relieve the situation in the very badly affected area bounded by the Loddon River, Pyramid Creek, and Macorna Channel, the Kerang East Drainage Scheme was evolved by the State Rivers and Water Supply Commission of Victoria. From 1934 to 1936, large open drains totalling 28 miles in length were excavated along the lines of the Nine Mile, Calivil, and Piccaninny Creeks, and a further

miles of spur drains were cut to reach most of the low-lying parts of the area. These drains will prove of great value in the more rapid removal of flood waters, and the opinion is widely held that improvement of conditions in the district has already followed their construction.

2. The Soil Survey

The object of the soil survey was to examine the soils in their deteriorated condition, to relate the types of soil to the present agricultural state of the area, and to define their salt status. The survey was designed to form the basis for possible rehabilitation and to assess the difficulties involved. It embraces the area bounded by the Loddon River, Pyramid Creek, and Macorna Channel, as indicated on the locality map (Fig. 1)

The total are mapped in 54,000 acres, of which a unit of about 14,000 acres was studied intensively first of all, for the definition of soil types, the occurrence and distribution of water-soluble salts, and their relation to pasture and crops.

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* The soil survey was carried out by the Division of Soils and the Victorian Department of Agriculture. The field work was shared by Messrs. J. G. Baldwin and G. H. Burvill, who jointly assume responsibility for the discussion of the soils and agriculture and views on reclamation. The laboratory work was undertaken by Mr. J. R. Freedman of the Victorian Agricultural Laboratory who contributed Section III to this Bulletin. At the time of the survey, Mr. Burvill, an officer of the Department of Agriculture of Western Australia, was seconded to the Division of Soils.

3. *Climatic Features*

Meteorological data for Kerang are set out in Table 1.

Table 1 – Official Meteorological Data for Kerang*

—	Number of Years Records	January	February	March	April	May	June	July	August	September	October	November	December	Year
Average rainfall (inches)	50	0.71	0.85	1.07	1.00	1.50	1.62	1.20	1.38	1.38	1.34	0.98	1.16	14.19
Mean maximum temperature (^{o}F)	25	88.0	88.5	81.4	73.1	63.8	57.5	56.9	60.7	66.2	73.2	80.8	86.2	73.0
Mean maximum temperature (^{o}F)	25	58.4	59.5	54.3	48.2	43.5	40.5	39.2	40.6	44.1	48.1	52.4	56.3	48.8
Mean relative humidity (per cent)	22	49	53	61	69	82	88	88	80	71	60	52	48	67

* From Coun. Sci. Ind. Res, Pamphlet No 42 (1933).

The average annual rainfall is 14.19 inches. A winter incidence is indicated by the monthly average figures; June, with 1.62 inches has the highest average. An examination of the records reveals, however, that recordings of over 3 inches have been made for all months of the year, but the reliability of the rains from May to October is considerably greater than during the summer months. The general reliability of the winter rains, coupled with lower temperatures and higher relative humidity, makes irrigation unnecessary during the May to October period.

4. *Physiography*

The surveyed area is remarkably flat, with a general fall of less than 20 feet in 14 miles from south to north, and a fall of only 6 feet in 16 miles from east to west. The creeks are shallow and broad; the beds of the two largest creeks, the Nine Mile and the Calivil, are seldom more than 5 feet below the highest parts of the adjacent plains, while of the smaller creeks the Piccaninny is little more than a hollow, and the Bannagher, a network of small watercourses. Before the main drains were cut, the creeks were merely a chain of swampy waterholes and lignum flats, except in wet periods. After heavy rains over the plains or over the ranges to the south, they would overflow and cause considerable flooding of the plains. Any impedance to the flow of these creeks, or of the Pyramid Creek or Loddon River into which they formerly entered, increased the magnitude and duration of the flooding. However, a certain amount of flooding is natural, and in various degrees is a characteristic of one of the major soil types, Tragowel clay (see Table 2).

There are a number of swamps in the area, not only along the creeks, but also in hollows on the plains themselves. The largest are the Tragowel Swamp, the Two Mile Swamp, Forster's Swamp, and Dry Lake. Old dune formations occur on the eastern side of many of the swamps, and may rise 10 to 20 feet above the general level; they are the only outstanding features of the area. The flood-plain of the Pyramid Creek is uneven, with small areas of slightly raised ground, and very gently undulating as compared with the plains to the south.

5. *Vegetation*

In the virgin state most of the area was grass-land with few trees. Along the larger watercourses and in areas subject to inundation, black box trees (*Eucalyptus largiflorens* syn. *Bicolor*) occurred naturally, and many still remain. Other trees occurred to a limited extent only, being confined to the lighter soils of the area, mostly mallee (*Eucalyptus oleosa*) and tea-tree (*Melaleuca pubescens*) on slight rises near the Pyramid Creek. Lignum (*Muehlenbeckia Cunninghamii*) grew on flooded areas but was more widespread than the black box, and its extent is reported to have increased with the various changes brought about since irrigation became more general and flooding more serious.

Except on areas which are used for cropping or on which pasture mixtures for intensive grazing have been established, barley grass (*Hordeum murinum* and *H. maritimum*), trefoil (*Medicago hispida* var. *denticulata*), and woolly clover (*Trifolium tomentosum*) are now the most important members of the vegetation. With them are frequently associated varying proportions of summer grass (*Chloris acicularis* and *Chloris truncata*) and root grass (*Danthonia semiannularis*), the last native to the area. Associated with the numerous areas and patches which are too saline to support grasses are a number of halophytes, including seablite (*Suaeda maritima*), samphire (*Salicornia australis*), and trailing salt-bush (*Atriplex semibaccatum*). Dillon bush (*Nitraria Schoberi*), a spreading shrub, has become well established over large areas where not checked by grubbing.

II. CLASSIFICATION OF THE SOILS

The soil of this survey fall into the major zonal group described by Prescott[*] as the Grey and Brown Soils, and are a southerly extension of the similar formation shown on his soil map in the south-west of New South Wales. The vegetation is characteristic – mainly savannah with tracts of savannah woodland – and the country is notably flat. The soils show typically a heavy textured uniform profile, with no separation of horizons by the eluviation of clay. Calcium carbonate, either as small nodules or in a soft amorphous form, is present in small amounts throughout the profile to a depth of more than 10 feet, and gypsum occurs in the subsoil zone. The maximum amount of calcium carbonate in the fine earth recorded in the Appendix is 9.3 per cent, but in most cases less than 1 per cent is found. The profile is massive, tends to a nutty structure in the upper horizons, and fissures as deep as 12 inches are common when the subsoil is completely dry. From the permeability of the soil to water, it is concluded that the tendency to structural cleavage is continued into the subsoil. Crabhole formations with the characteristic depression and mound are found in most of the types.

The heavy soils have been grouped into three major types, namely, Macorna clay, Kerang clay, and Tragowel clay, with several phases to each and the lighter soils into four minor types denoted as Types 1, 2, 3 and 4 (see Table 2). From the descriptions which follow, it is evident that the phases of Macorna clay and Kerang clay form a "catena[1]"; the factor affecting them is the slight differences in relative elevation causing a variable degree of temporary flooding in the wet season. The three phases of Tragowel clay form another sequence, as all are liable to flooding on a large scale but vary in the period necessary to clear the excess surface water. Calcium carbonate usually reaches a maximum between 2 and 6 feet in the heavy group of soils, but Kerang clay profiles also showed maxima below 10 feet.

The common origin of the major types is suggested by the continuous variation in characters between typical examples, and by several common features. A first subdivision into types and phases on the basis of colour in the upper layers gives an idea of the merging of types. Below 3 feet, shades of yellow and grey are characteristic of all profiles, which in addition have heavy clays within a few inches of the surface and are rather heavy and very low in coarse sand throughout the profile. Deep borings during the course of the survey suggest that all soil types may rest on a common base of mottled grey and yellow-brown heavy clay at depths of 5 to 10 feet. In the case of the three major soil types, it seems that the profiles have a common parent material of fluviatile clay sediments. Alluvial material of a more sandy nature has given rise to the light soils near the Pyramid Creek, Types 1, 2 and 3, while Type 4 has formed on windblown material but is now a fixed and mature soil. In the Pyramid Creek soils, the deeper, more sandy layers are practically free of calcium carbonate and the maximum concentration is in the second foot.

The characteristics of the various types and phases are summarised in Tables 2A and 2B and the extent of each given in Table 3 (page 14). Their distribution is shown on the soil map.

These soil types are recognised locally and fall into four divisions. Briefly, the Macorna clay and the Kerang clay form the "plains," "red," and "grey," respectively, covering nearly two-thirds of the area; the Tragowel clay embraces the swamp soils and "black" soils, occurring along watercourses and in and around swamps; the soils on the rises beside these swamps are the "red sandhills," denoted Type 4; and the tea-tree and mallee rises and other sandy soils along the Pyramid Creek fall into Types 1, 2, and 3, as the Pyramid Creek suite.

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[*] J. A. Prescott – The Soils of Australia. Coun. Sci. Ind. Res. Bull. 52, 1931.
[1] G. Milne – Soil Research, 4: 183, 1935.

Table 2a – Summary of Named Soil Types

Type	Phase	Surface	Subsurface and Subsoil	Deep Subsoil	Remarks
Macorna Clay	Red-brown	0” – 2” Brown *loam*	2” – 8” Dark red-brown *heavy clay* 8” – 20” Red-brown *medium* to *heavy clay*	20” – 30” Light brown *medium clay,* lt. gypsum, tr. lime 30” – 69” Yellow-grey *light* to *medium clay,* slt. gypsum in pockets, tr. lime	“Red” plains, treeless, carrying *Danthonia* and *Eriochlamys.* Natural pastures under irrigation are barley grass, trefoil, and woolly clover, and with any summer watering, *Chloris* sp. Crabholey in varying degrees
	Red-brown light profile	0” – 2” Brown *loam*	2” – 9” Dark red-brown *heavy clay* 9” – 16” Red-brown *medium clay*	16” – 33” Light brown *light* to *medium clay,* lt. gypsum, slt. pan, slt. lime 33” – 63” Light brown *light* clay, slt. gypsum, slt. pan	
	Brown	0” – 2” Grey-brown *clay loam*	2” – 7” Dark brown *heavy clay* 7” – 22” Brown (going lighter brown) *medium-heavy clay*	22” – 42” Grey-yellow, with light brown mottling *medium clay,* lt. gypsum, tr. lime 42” – 84” Grey-yellow *medium clay,* slt. gypsum in pockets, tr. lime	
Kerang Clay	Grey-brown	0” – 2” Grey *clay loam*	2” – 12” Dark grey-brown *heavy clay* 12” – 27” Grey-brown *medium* to *heavy clay*	27” – 84” Grey-yellow *medium* to *heavy clay* slt. gypsum in pockets, tr. lime	“Grey” plains, treeless, carrying *Danthonia* and *Enchylaena.* Natural pastures under irrigation are barley grass, trefoil, and woolly clover

NOTE: - lt = light; slt = slight; tr = trace.

Table 2a – Summary of Named Soil Types *(continued)*

Type	Phase	Surface	Subsurface and Subsoil	Deep Subsoil	Remarks
Kerang Clay	Grey	0" – 2" Grey *clay loam*	2" – 15" Grey *heavy clay.* 15" – 30" Yellowish-grey *heavy clay,* tr. lime	30" – 84" Yellow-grey *heavy clay,* sometimes slt. gypsum in pockets, 60" on	Crabholey in varying degrees
Tragowel Clay	Flooded	0" – 5" Grey *medium* to *heavy clay,* rusty mottling	5" – 24" Dark grey *heavy clay* 24" – 36" Grey *heavy clay*	36" – 54" Light grey *medium* to *heavy clay,* tr. lime	Box and lignum. Low ground. Very crabholey
	Self-mulching	0" – 5" Grey crumbly *heavy clay,* tr. lime nodules	5" – 48" Slightly yellowish-grey *heavy clay,* slt. lime nodules	48" – 75" Yellow-grey *heavy clay,* sometimes tr. gypsum	Box only in lower parts. Trefoil very common. Self-mulching. Very crabholey
	Woodland	0" – 5" Grey *medium clay*	5" – 22" Grey *heavy clay,* tr. of lime nodules 22" – 42" Yellowish-grey, with grey and yellow mottling, *heavy clay,* tr. of lime nodules and of lime	42" – 70" Grey, yellow-grey, and yellow mottled *heavy clay,* slt. lime	Much box, partly self-mulching. Very crabholey. Slightly undulating

NOTE: - lt = light; slt = slight; tr = trace.

Table 2b – Summary of Unnamed Soil Types

Type		Surface	Subsoil	Deep Subsoil	Remarks
Pyramid Creek Suite	1	0" – 6" Grey-brown *loam*	6" – 15" Brown *light* to *medium clay* 15" – 27" Brownish-yellow *light clay,* slt. lime or lime nodules from 10"	27" – 60" Yellow, slt. yellow-brown mottling, micaceous *sandy clay loam* 60" – 84" Yellow, slt. yellow-brown and yellow-grey mottling, micaceous *sandy loam.* 84" on Mottled *sandy clay,* becoming heavier, but sometimes yellow or light grey *sand*	Tea-tree and mallee rises, of slight elevation
	2	0" – 3" Grey-brown *loam* to *clay-loam*	3" – 8" Dark grey-brown *medium clay* 8" – 32" Yellowish-brown *medium clay,* becoming lighter slt. lime nodules 8" on	32" – 42" Yellowish grey-brown, yellow-brown, and light grey mottled, micaceous *clay loam* 42" – 60" Yellow-grey, yellow-brown, and light grey mottled, micaceous *sandy clay loam* 60" on Mottled *sandy clay,* becoming heavier	Plains, growing *Danthonia.* Resemble Kerang clay on surface, but lighter
	3	0" – 6" Grey *clay loam*	6" – 12" Grey *light clay* 12" – 18" Slightly yellowish-grey *medium clay,* trace lime	18" – 33" Yellow-with grey mottling, micaceous *light clay,* light lime, light rubble 33" – 96" Yellow, with yellow-brown, and then yellow-brown and yellow-grey mottling, *sandy clay loam,* micaceous 96" on Mottled *sandy clay,* becoming heavier	Carrying box-trees, with tea-tree on lighter parts. Resembles woodland phase of Tragowel clay in appearance but not crabholey
	4	0" – 6" Brown *sandy loam*	6" – 14" Dark red-brown, going to red-brown, *medium clay* 14" – 22" Light brown *light clay,* slt. pan, and sometimes slt. lime rubble	22" – 48" Light brown *clay loam,* lt. Pan, becoming less, often lt. Lime rubble to 30" 48" – 66" Light grey-brown *light clay,* slt. to lt. lime 66" – 84" Yellow-grey *medium clay.* Sometimes there is up to 24" of *sandy clay loam,* below 60", before the clay increases	Light surface. Always carrying *Stipa,* sometimes hakes, or pine, or tussock grass. Rises of low elevation, known as "red sandhills:

NOTE: - lt = light; slt = slight; tr = trace.

Table 3 – Areas of Soil Types

Macorna clay	Red-brown phase Brown phase Mixed phase	7,212 11,862 } 19,493 acres 419
Kerang clay	Grey-brown phase Grey phase Mixed phase	9,812 4,263 } 14,407 acres 332
Tragowel clay	Flooded phase Self-mulching phase Woodland phase	4,030 4,074 } 14,081 acres 5,977
Mixed Types	Macorna clay and Kerang clay Kerang clay and Tragowel clay	1,009 acres 2,288 acres
Pyramid Creek Suite	Type 1 Type 2 Type 3	473 228 } 950 acres 249
Miscellaneous Types	Type 4 Minor depressions Swamps	926 acres 85 acres 773 acres
		54,012 acres

Besides profile features, situation and relative elevation have been used to characterise the major types. These two factors determine the colour in the upper layers of the soil profile. Thus on the relatively elevated areas red-brown colours predominate, and brown colours on areas not so high. These correspond to the red-brown and the brown phases of the Macorna clay, which have been mapped separately. Passing to lower situations, grey-brown and then grey, colours are more common, and correspond to the grey-brown and grey phases of the Kerang clay. As crabholes occur to varying extent on both of these types, it is the profile of the level shelf between the crabholes that is taken to define the soil type. On the soil map the occurrence of crabholes is indicated with three arbitrary divisions – (1) few, or no crabholes, (2) moderately crabholey, (3) very crabholey. In relatively low-lying parts the soils are grey, and although only one soil type, the Tragowel clay, has been defined for such areas, the soil characteristics, depending on three different situations, give three phases, the flooded phase, the self-mulching phase, and the woodland phase.

The occurrence of brown and red-brown soils at the higher levels, and brownish grey and grey types at the lower levels or in local depressions has also been noted by Penman* in a survey of part of the Goulburn Valley. Here, as at Kerang, the relief is only slight and the soils are developed on alluvial material of fine texture.

1. Macorna Clay

This is the most extensive type mapped, covering 36 per cent of the area surveyed. It is referred to in the district as “red plains”. Actually, the surface is a brown clay loam or loam, passing in a few inches to a dark brown or dark red-brown heavy clay. The profile features are shown in Fig. 2.

* F. Penman – J. Dept. Agric. Vic, 34: 364, 1936.

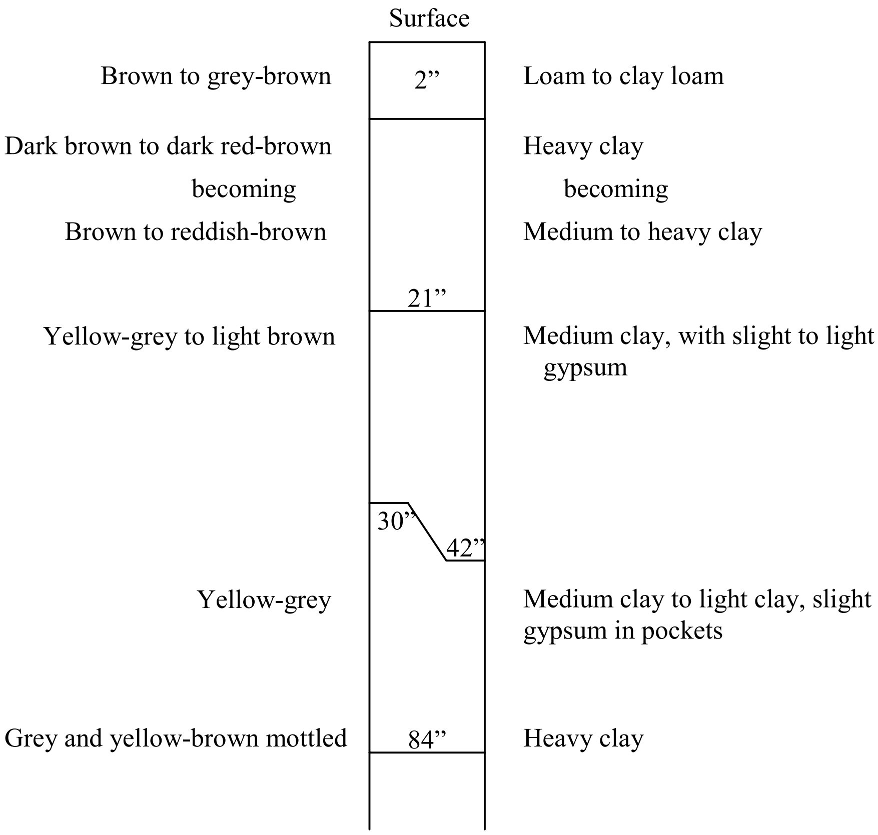

Fig. 2 – Macorna clay

The gypsum, which comes in quite abruptly at about 20 inches, is evenly distributed at first, and is associated with a lightening in apparent texture. These points, as well as the colour, characterise the type and differentiate it clearly from the Kerang clay.

They also serve to separate the type into two phases, the red-brown and brown, as can be seen in Table 2. The red-brown phase is the lighter and redder, with gypsum in greater quantity and at less depth, although the first 20 inches are very similar, except in colour, to the brown phase. Some profiles are so much lighter that they have been distinguished as "light profiles” on the map, although they could not be delimited sufficiently well for mapping. A representative example is described in Table 2.

The structure of the crabhole complexes that occur freely on this soil type and also on the Kerang clay agrees so well with the descriptions given by England[2] and by Leeper et al,[3] and with the theory of the latter, that nothing need be said about them here, except that the usual diameter of the crabhole itself was 10 to 20 feet. The Tragowel clay, however, though spoken of as “very crabholey,” has no such structure, the rises and hollows are there, the profile of the rise may resemble a “puff” profile, but it is the same as the profile in the hollow, and there is nothing to correspond with shelf.

Originally, the Macorna clay was quite treeless, but fairly well grassed, probably mainly with root grass (*Danthonia semiannularis*). Barley grass (*Hordeum murinum*) and trefoil (*Medicago hispida* var. *denticulata*) were no doubt introduced early in the period of pastoral occupation and were well established when the sheep stations were subdivided 60 years ago.

[2] Quoted by J. A. Prescott, Coun. Sci. Ind. Res. (Aust.), Bull. 52, p. 15 (1931).
[3] G. W. Leeper, et al. Proc. Roy. Soc. Vic, 49 (1): 77, 1936.

2. *Kerang Clay*

The Kerang clay is the soil of the "grey plains" of the district, comprising soil with grey clay loam surfaces, overlying grey-brown or grey heavy clays at shallow depths, and covering 27 per cent of the area. There is only a slight decrease, if any, in apparent texture with depth, and the gypsum lies deeper and is more scattered than in the Macorna clay. The main features are shown in Fig. 3.

	Surface	
Grey	2"	Clay loam
Grey to dark grey-brown becoming yellowish-grey to grey-brown	28"	Heavy clay, sometimes becoming slightly lighter
Yellow-grey	84"	Heavy clay, or slightly lighter, often with slight gypsum in pockets
Grey and yellow-brown mottled		Heavy clay

Fig. 3 – Kerang clay

The distinction between two phases of Kerang clay is drawn in Table 2. The grey-brown phase is browner, somewhat lighter at depth, and has more gypsum, than the grey phase. In elevation, the grey-brown phase is relatively higher than the grey, but both are intermediate between the Macorna clay and the Tragowel clay. They commonly adjoin areas of Macorna clay, or they may be mixed with Tragowel clay. The grey-brown phase occurring in areas of Tragowel clay, woodland phase, often carried box trees. Otherwise this type was treeless, and had vegetation similar to that on Macorna clay, except that a saltbush, *Enchylaena tomentosa,* was very common.

3. *Tragowel Clay*

The low parts of the area, 26 per cent of the whole, fall into one type, Tragowel clay. It is a heavy, very crabholey soil, with grey as its dominant colour, which three factors are associated with its liability to flooding. Water has been a very important influence in the development of the three phases into which the type has been divided. Profiles of the phases are given in Table 2, and the type is sketched in Figure 4.

	Surface	
Grey, sometimes with rusty streaks	5"	Medium clay to heavy clay, sometimes trace of lime nodules
Dark grey to slightly yellowish-grey	24"	Heavy clay, often slight lime nodules
Grey or yellowish-grey, sometimes mottled	48"	Heavy clay, often slight lime nodules
Light grey or yellow-grey or mottled	84"	Heavy clay, often slight lime nodules
Grey and yellow-brown mottled		Heavy clay

Fig. 4 – Tragowel clay

The *flooded phase* covers most of the swamps, and country along the Loddon River, and the Nine Mile and Calivil Creeks, that is, the lowest parts of the area and those most liable to flood. It is distinguished by its uniformly grey and uniformly heavy profile, and appeared in the field to be the heaviest soil of the survey. Box trees (*Eucalyptus largiflorens,* syn. *bicolor*) and lignum (*Muehlenbeckia Cunninghamii*) were the natural vegetation, with good grass, and sedges in the wetter parts.

The *self-mulching phase* is remarkable for its crumbly, self-mulching surface, which gives it its local name of "loose-top" but is nevertheless a heavy clay. This profile also is uniformly heavy, but the colour is a yellowish-grey, and it contains more lime than the other phases, right from the surface. The profile is, indeed, that of a crabhole puff, but without any corresponding crabholes; the surface is undulating, but even the small watercourses which run across it are essentially the same profile, compacted and slightly modified by water. The self mulching phase is liable to flooding also, but not so often, nor for so long at a time, as the previous phase, hence box and lignum grew in the lower parts only. After the opening up of the country trefoil grew very strongly on the loose mounds, with barley grass, canary grass (*Phalaris minor*) and swamp wallaby grass (*Amphibromus nervosus*).

The *woodland phase* is confined to the Pyramid Creek and Piccaninny Creek country, but is more extensive than either of the other two phases of the Tragowel clay. The surface soil is not so heavy, and yet it is not as crumbly as that of the self mulching phase, and below two feet the profile shows a characteristic mottling, increasing with depth, which is not seen in either of the other phases till a much greater depth. The local name of this soil, "black box" soil, refers to the surface colour (actually grey), and to the box trees which were the dominant feature of its vegetation. On a gently undulating surface this phase carried a good stand of box throughout, with lignum in some of the depressions. The herbage is said to have been very good.

Included under the three major soil types are a number of areas in which the profile showed at depth (usually below 4 feet) a sandy clay loam or sandy loam. Such areas are indicated on the map by the words "sandy layers".

4. Minor Soil Types

(a) Pyramid Creek Suite

This suite comprises three soil types, as shown in Table 2B, all occurring near the Pyramid Creek, and apparently with a common origin. The deep subsoil is high in micaceous fine sand, and silt.

Types 1 and 2 are slight rises, but Type 2 is treeless with root grass as its usual cover, while Type 1, which is much lighter, carries tea-tree (*melaleuca pubescens*). Actually these two types represent the opposite ends of a range; the lighter intermediates carry tea-tree and mallee (*Eucalyptus oleosa*), the heavier carry mallee alone. Such a mallee rise was sampled, and laboratory data are given for it in Appendix Table IV. However, the range of profiles under mallee is too great to make this a separate type, and it is better to consider mallee as occurring on some Type 1 rises, and on rises intermediate between Type 1 and Type 2.

Type 3 occurs in hollows, and on the slopes from the low rises of the other two types. On these slopes, with a surface lighter than typical, it may grow tea-tree as well as box. Usually it grows a fair stand of box, but is not crabholey like the Tragowel clay.

(b) Type 4

Numerous occurrences of Type 4 soil are mapped but none of them are extensive; in aggregate they cover less than 2 per cent of the area surveyed. The type is notable because it is so different from the soils with which it is associated. The profiles in Table 2 bring this out, particularly the light deep surface soil of this type. In addition, the mechanical analyses show about 12 per cent of coarse sand throughout the profile below the sandy loam top, whereas the coarse sand of all the types so far discussed is negligible; the fine sand content is also much higher than that of the three major types.

The elevation of these so-called "red sandhills" varies from twenty feet to less than one foot above the general level of the plains. They appear to have risen as accumulations of windblown material on the leeward side of what are now depressions, liable to inundation for varying periods. In one instance, the rise was being added to at the present time with clay dust from the barren, salty surface of such a "dry swamp”. These rises have been stable for a long time, and the profiles have reached an advanced stage of maturity.

All are alike in growing spear grass (*Stipa scabra*), but other vegetation varies – one carried pine (*Callitris* sp.), another a hakea (*Hakea vittata*) and tussock grass (*Lomandra leucocephala*), and so on.

(c) Minor Depressions

In several hollows east of the Calivil Creek, the soil profiles are variable but contain notable amounts of sand throughout. An average profile seems to be:- grey sandy loam, 0 inch to 9 inches, with rusty mottling and a hard pan from 4 inches; grey medium clay, 9 inches to 18 inches; light brown sandy clay, 18 inches to 48 inches; then a light brown sandy clay loam becoming heavier again at depth.

Such hollows probably maintain themselves in a moister condition that the plains, but are by no means swamps of any permanence, although box or lignum grows on them.

III. LABORATORY EXAMINATION OF THE SOILS

1. Mechanical Analysis

Reference has already been made in the descriptions of the soil types, to the major differences between the soil types and their phases. Mechanical analysis divides the types into two groups, the larger consisting of the “clay” types and the smaller consisting of the Pyramid Creek suite and the sandhill type (Type 4).

Examination of the distribution triangle and summation curves, Figs. 5 and 6, shows the high clay content of the subsoils of the “clay” group (the Macorna, Kerang, and Tragowel series), while the Pyramid Creek suite has a relatively high silt content. In the sandhill type, clay is high in the subsoil, but the silt is very low and the coarse sand is high by comparison with all other types. An outstanding feature is the very high fine sand content of the deep subsoil of Type 1 (light profile) and of Type 3 of the Pyramid Creek suite.

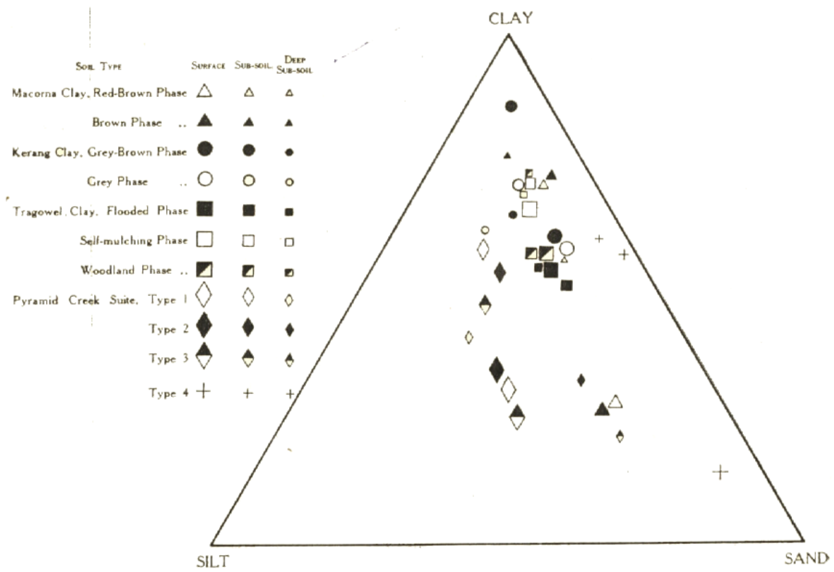

Fig. 5 – Mechanical Analysis Distribution Triangle.

With regard to the relation between field texture and mechanical analysis, the general tendency was for the soils to appear rather lighter in the field than their analyses would indicate. In this connection, the flocculating effect of soluble salts is a factor in certain cases.

Examination of the crabhole complex in the Kerang area shows it to be in accord with those recorded elsewhere (references p. 15). In the brown phase of Macorna clay, for example, the brown surface and subsurface of the shelf (profile 3356-63) are missing from a neighbouring puff (profile 3364-69). The upper 42 inches of the puff corresponds in colour and composition with the 22-38 inches zone of the shelf. In a crabhole (profile 3422-25)[4], the surface soil is darker and heavier than in the neighbouring shelf (profile 3416-21), but sandier to 34 inches than the puff sampled.

Below 34 inches, the crabhole resembles the surface of the puff, and the deep subsoils of puff, crabhole, and shelf are all similar in colour and composition.

Rubble and gravel occur as limestone and gypsum, sometimes with slight quartz near the surface. The actual amount of rubble is never very high, the highest being 7.7 per cent. The occurrence of rubble and gravel in the different phases and types has been noted in the descriptions of the soil types, and the actual amounts present in type profiles are given in the appendix. Profile 8044-47 (Kerang clay, grey-brown phase) differs from the general description of the phase in that no gypsum occurs even to a depth of 54 inches.

There is a sharp distinction in the nature of the sand fractions between the "clay" types and the Pyramid Creek suite. The quartz in the coarse sand fraction of the former is rounded, while in the latter it is angular and sharp-edged; in the latter, also, mica is found in the subsoil. Examination of the fine sand fractions by Miss Ann Nicholls, of the Geology School, University of Melbourne, showed that, in addition to containing a larger amount of felspars than the "clay" group, the Pyramid Creek suite contains hornblende, which is absent from the "clay" group.

The colours of the sand fractions follow those of the soils themselves in a general way, except that, even in the darkest types, some pink quartz grains are present.

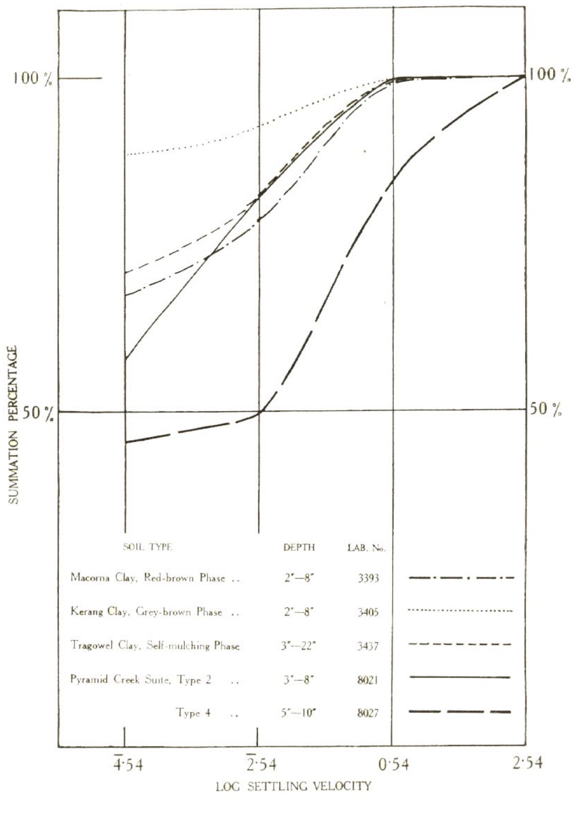

Fig 6 – Summation curves illustrating typical mechanical analyses

[4] The puff and crabhole were not adjoining profiles, but the comparison is legitimate because the two shelf profiles are similar in texture.

2. Reaction

Determinations of reaction, pH, were made by the glass electrode method, the results being given in the Appendix.

Table 4 – Frequency Distribution of pH of Surface Soils.

pH Range	5.5 – 6.0	6.0 – 6.5	6.5 – 7.0	7.0 – 7.5	7.5 – 8.0
Frequency	1	5	10	5	2

Table 4 illustrates the distribution of pH values of all surface soils which, as shown in the appendix, are shallow in many cases. The lowest value of 5.7 is for a grey-brown phase of Kerang clay. The highest values are for a puff and for the woodland phase of Tragowel clay. The reactions of surface puff soils are higher than those of surface shelf samples, and reactions for crabholes are in the lower ranges.

In nearly every profile, a pH of 8.0 is attained before reaching a depth of 12 inches. This increase of pH is accompanied by an increase in calcium carbonate content, and the maximum pH us usually at the depth of maximum lime concentration, which, in many cases is reached before 3 feet, and in the majority of cases before 7 feet. In many instances, there is then a decrease in pH in the lower depths, accompanied by a decrease in lime content, and in some instances, by the appearance of gypsum. In a few profiles, there is a subsequent rise in pH in the very deep layers (below 7-10 feet), accompanied by a large increase in lime content.

3. Nitrogen

Total nitrogen was estimated on all surface soils, and, where the surface was shallow, on the subsurface also. There is a great decrease in nitrogen in the subsurface as compared with the shallow surface soils.

The values for surface soils vary greatly, even within the same phase of a type. The majority of surface soils have values greater than 0.10 per cent, the lowest being Type 4, 0.062 per cent, and the highest 0.370 per cent (grey-brown phase, Kerang clay).

4. Hydrochloric Acid Extracts

Table 5 sets out the chemical analysis of hydrochloric acid extracts of surface soils.

Table 5 – Chemical Analysis of Soils.
(Figures represent percentages of air-dry soil)

Soil Type	Sample Number	Depth	P_2O_2	K_2O	CaO	MgO
		(inches)	%	%	%	%
Macorna Clay						
Red-brown phase	3392	0-2	0.10	0.29	0.14	0.26
Brown phase	3416	0-3	0.11	0.33	0.14	0.21
Kerang Clay						
Grey-brown phase	3404	0-2	0.10	0.59	0.29	0.66
	8044	0-4	0.07	1.61	0.25	0.58
Grey phase	3378	0-3	0.07	0.23	0.19	0.54
Tragowel Clay						
Flooded phase	3385	0-5	0.09	0.36	0.20	0.41
Self-mulching phase	3442	0-4	0.09	0.27	0.25	0.58
Woodland phase	8034	0-5	0.07	1.50	0.45	0.82
Pyramid Creek Suite						
Type 1	8014	0-6	0.09	0.73	0.20	0.32
Type 2	8020	0-3	0.09	1.28	0.60	0.52
Type 3	8008	0-6	0.08	1.71	0.67	0.50
Type 4	8026	0-5	0.08	0.53	0.14	0.17

Phosphoric acid is moderate but fairly constant throughout, the average being 0.09 per cent.

Potash is fair, and in some cases high. The high values for the grey-brown phase of Kerang clay are probably related to high clay content. The high potash of the Pyramid Creek suite and of the woodland phase of Tragowel clay is probably due to enrichment by recent deposition of alluvial material.

There are moderate amounts of lime and magnesia present, the highest values, probably for the same reasons as with potash, occurring in the grey-brown phase of Kerang clay, the Pyramid Creek suite, and the woodland phase of Tragowel clay.

Type 4 has low values, except for potash which is high for such a low clay content.

5. Soluble Salts in Soils, Waters, and Incrustations.

Figures for soluble salts in soils were obtained by conductometric methods, and show a fairly large range of values, from 0.04 per cent to 2.91 per cent (see Appendix). Variations in soil salinity in the samples examined are in accord with the general discussion on page 25 *et seq.* Since most of the samples are from land under grass, the general tendency is for total soluble salts, and also for chlorides, to increase with depth from the surface. On the other hand, the effect of lack of cover in favouring accumulation of salt at the surface may be seen in the higher salinity of the surface soil of bare puffs as compared with the subsoil and with adjacent shelf soils.

Table 6 shows a more detailed analysis of certain samples. Only one of these (3369) contained visible gypsum. It will be seen that bicarbonate assumes a greater importance in the samples with lower total salts, while chloride and sulphate are important with higher total salts. Carbonate is absent entirely. The variation in sodium approximates closely to chloride variation, while potassium is low in all cases. The low figures for calcium and magnesium show that high proportions of the anions must be in combination with sodium.

Table 6 – Analysis of Soluble Salts
(Expressed as parts per 100,000 of air-dry soil.)

Soil Type	Sample No.	Depth (inches)	Total Soluble Salts	Cl	SO_4	HCO_3	CO_3	Ca	Mg	K	Na
Macorna Clay											
Brown phase	3356	0-2	48	8	3	12	Nil	..	..	..	..
Brown phase puff	3369	120-138	1558	486	476	10	Nil	..	..	..	..
Kerang Clay											
Grey-brown phase	8046	13-30	1826	946	155	27	Nil	34	62	5	525
Grey phase puff	3432	0-4	2910	1400	229	20	Nil	..	..	..	..
Grey phase puff	3434	24-48	1416	759	95	31	Nil	..	..	..	..
Tragowel Clay											
Flooded phase	3386	5-24	290	121	28	12	Nil	..	..	..	..
Self-mulching phase	3436	0-3	130	24	4	40	Nil	..	..	..	..
Pyramid Creek Suite											
Type 1	8001	0-2	51	8	4	14	Nil	2	7	4	7
	8015	6-13	463	192	46	30	Nil	6	10	7	129
Type 2	8020	0-3	87	30	4	16	Nil	4	6	3	16
Type 3	8010	12-18	564	269	52	31	Nil	8	16	7	167
Type 4	8026	0-5	36	3	2	15	Nil	1	5	2	4

Soil Waters – Analyses of soil waters for chloride were made all through the survey, and samples were also taken from the type profiles. There is a broad relationship between chloride in the soil water and that in the soil at the same depth as the water table, the former being usually between four and five times the latter.

Chemical analyses of soil waters from the type samples bores were made, the results being given in Table 7.

Total salts are high in most cases. The chloride content varies considerably, but there is a fairly uniform ratio between chloride, expressed as sodium chloride, and total salts, the mean value of the ratio being 0.82.

The ratio between sulphate and chloride varies greatly, even within the same phase. There is no carbonate present, but there is a small, and fairly constant, amount of bicarbonate.

Soil Incrustations – In certain parts of the area, white powdery incrustations were seen on the surface of the soil. These usually occurred near channels or near areas where the land is wet for long periods. Two samples of surface scrapings were analysed, with the results shown in Table 8.

A certain amount of soil was scraped up with the incrustation and this accounts for the high acid-insoluble content, and also, for the iron and aluminium content. Chloride content of the soluble part was low in both samples. Calcium carbonate was absent from one sample, and very low in the other.

Table 7 – Analysis of Soil Waters.

Soil Type	Sample Number	Depth (inches)	Total Salts	Cl	SO_4	CO_3	HCO_3
			%	%	%	%	%
Macorna Clay							
Red Brown phase	3,452	72	2.10	0.68	0.65	nil	0.04
	583	70	3.75	2.00	..	..	..
Brown phase	3,447	96	4.67	2.42	0.50	nil	0.02
	3,453	78	2.79	0.74	0.99	nil	0.03
	3,455	84	2.07	0.70	0.60	nil	0.04
Brown phase puff	3,448	102	4.95	2.66	0.43	nil	0.02
Kerang Clay							
Grey-brown phase	3,449	68	4.57	2.20	0.74	nil	0.02
	3,454	72	4.74	2.26	0.76	nil	0.02
	584	60	4.59	2.67	..	..	..
Grey phase	3,450	108	5.26	2.80	0.52	nil	0.02
	3,456	79	5.59	3.08	0.40	nil	0.01
Tragowel Clay							
Flooded phase	3,451	49	2.74	1.24	0.38	nil	0.02
Self-mulching phase	3,457	108	4.00	2.11	0.48	nil	0.01
Woodland phase	582	108	2.24	1.10	..	..	..
Pyramid Creek Suite							
Type 1	580	78	3.34	1.81	..	..	..
Type 3	579	100	3.60	1.96	..	..	..
Type 4	581	108	2.16	1.07	..	..	..

Sulphate content was very high, and although calcium and magnesium were fairly high, they do not account fully for the sulphate content. Some proportion of the sulphate is therefore combined with other cations, probably chiefly sodium.

Table 8 – Analysis of Soil Incrustations

Sample Number	Acid Insoluble	Cl	Ca	$CaCO_3$	Mg	SO_4	Fe_2O_3 + Al_2O_3
	%	%	%	%	%	%	%
3,458	48.46	0.04	2.69	nil	1.17	19.94	10.16
3,459	53.40	0.98	1.22	0.30	1.41	10.54	11.90

6. Replaceable Bases

Results of estimation of replaceable bases are given in Table 9.

The amount of total bases is low where the clay content is low, and increases with decreasing clay content. With regard to individual bases the amount of replaceable magnesium is high and fairly uniform throughout. Magnesium is dominant in the major soil types, with calcium subdominant, and sodium almost equal to calcium, while in the Pyramid Creek soils, the woodland phase of Tragowel clay, and Type 4, calcium is the dominant replaceable base.

Table 9 – Replaceable Bases in Soils.

Soil Type	Sample No.	Depth	$CaCO_3$	pH	Total Soluble Salts	Clay	Total Bases. Milligram Equivalents per 100g soil	Percentage of Total Bases			
								Ca	Mg	Na	K
		inches	%		%	%					
Macorna Clay											
Red Brown phase	3393	2-8	0.03	8.1	0.30	61.3	31.5	29	44	23	5
	3394	8-20	0.08	8.5	1.00	66.5	40.9	25	42	29	4
	8039	1-4	0.00	6.6	0.17	42.9	18.8	44	42	8	6
Brown phase	3357	2-7	0.01	7.7	0.27	64.0	31.7	32	43	15	10
	3358	7-15	0.10	8.2	1.61	61.7	36.4	26	43	26	5
Kerang Clay											
Grey-brown phase	3405	2-8	0.03	7.7	1.89	75.7	44.9	23	43	28	6
	3406	8-15	0.02	8.0	2.09	76.6	47.8	29	43	24	5
	8044	0-4	0.00	6.9	0.69	55.7	27.5	29	40	23	8
Grey phase	3379	3-17	0.02	7.1	0.18	50.7	36.5	25	47	23	5
	3383	78-120	0.05	8.1	1.61	51.4	27.4	24	46	26	4
Tragowel Clay											
Flooded phase	3386	5-24	0.02	6.4	0.31	49.3	25.1	36	45	13	5
Self-mulching pH.	3437	3-22	2.40	8.2	0.71	61.8	29.0	41	42	15	2
Woodland phase	8034	0-5	0.00	7.7	0.18	53.4	29.1	48	36	8	8
Pyramid Creek Suite											
Type 1	8014	0-6	0.00	7.4	0.26	24.1	12.5	44	36	11	9
	8002	2-9	0.00	7.8	0.09	50.7	25.4	50	38	6	6
Type 2	8021	3-8	0.04	7.7	0.34	54.7	29.2	49	36	8	7
Type 3	8008	0-6	0.01	6.6	0.40	42.3	24.4	47	35	9	9
Type 4	8026	0-5	0.01	6.9	0.04	13.8	9.0	51	29	6	14

The values for the individual bases, taken in conjunction with those for chemical analysis (Table 5), suggest a relationship between the woodland phase of Tragowel clays and the Pyramid Creek soils. This is supported by the fact that occurrences of the woodland phase of Tragowel clay are restricted to the vicinity of the Pyramid Creek. As indicated in an earlier section, this relation may be partly due to the influence of recent alluvial deposition.

Sodium is of less importance as a replaceable base in the Pyramid Creek suite and in Tragowel clay, which is subject to inundation, than in the other types. It is possible that the higher proportions of sodium in Macorna clay and Kerang clay may be the result of the increase of sodium salts in the surface soils of these types during the past thirty years.

Potassium occurs in relatively small proportions in the replaceable bases, but when expressed as parts of potash (K_2O) per 100,000 of soil, the figures range from 31 to 150, suggesting fairly good availability of potash in the majority of these soils.

IV. RELATION BETWEEN VEGETATION AND SOIL SALINITY.

The vegetation of the Kerang district has altered profoundly in the 30 years since saline conditions were first noticed there. Some of the present members were common then, and have survived because they grow on unchanged areas or because they have been able to adapt themselves to a more saline environment. But there has also been both an improvement by the introduction of better pasture and forage plants, particularly on the more intensively developed areas, and a retrogression with the dominance of various halophytes under conditions of increasing soil salinity.

Chlorides, mostly sodium chloride, form the greatest part of the water soluble salts in the Kerang soils, except for layers where visible gypsum is present or where the total water soluble salts are relatively low (see Table 6). Moreover, chlorides are among the most toxic of the salts commonly occurring in saline soils, whereas gypsum has practically no adverse effect. Hence all subsequent salt figures refer to chlorides, expressed as sodium chloride, as percentage of air-dry soil. The high values prevailing have to be interpreted in relation to the heaviness of the soils, which gives a comparatively high salt tolerance.

The relations between vegetation cover, salinity of the profile, and irrigation, are brought out in Table 10.

Table 10 – Frequency Table showing the relation between Irrigation, Vegetable Cover, and Percentage of Salt (NaCl) at various depths in the profile.

Condition of Plant Cover	Number of Samples in which Salt Percentage was:-										Total Number of Samples
	< 0.11	0.11 – 0.20	0.21 – 0.30	0.31 – 0.40	0.41 – 0.60	0.61 – 0.80	0.81 – 1.00	1.01 – 1.51	1.51 – 2.00	>2.00	
Depth: 0-3 inches											
Recently irrigated	21	5	2	1	..	..	1	..	..	..	30
Green herbage	62	27	9	2	6	..	..	..	..	..	106
Dry herbage	6	8	2	2	5	4	5	1	..	..	33
Halophytes	..	..	..	2	3	1	4	1	..	1	12
Bare ground	1	5	2	2	7	10	7	31	21	18	104
Depth: 0-12 inches											
Recently irrigated	32	16	9	3	3	1	1	1	..	..	66
Green herbage	87	81	42	18	48	20	7	3	..	..	306
Dry herbage	8	6	22	25	44	38	26	17	2	..	188
Halophytes	2	..	..	1	2	10	9	15	5	1	45
Bare ground	..	3	4	6	9	16	29	73	22	10	172
Depth: 24-36 inches											
Irrigated	28	35	26	31	56	30	13	11	..	..	230
Not irrigated	7	8	11	17	48	78	92	77	5	..	343
Depth: 60-72 & 72-84 inches											
All conditions	5	3	2	6	21	26	23	10	..	..	96

NOTE: The soil samples from which these data were compiled were taken during the period April-July 1937. Owing to the low rainfall at Kerang during this period, very little germination and growth occurred on many unirrigated areas.

"***Recently irrigated***" refers to areas on which it was apparent from the moist and wet conditions of the soil that irrigation water had been applied within the previous few weeks.

"***Green herbage***" refers to areas on which green herbage existed as permanent pasture or had been germinated by rain or irrigation.

“***Dry herbage***” refers to areas where there had been no germination at the time of sampling, but dry herbage from the previous season existed. No sample has been included in more than one group.

This table shows the progressive improvement of conditions passing from bare ground, through land under halophytes, to ground under dry herbage, and then under green herbage. It also shows, in the “recently irrigated” line, the “washing down” of salt by irrigation water. The effect of irrigation and adequate cover in lowering the salt concentration is seen to extend to a depth greater than 3 feet, but generally not as great as 5 feet. As the analyses of samples from below 5 feet showed no similar general effect except sometimes after a heavy irrigation, the data for the 5 to 7 feet level has been grouped in the table.

The table also indicates general salt gradients – an increase with depth under herbage, and a decrease with depth under bare ground, both reaching similar concentrations with depth. Hence the amount of salt in the ground water, which is related to the concentration of salt in the soil at that depth, is not simply related to the concentration nearer the surface.
Table 10 further emphasises the wide range of salt conditions existing in both the surface soil and subsoil of this area. The reclamation of salt-affected land, unless intensive methods of improvement can be adopted, depends upon a series of plants which will cover such a range. An attempt was made to assess the salt tolerance of the more important species in the wide variety of plants occurring at Kerang. The earlier samples indicated that the growth of the principal herbage plants such as grasses and clovers is governed by the salt status of the first few inches of soil and it was decided to use to figure for 0-6 inches depth as a fair measure of the salt tolerance of the species growing in any particular area. The roots of many species growing in any particular area. The roots of many species may not go even as deep as 6 inches but allowance must be made for a fluctuating movement of salt in this layer associated with alternate periods of wet and dry weather.

The data for salt tolerance for plants for which relatively large numbers of determinations were available are illustrated in Figs. 7 (*a*) and (*b*). The degree of salt tolerance for each species is indicated by the proportion of samples in the 0-0.1 per cent NaCl range and the spread of the diagram to the right. The smaller the proportion of samples in that range and the greater the spread to the right, the greater is the salt tolerance of a given species.

Fig. 7 (*b*) shows the effect of salt concentration on most widespread grass in the area, barley grass. This includes the species *Hordeum murinum* as the least tolerant, and *H. maritimum* as the most tolerant, and a complete range of types between them. Poor barley grass is seen to be almost halophytic, and the difference between fair and good barley grass appears to be due to factors other than salt, probably general fertility factors and rates of stocking. It cannot be claimed that barley grass would grow even poorly at the higher concentrations indicated in Fig. 7 (*b*) if the salt were evenly distributed throughout the 6-in layer. A few samplings made to 3 inches among young barley grass which was dying even though the soil was quite moist, showed about 0.4 per cent NaCl, so that if barley grass grows on areas showing more than this figure for a 0-6 inches layer it must be assumed that the grass depends on a less saline layer in the first 2 or 3 inches.

Table 11 gives a more complete list of Kerang plants with their salt tolerances. No figure can be given for a deep rooting plant such as Dillon bush, and the 6-in layer figure for a moderately deep rooter such as samphire is given, rather to indicate the highly saline surface conditions where this plant grows, than as an accurate measure of its salt tolerance.

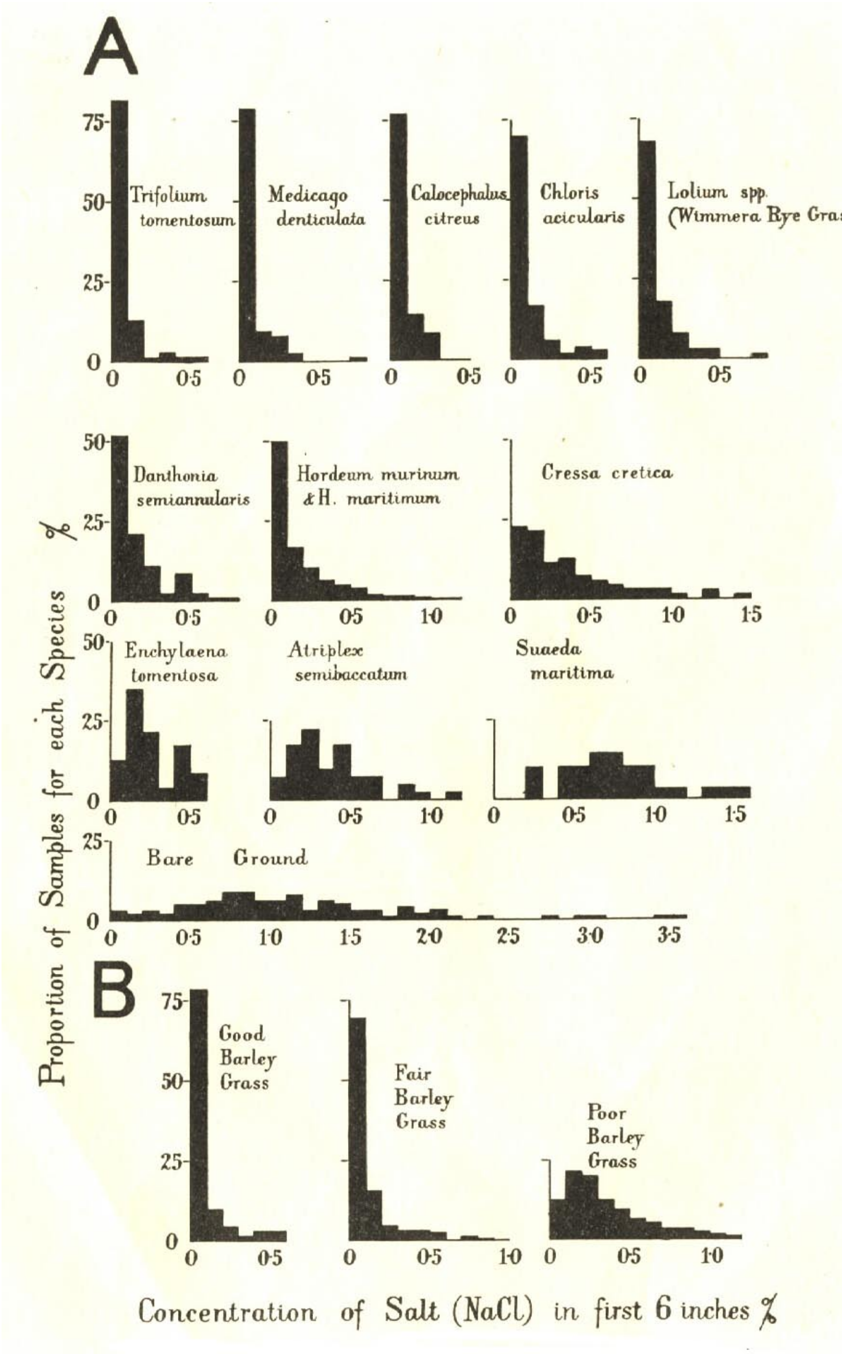

Fig. 7A – Diagrams showing the salt tolerance of various species of plants at Kerang.

Fig. 7B – Diagrams showing the effect of salt concentration on the growth of Hordeum murines and H. maritimum.

Table 11 – A list of Kerang Plants in descending order of Salt Tolerance.

Plant		Salt Tolerance NaCl, 0-6 inches	
Common Name	**Specific Name**	**Range**	**Model Value**
		%	%
Samphire	*Salicornia australis*	Up to 2.0	1.0
Twin-leaf	*Zygophyllum Billardieri*	0.5-2.0	1.0
Seablite	*Suaeda maritima*		
Sand-spurry	*Spergularia rubra*	} 0.2-1.6	0.7
Barb grass or ironweed	*Lepturus cylindricus*		
*Trailing saltbush	*Atriplex semibaccatum*	0.1-1.2	0.4
*Barrier saltbush	*Enchylaena tomentosa*	Up to 1.2	0.3
Rosinweed	*Cressa cretica*	Up to 0.9	0.2
Woolly mantle	*Eriochlamys Behrii*	Up to 1.5	0.1
*Barley grass	*Hordeum murinum and H maritimum*	Up to 1.2	0.1
*Root grass	*Danthonia semiannularis*	Up to 1.2	0.03
*Wimmera rye grass	*Lolium* spp.		
*Oats	*Avena sativa*	} Up to 0.8	0.03
*Spider grass or summer	*Chloris acicularis and C. truncata*		
grass		Up to 0.7	0.03
*Trefoil	*Medicago hispida*	Up to 0.6	0.04
*Brome fescue	*Festuca myuros*		
*Couch grass	*Cynodon Dactylon*	Up to 0.8	0.03
*Woolly clover	*Trifolium tomentosum*		
*Millet	*Panicum miliaceum*	} Up to 0.6	0.03
Camomile	*Calocephalus citreus*		
*Rye grass	*Lolium perenne*	Up to 0.4	0.03
*Subterranean clover	*Trifolium subterraneum*		
*White clover	*T. repens*		
*Canary grass	*Phalaris* spp.	} Up to 0.3	0.03
*Paspalum	*Paspalum dilatatum*		
*Lucerne	*Medicago sativa*		
*Soft brome grass	*Bromus hordeaceus*	Up to 0.2	0.03
*Blown grass	*Calamagrostis filiformis*	Up to 0.15	0.03
		Up to 0.10	0.02
		Up to 0.10	0.01

* Eaten by stock

V. AGRICULTURAL SITUATION IN THE DISTRICT.

1. General

The district of Kerang is devoted to dairying and the grazing of sheep, covering roughly equal proportions of the area of the survey. One third of the holding are greater than 500 acres, and one third are between 300 and 400 acres, so that the use of the land is fairly extensive. Irrigation, although general, often amounts to only one or two waterings a year, and a few of the larger holdings are run as dry propositions except in emergencies. Many farms have areas of improved pastures and lucerne, and grow annual cereal and fodder crops for their stock, but the large part of most farms, and indeed the whole of some properties, is unimproved pasture with more or less bare ground. The productivity of such natural pastures, even under irrigation, is very low and may vanish altogether with increasing salinity. Salt accumulations readily in the surface layers of the soil, and although the district has its own peculiar difficulties, such as flooding, as well as the usual problems of grazing and dairying management, the salt problem is by far the most important one.

2. Course of Deterioration

Rapid progress in development followed the start of irrigation in the Kerang country, but salt effects were noticed very close to the Macorna Channel soon after its opening, and it is said that ten years later the effects were spreading steadily northwards across the plains. Crops failed here and there, pastures deteriorated, Dillon bush and samphire appeared in increasing quantities, and bare, salty ground became common. Usually the decline was gradual, but in some cases, following floods, good land would go right out of production in a year.

The loss of productivity is linked with a general rise in the level of the water table. The earliest evidence of its position is that about 1880, before irrigation began, a salt water table lay at 20 to 30 feet beneath the plains between Nine Mile and the Calivil Creeks. Further, before 1890, no ground water was even encountered in excavating tanks to 11 feet. But by 1900, salt water was only 10 feet below the surface at Tragowel, and two years later it had risen there to 7 feet. At present the general depth of the water table for a large part of the district appears to be about 6 feet, even when unirrigated for more than a year. Of course, shortly after an irrigation the level is much higher, even less than 2 feet, but drops back in a few weeks to its normal level.

The causes of the decline were not recognised until the trouble was in an advanced stage, when loss of productivity meant lack of reserves to meet emergencies, and the situation was unfortunately at its worst during the period of financial depression between 1930 and 1933. By 1934, however, it is said that a natural improvement has been accelerated in the last two years by the new drains.

At the same time, even before the situation became extreme, methods for prevention and cure were being worked out. As these methods proved themselves, and as opportunities became available, some pastures were built up to reasonable, or even high, production and held to that standard. The salvation of the district lies in extending these ideas, and a scientific justification of them is desirable.

3. Causes of Declining Production

Although no virgin profiles were available for examination, chloride concentrations in the upper layers must have been very low originally to permit the growth of the pastures for which the districts was famous. The irrigation water has always been good, so the salt must have come from below. Undoubtedly, the ultimate cause of the increase of salt in the upper horizons at Kerang is the presence of a highly saline water table too close to the surface.

In the survey, it was impossible to define the conditions accurately, but the following information may be cited. More than 200 random samples of ground water from land not irrigated recently (ie., in the preceding six weeks) gave an average of 3.6 per cent NaCl; and one was as high as 7.75 per cent. The depth of the table below the surface for these samples varied from 3 feet to 9 feet, and in nearly every boring to 7 feet water could be found. Land irrigated recently showed water closer to the surface, but less salty, as would be expected. The average of 60 samples of this water was 1.5 per cent, with a maximum of 4 per cent.

As for the causes of such a high water-table, any factor contributing to the increase of ground water would be suspect, but it has been impossible to apportion the blame between the various factors in the course of this survey.

The first factor coming to mind is heavy watering, for which there is abundant evidence at all times and on every important type of soil. In early irrigation days, when Kow Swamp was the sole source, the supply of water was limited, but nevertheless, the rate of application could be heavy, since only small portions of holdings were irrigated. The inclusion of Torrumbarry Weir in the scheme made plenty of water available. No water meters were put in for some years after this, and an unrestricted use of water prevailed over large areas. This was checked when measuring wheels were installed for every block, but a proper knowledge of the dangers of too much irrigation water has only become general in the last few years.

Heavy watering used to be common for several reasons. It was though to carry any crop further towards the next irrigation, and to be essential for summer-growing crops. Millet land, for example, used to be kept under water throughout the growing season, and one method of procuring summer feed was by watering low parts with a constant small stream, producing swampy conditions. The best local practice at present, however, proves these beliefs to be wrong. Again, grading used to be the exception, and on crabholey land large applications of water are necessary to cover the major part when it is ungraded. Cracks, common in such heavy ground, also take up a great deal of water at times. Lastly, means of getting rid of surplus water at the end of an irrigation were frequently inadequate, and the excess was left on the ground.

Flooding is another factor. Owing to the district's low relief, floods from local rains and from higher country as far to the south as the Dividing Range are of frequent occurrence, and are said to have lain on the land for long periods formerly, even for months. The poor natural drainage was hampered by road and water-supply structures, by levees diverting water, and by the state of the larger creeks, especially the Nine Mile and the Calivil. Water was held constantly in these creeks and provided ideal conditions for the growth of cumbungi (*Typha* sp.) and lignum, which impeded their free flow. This source of trouble is now largely removed. Although the extensive system of open drains recently constructed by the Government may not prevent flooding, they will, when supplemented by the farmers own laterals, certainly give a quick removal of all flood water.

Seepage, that is to say, the raising of the water-table in one place by lateral movement from an adjacent body of water or saturated soil, is the last influence to consider. It is definitely a factor over limited distances. The Macorna clay and Kerang clay are surprisingly permeable, in spite of their high clay figure on analysis, apparently by virtue of minute fissures in the deep horizons due to the soil structure, and to the presence of gypsum, particularly in the first-named soil. The Tragowel clay appears to be the least pervious, but even in it, downward penetration of water is quite rapid. In Macorna clay it was found that irrigation in one part raised the water table considerably over a distance of 8 chains; in Kerang clay the distance was less, about 2 chains; but neither of these figures is necessarily a maximum one for all cases. On surface evidence seepage effects may extend for at least 4 chains from irrigated land.

Seepage from channels occurs in some cases, but there was no definite evidence of it for more than 8 chains from the Macorna Channel, the largest channel of all, in the more permeable Macorna clay, and no evidence of any seepage at all from it in Kerang clay. All channels in the district are only earth-works, and although their beds have probably become less pervious with time, considerable seepage may have occurred in the early years of their use. The soils in the Pyramid Creek suite are the most permeable in the area, but are so limited in extent that they cannot provide evidence of seepage for great distances, though it is sometimes very bad. The bed of the Pyramid Creek, which is used as a carrier of water by the authorities, appears relatively impervious and, so long as the water is kept within the banks, no direct harm can be attributed to it. Of its effect on underground drainage nothing is known.

Under the conditions prevailing in the Kerang district, with the general high level of the water table, the maintenance of a good vegetative cover is absolutely essential to prevent surface accumulation of salt. Practices which weaken or destroy the herbage are actually dangerous. Over-grazing has been common, and has led to the loss of much country which might have survived if lightly stocked. The Dillon bush, a shrub which thrives in ground with a high and saline water table, harbours enough rabbits to be a serious menace in this respect. Lack of essential plant nutriments can weaken the resistance of plants to salty conditions and to over-stocking, and even now there are large areas of grazing country and some cropping land which have never been treated with fertilisers. This is not to say that top-dressing would show results at present, for now it is salt, not essential plant foods, that is the common limiting factor for affected land. Finally, threatened ground may be expected to become very much worse when the cover is destroyed by ploughing or cultivation, unless properly managed.

4. Reclamation

Much affected land is making the first steps of recovery under natural conditions, but whether that recovery can be continued, or even maintained, on the same lines is not known. On holding managed extensively, the process is encouraged by the clearing of lignum and Dillon bush, and by the withholding of stock and irrigation water as much as possible. Complete recovery under such conditions is slow. Moreover, the resultant pasture is a relatively poor one, mainly barley grass, with proportions of trefoil, woolly clover, spider grass, and other species varying with the fertility and the nature of the irrigation.

Working more intensively, the land can be brought up to high production. Broadly speaking, the method involves the following steps: (.i.) clearing and cultivating; (ii) sowing an annual crop for two or three years, grading before each sowing, and irrigating by the best methods; (iii) final grading, and sowing of a pasture mixture for irrigation; (iv) regrading and resowing is usually necessary after seven to ten years, particularly where the soil was previously crabholey, as such land tends to revert to its original condition. Fertilising with superphosphate is necessary throughout the programme, except possibly for the first annual crop. The annual crops chosen are usually millet, because of the desirability of summer watering, or oats, sometimes with rye grass. Successful establishment of sown pastures of various types has been attained in this area, including perennial rye grass – white clover swards, Wimmera rye grass or *Phalaris* with subterranean clover, paspalum-clover association, and pasture species together with lucerne. A local strain of white clover is being used to an increasing extent, and alsike clover, red clover, and cocksfoot have been incorporated in mixtures sown in the districts.[*]

There is some danger of seepage effects on adjacent unimproved land in such a programme, but this is minimised by careful irrigation management, including light waterings at relatively frequent intervals. It is also recognised that some soils are more difficult to deal with than others. The red-brown phase of the Macorna clay is probably the most troublesome, as immediately below its surface layer there is a very intractable clay, difficult to cultivate and to irrigate. The greatest difficulty in the way of improvement is finance, but in addition, the change from an extensive to a more intensive system, even over a small area, requires initiative and adaptation. So far, the improved pastures have been used chiefly for dairying, and their possibilities for fat lamb production hardly seem to have been realised.

The extent of improved pastures in the district, and the areas of country returning naturally and being brought back into reasonable production, show than reclamation is thoroughly practicable. Inherently, there is no reason why reclamation should be impossible, since there are now examples of improvement on every soil type in the area of this survey.

VI. ACKNOWLEDGEMENTS

The authors wish to thank Mr. J. K. Taylor, of the Soils Division, Council for Scientific and Industrial Research, and Mr. F. Penman, of the Victorian Department of Agriculture, who directed the survey; Professor J. A. Prescott, Chief of the Soils Division, for his assistance with advice and criticism; Mr. P. D. Hooper, of the Soils Division, for the draughting of the soil map; and the staff of the National Herbarium, Melbourne, particularly Mr. P. F. Morris, for the identification of botanical specimens. They are also indebted to the State Rivers and Water Supply Commission for the supply of maps and of office facilities at Kerang and to the staff of the Kerang office, especially Mr. H. B. Lincoln, District Engineer.

[*] The Victorian Department of Agriculture has in progress in this area trials to determine the suitability of various pasture species for irrigation under local conditions and to investigate the effects of fertilisers and soil amendments on production of irrigated pasture.

APPENDIX - MECHANICAL ANALYSES AND OTHER DATA FOR KERANG SOILS.

All figures are shown as percentages of fine earth except those for reaction, depth, and "rubble and gravel," the latter being percentages of the field samples. As indications of field texture, SL signifies sandy loam; L, loam; SCL, sandy clay loam; CL, clay loam; FSC, fine sandy clay; LC, light clay; LMC, light medium clay; MC, medium clay; MHC, medium heavy clay; HC, heavy clay; An asterisk against total soluble salts indicates that the sample contains gypsum.

Table I – Mechanical Analyses and other Data for Macorna Clay Profiles.

---	Red-brown Phase Shelf											
Laboratory number	**3392**	**3393**	**3394**	**3395**	**3396**	**3397**	**8038**	**8039**	**8040**	**8041**	**8042**	**8043**
Depth (inches)	0-2	2-8	8-20	20-30	30-69	69-84	0-1	1-4	4-9	9-15	15-33	33-63
Texture	L	HC	MHC	MC	LMC	MC	L	CL-LC	HC	MC	LMC	LC
Rubble and gravel	Tr.	. .	. .	Tr.	0.7	0.7	. .	. .	. .	Tr.	0.1	Tr.
Coarse sand	2.7	0.9	0.6	0.4	0.5	0.2	1.5	0.6	0.3	0.3	0.2	0.1
Fine sand	47.5	19.0	17.8	19.0	26.0	13.8	48.6	35.4	19.4	21.5	21.2	28.0
Silt	18.0	10.1	9.4	8.1	13.1	17.2	14.5	15.4	9.9	11.5	14.2	22.0
Clay	25.2	61.3	66.5	59.6	51.2	60.3	28.1	42.9	64.2	59.4	44.1	43.9
Moisture	2.5	7.5	6.0	7.1	5.7	6.0	2.7	3.5	4.2	4.5	5.8	3.1
Loss on acid treatment	0.8	2.6	2.7	5.3	4.7	4.5	1.5	0.9	2.4	3.4	15.4	4.3
Loss on ignition	6.3	7.2	6.2	5.2	4.7	5.2	7.1	5.7	7.3	6.3	4.7	4.5
Calcium carbonate	0.03	0.03	0.08	0.15	0.96	0.57	0.01	0.00	. .	0.05	0.05	0.48
Total soluble salts	0.06	0.30	1.00	*	*	*	0.07	0.17	0.86	*	*	*
Chloride (as Cl)	0.012	0.074	0.170	0.047	0.041	0.080	0.019	0.070	0.353	0.584	0.522	0.404
Nitrogen	0.181	0.127	. .	. .	. .	. .	0.194	0.103	. .	. .	. .	. .
pH value	6.4	8.1	8.5	8.0	8.3	8.3	6.8	6.6	7.5	8.0	8.0	8.1

Table I – Mechanical Analyses and other data for Macorna Clay Profiles. (*continued*).

---	Brown Phase Shelf													
Laboratory number	**3356**	**3357**	**3358**	**3359**	**3360**	**3361**	**3362**	**3363**	**3398**	**3399**	**3400**	**3401**	**3402**	**3403**
Depth (inches)	0-2	2-7	7-15	15-22	22-38	38-75	75-120	120-204	0-1	1-6	6-22	22-48	48-84	84-120
Texture	CL	HC	MHC	MHC	HC	MC	MC	HC	L-CL	HC	MHC	MC	MC	HC
Rubble and gravel	. .	. .	. .	0.1	0.5	0.9	0.1	. .	. .	. .	. .	2.3	1.1	Tr.
Coarse sand	3.9	1.5	1.3	1.2	0.7	0.4	1.0	2.1	1.1	0.7	0.2	0.1	0.1	0.1
Fine sand	47.2	17.3	16.7	16.4	13.0	10.2	8.7	16.0	39.7	13.3	12.9	10.1	8.5	8.3
Silt	20.9	10.1	8.8	7.8	8.9	10.8	17.7	16.1	22.8	11.3	13.2	. .	. .	. .
Clay	24.0	64.0	61.7	64.0	65.0	68.3	65.2	58.6	29.4	63.2	67.0	. .	. .	. .
Moisture	1.9	6.8	6.7	7.3	7.1	6.4	5.4	5.9	3.0	7.9	6.4	. .	. .	. .
Loss on acid treatment	1.0	2.0	3.2	5.3	5.8	4.6	3.1	2.9	1.3	3.2	2.3	. .	. .	. .
Loss on ignition	4.7	7.1	6.8	6.4	6.1	6.1	5.4	5.1	7.8	7.1	5.9	. .	. .	. .
Calcium carbonate	0.04	0.01	0.10	0.05	0.37	0.82	0.35	0.04	0.05	0.06	0.04	0.97	0.55	0.11
Total soluble salts	0.05	0.27	1.61	*	*	1.50	1.35	1.89	0.08	0.13	0.75	*	*	*
Chloride (as Cl)	0.008	0.116	0.691	0.758	0.643	0.558	0.486	0.664	0.023	0.039	0.244	0.200	0.173	0.237
Nitrogen	0.127	0.059	. .	. .	. .	. .	. .	. .	0.232	0.076	. .	. .	. .	. .
pH value	6.5	7.7	8.2	8.2	8.1	8.5	8.3	7.8	6.4	7.9	8.5	8.2	8.2	8.3

Table I – Mechanical Analyses and other data for Macorna Clay Profiles. (*continued*).

---	Brown Phase Shelf						Brown Phase Puff						Brown Phase Crabhole			
Laboratory number	**3416**	**3417**	**3418**	**3419**	**3420**	**3421**	**3364**	**3365**	**3366**	**3367**	**3368**	**3369**	**3422**	**3423**	**3424**	**3425**
Depth (inches)	0-3	3-11	11-24	24-40	40-84	84-114	0-6	6-42	42-62	62-92	92-120	120-138	0-6	6-17	17-34	34-62
Texture	CL	MHC	MHC-MC	LMC	LMC	MC-HC	MHC	HC	HC	MHC	MHC	HC	HC	HC	HC	MHC
Rubble and gravel	. .	Tr.	. .	0.6	0.9	0.9	1.5	1.2	1.5	0.6	0.1	0.3	. .	. .	0.2	1.5
Coarse sand	1.5	0.5	0.2	0.2	0.2	0.2	0.7	0.5	0.4	0.3	0.6	2.0	0.8	0.6	0.4	0.3
Fine sand	42.0	17.4	14.4	16.6	14.8	12.6	12.8	12.8	10.2	9.4	8.3	19.8	29.9	22.2	17.9	13.1
Silt	27.2	13.8	8.9	. .	. .	. .	11.7	11.1	10.8	13.3	18.5	17.6	23.5	15.2	13.3	10.6
Clay	25.2	60.3	67.2	. .	. .	. .	66.0	66.1	68.1	68.0	64.5	53.1	39.5	55.1	61.8	63.5
Moisture	2.5	7.2	7.8	. .	. .	. .	7.5	7.7	6.4	6.4	5.6	5.1	4.1	5.6	5.7	7.1
Loss on acid treatment	1.3	2.7	4.0	. .	. .	. .	3.1	4.1	6.8	4.7	3.3	4.4	1.7	1.2	2.4	6.5
Loss on ignition	5.4	7.1	6.2	. .	. .	. .	7.2	6.5	6.0	6.2	5.7	4.9	5.6	5.2	5.7	5.7
Calcium carbonate	0.02	0.01	0.61	1.13	0.27	0.28	0.34	1.14	1.76	1.34	0.39	0.02	0.02	0.00	0.29	0.82
Total soluble salts	0.08	0.65	*	*	*	*	0.84	1.29	1.44	1.35	*	*	0.06	0.09	0.33	*
Chloride (as Cl)	0.027	0.249	0.471	0.296	0.174	0.163	0.342	0.540	0.574	0.456	0.489	0.486	0.009	0.023	0.059	0.029
Nitrogen	0.153	. .	. .	. .	. .	. .	0.074	. .	. .	. .	. .	. .	0.118	. .	. .	. .
pH value	6.6	7.9	8.2	8.0	8.0	8.0	7.7	8.1	8.4	8.5	8.3	7.8	6.7	7.6	8.0	8.0

Table II – Mechanical Analyses and other data for Kerang Clay Profiles.

---	Grey-Brown Phase Shelf															
Laboratory number	**3370**	**3371**	**3372**	**3373**	**3374**	**3375**	**3376**	**3377**	**3404**	**3405**	**3406**	**3407**	**3408**	**3409**	**3410**	**3411**
Depth (inches)	0-1	1-3	3-12	12-22	22-48	48-84	84-120	120-144	0-2	2-8	8-15	15-25	25-48	48-84	84-132	132-204
Texture	L-CL	MC	MHC	MC	MHC	MHC	HC	HC	MC	MC	MC	MC	MC	MC	MC	HC
Rubble and gravel	. .	. .	. .	. .	0.2	1.1	7.7	3.8	. .	. .	. .	. .	0.3	1.7	1.2	1.1
Coarse sand	2.1	1.8	0.6	0.5	0.3	0.4	0.5	0.5	2.1	0.5	0.4	0.5	0.4	0.6	0.6	0.5
Fine sand	36.0	27.1	11.9	13.8	15.6	15.5	11.9	11.4	22.9	6.0	6.3	7.9	6.5	7.0	10.8	13.5
Silt	16.1	12.5	4.2	7.8	10.0	14.4	. .	. .	10.6	3.5	5.8	5.9	5.9	. .	. .	. .
Clay	31.3	48.2	71.6	60.9	56.4	56.3	. .	. .	54.0	75.7	76.6	72.6	72.3	. .	. .	. .
Moisture	4.3	6.1	7.6	8.5	8.0	7.5	. .	. .	7.0	10.7	8.8	8.9	9.8	. .	. .	. .
Loss on acid treatment	2.1	2.3	4.1	8.9	11.7	7.3	. .	. .	2.5	4.3	4.0	4.9	7.2	. .	. .	. .
Loss on ignition	10.5	6.7	7.6	7.6	7.6	5.5	. .	. .	7.2	8.0	7.0	7.0	6.3	. .	. .	. .
Calcium carbonate	0.04	0.03	0.04	3.42	5.06	1.99	1.02	1.47	0.05	0.03	0.02	0.04	0.38	0.26	2.00	9.31
Total soluble salts	0.93	0.81	2.09	*	*	*	*	*	1.00	1.89	2.09	2.30	*	*	*	*
Chloride (as Cl)	0.408	0.320	0.900	0.670	0.437	0.427	0.510	0.704	0.243	0.679	0.680	0.667	0.601	0.606	0.677	0.709
Nitrogen	0.370	0.112	. .	. .	. .	. .	. .	. .	0.094	0.040	. .	. .	. .	. .	. .	. .
pH value	5.7	7.0	7.9	8.6	8.4	8.4	8.2	8.4	6.7	7.7	8.0	8.1	7.9	7.9	8.5	8.5

Table II – Mechanical Analyses and other data for Kerang Clay Profiles. (*continued*)

---	Grey-Brown Phase Shelf				Grey-Brown Phase Crabhole				Grey Phase Shelf						
Laboratory number	**8044**	**8045**	**8046**	**8047**	**3412**	**3413**	**3414**	**3415**	**3378**	**3379**	**3380**	**3381**	**3382**	**3383**	**3384**
Depth (inches)	0-4	4-13	13-30	30-54	0-2	2-9	9-25	25-60	0-3	3-17	17-32	32-52	52-78	78-120	120-204
Texture	MC	HC	MHC	MC	MHC	HC	HC	MHC	HC	HC	HC	HC-MHC	HC	MHC	HC
Rubble and gravel	. .	. .	0.7	0.2	. .	. .	1.3	1.3	. .	. .	. .	1.1	0.5	. .	0.8
Coarse sand	3.5	1.4	1.4	1.2	0.8	0.8	0.7	0.5	1.9	1.0	1.0	1.1	1.0	0.8	3.5
Fine sand	20.2	8.2	10.0	11.4	11.7	11.3	10.0	9.9	23.5	13.8	14.0	13.6	12.9	20.6	19.3
Silt	10.8	5.0	7.6	10.7	9.1	7.4	6.5	7.5	12.6	11.8	13.3	14.0	20.8	21.2	13.1
Clay	55.7	73.9	69.3	65.2	64.5	69.7	72.2	71.5	50.7	63.4	64.5	56.4	56.2	51.4	54.4
Moisture	6.5	7.7	8.2	6.6	7.9	9.2	8.3	6.2	6.3	8.2	6.2	7.4	6.2	5.1	6.2
Loss on acid treatment	2.6	4.0	4.7	6.0	2.3	2.3	3.2	5.6	1.9	2.0	3.0	9.8	4.9	3.1	5.1
Loss on ignition	6.4	8.0	6.8	6.9	9.8	6.9	6.6	7.2	6.5	6.6	5.7	5.4	5.3	4.7	5.2
Calcium carbonate	. .	0.01	0.87	2.84	0.03	0.04	1.04	2.57	0.02	0.03	0.09	0.31	0.13	0.05	0.50
Total soluble salts	0.69	1.61	1.83	1.44	0.12	0.05	0.59	*	0.18	0.87	1.35	*	*	1.61	*
Chloride (as Cl)	0.287	0.752	0.946	0.647	0.024	0.013	0.221	0.516	0.070	0.339	0.478	0.443	0.536	0.585	0.711
Nitrogen	0.105	. .	. .	. .	0.173	0.062	. .	. .	0.090	. .	. .	. .	. .	. .	. .
pH value	6.9	7.4	8.3	8.5	6.2	7.2	8.1	8.2	7.1	8.0	8.0	8.0	8.2	8.1	8.5

Table II – Mechanical Analyses and other data for Kerang Clay Profiles. (*continued*)

---	Grey Phase Shelf						Grey Phase Puff			
Laboratory number	**3426**	**3427**	**3428**	**3429**	**3430**	**3431**	**3432**	**3433**	**3434**	**3435**
Depth (inches)	0-3	3-15	15-36	36-69	69-144	144-204	0-4	4-24	24-48	48-100
Texture	MC	HC	HC	HC	HC	HC	HC	HC	HC	HC
Rubble and gravel	. .	. .	. .	0.1	0.1	0.1	Tr.	. .	0.5	0.1
Coarse sand	4.1	1.0	0.8	0.8	1.3	0.9	0.9	0.7	0.6	0.7
Fine sand	30.6	11.8	12.3	12.9	12.3	12.4	12.3	11.3	11.3	13.1
Silt	13.6	7.4	8.0	11.6	. .	. .	9.7	9.7	8.3	13.7
Clay	42.1	71.0	66.5	62.9	. .	. .	64.2	65.0	67.9	64.9
Moisture	5.0	7.6	7.4	7.1	. .	. .	8.1	9.3	7.0	5.3
Loss on acid treatment	2.0	2.5	5.4	6.4	. .	. .	4.9	5.0	5.2	3.7
Loss on ignition	6.5	6.5	6.6	6.3	. .	. .	9.6	7.1	6.7	5.9
Calcium carbonate	0.02	0.06	2.01	1.35	1.03	4.44	0.18	1.06	1.16	0.46
Total soluble salts	0.57	1.04	1.15	*	*	*	2.91	1.89	1.42	*
Chloride (as Cl)	0.218	0.389	0.406	0.530	0.710	0.813	1.400	0.865	0.759	0.774
Nitrogen	0.146	. .	. .	. .	. .	. .	0.117	. .	. .	. .
pH value	6.7	8.0	8.6	8.5	8.4	8.5	7.3	8.1	8.1	8.2

Table III – Mechanical Analyses and other data for Tragowel Clay Profiles.

---	Flooded Phase							Self-mulching Phase					
Laboratory number	**3385**	**3386**	**3387**	**3388**	**3389**	**3390**	**3391**	**3436**	**3437**	**3438**	**3439**	**3440**	**3441**
Depth (inches)	0-5	5-24	24-36	36-54	54-84	84-156	156-204	0-3	3-22	22-48	48-75	75-120	120-174
Texture	MHC	HC	HC	MHC	MHC-HC	HC	HC	MHC	MHC-HC	HC	HC	HC	HC
Rubble and gravel	Tr.	. .	Tr.	Tr.	0.1	Tr.	. .	. .	0.2	. .	0.7	0.1	0.6
Coarse sand	1.1	2.0	1.0	0.5	1.5	2.8	0.4	1.0	0.8	0.5	0.4	0.7	1.0
Fine sand	25.9	29.6	26.7	21.0	25.2	16.8	15.0	17.0	14.9	14.6	15.5	15.4	8.4
Silt	14.2	14.0	18.1	16.9	15.8	14.4	20.5	12.1	10.1	11.6	11.3	16.3	. .
Clay	49.3	45.9	50.6	54.0	51.8	57.8	56.3	58.0	61.8	62.4	59.0	58.6	. .
Moisture	5.5	5.4	4.4	5.0	4.7	5.7	5.0	7.3	8.4	7.4	7.4	6.5	. .
Loss on acid treatment	2.1	4.4	1.9	2.9	2.8	3.3	2.3	2.6	6.0	5.9	7.2	4.1	. .
Loss on ignition	6.0	4.2	4.0	4.6	4.4	4.9	4.8	9.0	7.1	5.7	5.6	4.6	. .
Calcium carbonate	0.02	0.05	0.06	0.32	0.06	0.97	0.07	0.15	2.40	2.33	1.06	0.23	0.35
Total soluble salts	0.31	0.29	0.58	0.74	0.79	1.20	1.09	0.13	0.71	1.35	*	*	*
Chloride (as Cl)	0.132	0.121	0.203	0.224	0.243	0.393	0.365	0.024	0.269	0.542	0.489	0.420	0.547
Nitrogen	0.069	. .	. .	. .	. .	. .	. .	0.212	. .	. .	. .	. .	. .
pH value	6.4	7.4	8.3	8.3	8.2	8.7	8.2	7.4	8.2	8.4	8.1	8.2	8.2

Table III – Mechanical Analyses and Other Data for Tragowel Clay Profiles. (*continued*)

---	Self-mulching Phase					Woodland Phase			
Laboratory number	**3442**	**3443**	**3444**	**3445**	**3446**	**8034**	**8035**	**8036**	**8037**
Depth (inches)	0-4	4-10	10-36	36-69	69-84	0-5	5-22	22-42	42-70
Texture	HC	HC	HC	HC	HC	MC	HC	HC	HC
Rubble and gravel	. .	. .	0.3	1.3	0.4	. .	0.1	0.3	1.3
Coarse sand	2.5	2.3	1.2	0.7	0.6	1.0	0.7	0.2	0.2
Fine sand	19.5	16.0	15.8	16.6	15.6	25.0	24.5	15.5	18.6
Silt	13.6	13.5	12.5	13.0	16.0	13.6	15.6	9.6	12.8
Clay	56.4	59.3	63.5	61.7	61.1	53.4	55.2	65.2	60.5
Moisture	6.4	6.6	6.1	6.0	5.6	5.1	3.8	7.2	5.1
Loss on acid treatment	1.7	1.4	2.3	2.8	2.4	2.5	2.2	1.8	3.9
Loss on ignition	6.2	5.5	5.6	5.5	5.3	6.7	5.2	5.7	5.6
Calcium carbonate	0.01	0.05	0.09	0.48	0.64	0.00	0.24	1.67	1.67
Total soluble salts	0.06	0.09	0.13	0.29	0.25	0.18	0.33	0.62	0.61
Chloride (as Cl)	0.013	0.022	0.049	0.067	0.064	0.064	0.106	0.208	0.211
Nitrogen	0.073	. .	. .	. .	. .	0.118	. .	. .	. .
pH value	6.7	7.2	8.5	8.8	8.7	7.7	8.5	8.6	8.7

Table IV – Mechanical Analyses and other data for Types 1-3.

Pyramid Creek Suite.

---	Type 1 (Light Profile)						Type 1 (Heavy Profile)						
Laboratory number	**8014**	**8015**	**8016**	**8017**	**8018**	**8019**	**8001**	**8002**	**8003**	**8004**	**8005**	**8006**	**8007**
Depth (inches)	0-6	6-13	13-27	27-45	45-66	66-84	0-2	2-9	9-15	15-27	27-40	40-57	57-84
Texture	L	LMC	LC	SCL	SCL-SL	SL	L	MC	MC	MC	LC	FSC	LC
					. .								
Rubble and gravel	. .	. .	1.7	. .	0.1	. .	. .	. .	0.5	0.4	Tr.	. .	. .
Coarse sand	0.2	0.1	0.2	0.1	57.1	0.02	0.3	0.1	0.1	0.3	0.2	0.2	0.1
Fine sand	38.3	21.7	30.3	44.2	20.8	70.3	32.0	20.5	15.0	16.7	17.7	22.4	18.5
Silt	35.4	29.5	34.7	28.1	20.0	12.7	32.9	23.1	22.3	30.7	36.2	35.5	31.6
Clay	24.1	46.3	33.3	24.2	1.4	15.6	28.8	50.7	54.5	46.7	43.8	39.6	46.6
Moisture	1.5	2.3	2.4	1.3	1.5	1.8	1.9	3.1	4.0	2.5	2.9	2.7	3.5
Loss on acid treatment	1.2	1.6	1.9	1.2		1.3	1.6	1.5	3.8	4.1	1.6	1.5	1.5
Loss on ignition	4.4	5.1	4.0	3.1	3.0	2.3	6.2	5.4	6.1	5.3	4.3	4.1	4.4
Calcium carbonate	. .	0.02	0.55	0.04	0.01	0.00	. .	. .	1.40	1.84	0.11	0.01	0.00
Total soluble salts	0.26	0.46	0.65	0.69	0.79	0.81	0.05	0.09	0.25	0.33	0.35	0.48	0.65
Chloride (as Cl)	0.113	0.192	0.265	0.288	0.337	0.354	0.008	0.026	0.069	0.099	0.123	0.149	0.245
Nitrogen	0.108	. .	. .	. .	. .	. .	0.155	0.089	. .	. .	. .	. .	. .
pH value	7.4	8.4	8.9	8.1	7.9	7.9	6.7	7.8	8.6	8.7	8.3	7.6	7.3

Table IV *(continued).*

Pyramid Creek Suite *(continued)*

---	Type 2						Type 3					
Laboratory number	**8020**	**8021**	**8022**	**8023**	**8024**	**8025**	**8008**	**8009**	**8010**	**8011**	**8012**	**8013**
Depth (inches)	0-3	3-8	8-19	19-33	33-42	42-48	0-6	6-12	12-18	18-33	33-63	63-96
Texture	L-CL	MC	MC	LMC	CL	SCL	L-CL	LC	MC	LC	SCL	SCL
Rubble and gravel	. .	. .	0.2	. .	. .	. .	. .	. .	. .	3.4	0.7	0.1
Coarse sand	1.2	0.5	0.2	0.3	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.2
Fine sand	28.2	17.3	20.3	20.3	30.6	45.0	23.6	23.3	22.5	24.8	53.1	61.5
Silt	32.7	23.3	23.0	29.5	28.2	21.0	26.7	28.6	28.5	32.8	20.0	18.8
Clay	32.7	54.7	49.8	45.5	38.8	31.3	42.3	44.5	43.8	38.2	25.3	18.9
Moisture	2.8	3.4	3.5	2.5	1.9	1.6	3.8	2.6	3.8	2.6	1.8	1.6
Loss on acid treatment	1.8	1.8	4.0	2.9	2.1	2.0	2.2	1.8	2.5	3.0	1.4	1.3
Loss on ignition	6.0	6.0	5.6	4.8	4.1	3.7	6.9	5.5	6.4	4.4	2.9	2.6
Calcium carbonate	0.00	0.04	1.77	0.54	0.15	0.01	0.01	0.00	0.04	1.09	0.08	. .
Total soluble salts	0.09	0.34	0.75	0.95	1.04	1.04	0.40	0.50	0.56	0.65	0.67	0.81
Chloride (as Cl)	0.030	0.143	0.305	0.378	0.397	0.408	0.183	0.209	0.269	0.261	0.272	0.356
Nitrogen	0.138	. .	. .	. .	. .	. .	0.176	. .	. .	. .	. .	. .
pH value	7.3	7.7	8.4	8.3	8.1	7.5	6.6	7.5	8.0	8.7	8.2	7.4

Table V – Mechanical Analyses and other data for Type 4.

Type 4.

Laboratory number	8026	8027	8028	8029	8030	8031	8032	8033
Depth (inches)	0-5	5-10	10-13	13-22	22-36	36-48	48-66	66-84
Texture	SL	MC	LC	LC	CL	CL	LC	SCL
Rubble and gravel	. .	. .	0.7	4.6	1.9	1.9	1.7	0.3
Coarse sand	22.9	15.3	11.7	12.3	13.2	12.2	10.4	11.6
Fine sand	55.0	33.8	25.9	25.7	24.9	24.0	21.3	35.1
Silt	6.9	4.0	3.6	1.9	3.0	2.7	4.3	4.5
Clay	13.8	44.1	53.9	52.6	51.2	53.8	53.8	43.0
Moisture	1.2	2.7	4.9	5.2	5.4	5.3	5.3	4.1
Loss on acid treatment	0.7	1.3	1.9	4.0	3.8	4.5	6.5	4.1
Loss on ignition	2.9	4.7	5.3	5.9	5.1	5.6	6.4	4.3
Calcium carbonate	0.01	0.01	0.06	1.41	1.07	2.32	3.82	1.91
Total soluble salts	0.04	0.08	0.38	0.65	0.79	0.92	0.92	0.81
Chloride (as Cl)	0.003	0.032	0.162	0.258	0.325	0.370	0.372	0.325
Nitrogen	0.062	. .	. .	. .	. .	. .	. .	. .
pH value	6.9	7.7	8.3	8.6	8.6	8.6	8.6	8.6

T. RIDER, Acting Government Printer, Melbourne