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SOIL SURVEY

of the

ROBINVALE IRRIGATION AREA

Part of Parishes of

BUMBANG AND TOLTOL
COUNTRY OF KARKAROOC
VICTORIA

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SUMMARY

An area of 14,165 acres in the vicinity of Robinvale on the Murray River has been covered by a soil survey with the object of defining the most suitable soils for development to vines and citrus under irrigation. A unit of approximately 5,500 acres has been selected for settlement for returned servicemen.

The landscape is one of sequence of east-west sand-ridges interspersed with broad hollows, and, in the virgin areas, carrying eucalypt scrub and belar forest.

Geologically, the deposits are Pleistocene sands, frequently calcareous, and of lacustrine, fluviatile, and aeolian origin.

The soils belong to the solonised brown soil group. General features of the soils are their brown colour and alkaline reaction throughout the profile, the presence of calcium carbonate and soluble salts in the B and C horizons, and the presence of illuvial clay horizons formed under the influence of sodium ions in the exchange complex. Analytical data are presented which illustrate these and other chemical and physical properties of the soils.

Twelve soil types which have been recorded and named in previous soil surveys are described; also are recorded three new soil types which have been left unnamed.

Soil types in the Barmera, Nookamka, and Coomealla series comprise the bulk of the area. With the exception of the Nookamka clay loam, and subject to satisfactory salt status, these soils are suitable for vines. The area of citrus soils is small; suitable situations are in the Murray sand, Berri sand, and Barmera sand soil types. The Belar clay loam and Type A are soil types not recommended for horticulture.

Soil salinity has been investigated and areas with a high salt hazard have been avoided for settlement. Inherent salinity is greatest in the Coomealla loam and Type A sol types. The former will require particular attention under irrigation to avoid salinity problems.

Experience and investigational work with the soil types in established horticultural areas is available for application at Robinvale. It has been utilised already in settlement and block design, and, further, should enable settlers to irrigate the soils to the best advantage. Properties of the soils are discussed in relation to water usage and drainage. Caution in the excessive use of water and early provision for drainage are advocated.

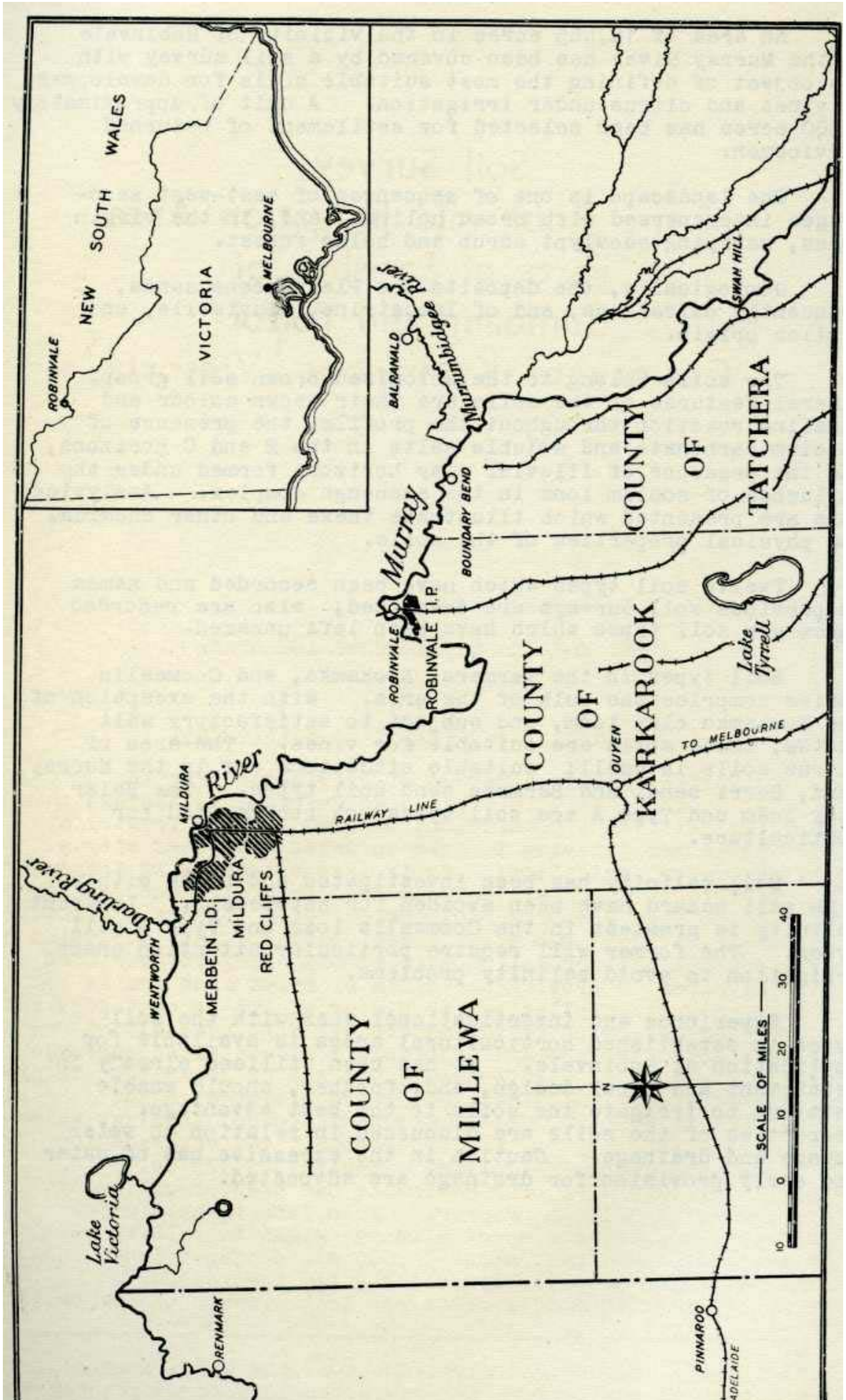

Figure 1 – Locality Plan

Soil Survey of the Robinvale Irrigation Area
Parts of Parishes of Bumbang and Toltol
Country of Karkarooc, Victoria*

GENERAL FEATURES OF THE AREA.

1. The Robinvale Irrigation Settlement.

Following on the return of servicemen from the 1939-1945 World War, the Victorian government, through the Soldier Settlement Commission, decided to make provision for those men desiring to take up dried fruit and citrus blocks under irrigation. Controlled expansion of these horticultural crops by the Commonwealth government was agreed upon by Victoria from the outset. Investigations showed that there was insufficient suitable land adjoining the established irrigation settlements along the northern Murray River to provide the quota of dried vine fruits and citrus plantings allocated to Victoria, and to meet possible future expansion of these industries. As a result of investigations into lands suitable for settlement schemes after the 1914-18 war, about 25,000 ac of Crown land within parishes of Bumbang, Toltol and Annuello had been set aside from alienation by the Lands Department and reserved for future uses under irrigation. Earlier, 9,375 ac. Adjoining this area near Robinvale had been proclaimed an Agricultural College Reserve. This land is held under short term grazing licence with the right to cultivate. There are, therefore, about 35,000ac. of Crown lands in this district potentially suitable for irrigation. Probably more then half of it has been cleared of timber, originally for wheat growing, but now it has mostly reverted to native pastures and is utilised for grazing sheep, with wheat as a sideline in some localities. There has long been some private pumping on the river frontage, principally for market gardens, but about 200 ac of freehold near Robinvale township has been planted with vines, citrus, and stone fruits. Attention was naturally focused on this district and preliminary investigations, including reconnaissance of the soils, were undertaken in 1946 to determine the practicability of developing the land in the immediate vicinity of Robinvale for vines and citrus under irrigation by pumping from the Murray River. Settlement was considered feasible and work on the project was started without delay. The location of the area is shown in Figure 1.

Allocation to soldier settlers of 100 blocks, each of approximately 25 ac. total area, we planned initially and a target of 500 ac. to be planted with vines was set for 1947. About 2,700 ac. of the most easily accessible land was selected for immediate soil survey. This was completed in February 1947, but in anticipation of future expansion the area was extended later in 1947 and again in 1948. In 1949, a further allocation of 66 blocks for serviceman was authorised, increasing the total area of the settlement to about 5,500 ac. and the irrigable area of soils suitable for horticulture to slightly more than 4,000 ac. In all a total area of 14,465 ac. in the parishes of Bumbang and Totol has been soil surveyed in detail.

That the soil survey data has been used extensively in planning the settlement is illustrated by the fact that it has been necessary to survey more than 14,000 ac. in order to secure 5,500 ac of good land in a reasonably compact area that can readily be supplied with water. Areas with the dominant soils texturally unfavourable for horticulture, or possessing salt or frost hazards have been excised entirely from settlement. Within the individual blocks, no plantings have been made on such situations but they have been utilised as far as possible for building sites, yards and roads. Irrespective of total area each block includes a commandable area of not less than 20 ac. of soils suitable for viticulture. Vines are restricted to a maximum planting of 15 ac. for dried fruits of which not more than 10 ac. are sultanas; grapes for other purposes may be planted the remaining 5 ac. citrus and stone fruits are planted only where the soils are considered suitable; however the extent of such soils is small. Therefore, it has not

* The soil survey was carried out by the Soils Section, Department of Agriculture to provide basic information for the State Rivers and water Supply Commission and the Soldier Settlement Commission who together were responsible for the design of the settlement.

been possible to provide each block with an area of soil types suitable for citrus, although subdivision has been designed to meet this requirement as far as practicable.

Water is supplied from the Murray River by an installation of two main pumps with a combined discharge of 60 cusecs. The lift is 76 ft. to a dissipator with an open concrete channel as the main supply line. This supplies water to a reinforced concrete pipe reticulation system which serves each block. The majority of blocks are commanded from this lift, but re-lifts at two points are necessary to serve 35 blocks to the west of the railway. Local high spots above the general supply level are very few.

Underground drainage was considered to be desirable, although not to be essential, in the early stages of development; but rather than delay settlement, provision has been made for the installation of a drainage scheme at a later date.

2. Climate.

Climatological data (to 1949), supplied by courtesy of the Meteorological Branch, Department of Interior, for Robinvale and Euston, with those for Mildura for comparison, are shown in Table 1. Average yearly rainfall for Robinvale is 10.67 in. for a period of 21 years, but the value of 12.09 in. for Euston, taken over a very much longer period, is considered the more reliable figure for the area. Winter rainfall is higher than summer rainfall, the six-monthly values being May to October, 7.12 in. and Nov. to April, 4.97 in. Similar conditions, but at slightly lower monthly levels, prevail at Mildura. For the Murray River dried fruit areas generally, rainfall is relatively high in February, and summer rains have been the cause of considerable damage to fruit in some years.

At Euston, the average yearly temperature range is from 49.1^0F to 75.3^0F., with a mean value of 62.2^0F. Compared with Mildura the mean maximum temperature is only 0.3^0F. lower. The summer months are hot and the mean maximum temperatures are almost identical with those for Mildura, exceeding 82^0F. from November to March and 74^0F. in April. Therefore, drying conditions for fruit at Robinvale can be expected to be equal to those at Mildura in so far as temperature is concerned; however, as indicated above, Mildura is probably favoured by less rain during the drying period. In regard to minimum temperatures and their influence on vine injury by frost, conditions are likely to be less favourable at Robinvale. September and October mean values are of the most significance, and these normals for Euston are 2.0^0F and 1.8^0F lower than for Mildura. Further data from Euston indicate the possibility of late frosts at Robinvale. During September screen temperatures on the average fall below 32^0F (heavy frost) on 0.6 day and below 36^0F (light frost) on 2.8 days; during October heavy frosts are unlikely but light frosts occur on the average on 0.4 day in the month. Similar data for Mildura indicate light frosts on 0.1 day in both September and in October, but no heavy frosts in either month.

Monthly evaporation figures for Mildura shown in Table 1 are calculated values (Prescott, 1938). These are slightly higher than evaporimeter readings from a free water surface recorded in the same area at the Commonwealth Research Station, Merbein. However, through their ratio with rainfall (F/E), the values are useful to illustrate the general aridity of the climate. The R.E figures show rainfall that there is complete dominance of evaporation over rainfall for all months of the year. The highest R to E ratios are for June and July , but even in these two winter months the average rainfall is only about two thirds of the potential evaporation. From November to March the average rainfall is one tenth or less of the evaporation.

3. Geology and Topography.

The area lies towards the eastern limit of the ancient Murray Gulf, a sea of the Tertiary period. Hills (1946) in describing the geology of north-western Victoria, records deposits of great thickness – possibly exceeding 800 ft. – in this former Gulf area. He states, "In the area where marine deposits occur, ligneous clays o f continental and shallow marine origin are overlain by Miocene limestones, and these in turn by marine Pliocene shell marls and glauconitic sands, and later deposits." These later deposits are mainly sands of lacustrine, fluviatile, and aeolian origin, laid down during alternating wet and dry periods of the Pleistocene and later periods. These formations are loosely compacted and represent the land surface of today.

Table 1 – District Climatological Data (1949)

	No of years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Robinvale														
Rainfall (in)	21	0.89	1.03	0.72	0.73	0.76	1.04	1.11	0.87	0.72	1.10	0.89	0.81	10.67
Euston														
Rainfall (in)	71	0.68	1.02	0.74	0.77	1.10	1.39	1.10	1.20	1.21	1.12	0.87	0.89	12.09
Mean Max	41	89.8	0.1	84.1	74.4	66.6	59.6	59.3	63.3	69.4	76.1	82.8	88.0	75.3
Temp Mean Min	41	60.0	60.5	55.8	48.2	42.9	38.8	37.3	39.2	44.1	49.1	54.4	58.4	49.1
^{o}F Average	41	74.9	75.3	70.0	61.3	54.7	49.2	48.3	51.3	56.7	62.6	68.6	73.2	62.2
Mildura														
Rainfall (in)	58	0.73	0.90	0.70	0.55	1.01	1.05	0.91	1.01	0.96	1.00	0.84	0.71	10.37
Average Temp ^{o}F	56	75.4	75.8	70.8	62.5	56.3	50.9	50.0	53.2	58.0	63.7	69.3	73.9	63.3
Meal rel humidity % at 9.00 am	38	50	55	60	67	75	82	83	73	63	57	50	48	64
Evaporation (in)		10.69	8.79	7.28	4.30	2.66	1.51	1.42	2.58	4.13	6.09	8.40	10.57	68.42
Rainfall														
Evaporation		0.07	0.10	0.10	0.13	0.38	0.70	0.64	0.39	0.23	0.46	0.10	0.07	0.15

The Robinvale area is bounded in the north, east, and west by a great bend of the Murray River. In places, as in the vicinity of the Euston Weir , the river is cutting directly into the Pleistocene and Recent deposits so forming an escarpment directly to the water. Elsewhere, according to the meanderings of the river, the high land falls away either abruptly or gradually to the flood plain of the river. This flood plain, which does not enter the surveyed area, lies approximately below the 175 ft. contour. The land above t his level rises to a maximum of 350 ft. above sea level at the summit of Blue Ridge, several miles to the south of Robinvale township, but most of the area is situated between the 195 ft. and 240 ft. contours. Blue Ridge is the dominant feature of the landscape and runs approximately north and south and lies slightly to the east of the north south axis of the area. It is one of a number of similar north-south ridges which, with broad troughs, from major features of the Mallee Murray Basin. Hills (loc cit) considers that these have been formed as the result of movements in the underlying bedrock.

An undulating topography is maintained throughout the area by sequences of smaller sand-ridges of from 10 ft. to 25 ft. elevation. The longitudinal axes of these run approximately east and west and parallel the prevailing strong winds. This type of sand-ridge formation is common to the Mallee area generally and obviously is the result of re-sorting of the alluvial deposits by wind action and of the deposition of wind borne materials from further afield.

Apart from a few short eroded on the steeper escarpments to the river flats, there are no watercourses within the area. These gullies are the result of severe but intermittent thunderstorms. Normally most of the rainfall is absorbed rapidly, and even in the corridors between the ridges water does not remain for long on the surface.

4. Vegetation.

Early clearing was somewhat haphazard and thickets of mallee scrub are scattered indiscriminately over the area. In addition, there are several extensive stands of virgin forest, untouched except for the removal of some Murray pine. [*]

The largest of the scrub occurrences are on extensive gentle slopes and flat situations where the soil types are principally Coomealla loam, Nookamka loam, and type A. Here the vegetation is mostly mallee (*Eucalyptus* spp.), blue bush (*Koshia* spp.), and salt bush (*Bassia* spp., *Atriples* spp.) with some acacia (*A*.spp.) and belar (*Casuarina lepidophloia*).

In the forest areas, the flora is more diverse, some of the common species in addition to the above being Murray pine, (*Callitris glauca*), sandwood (*Myoporum platycarpum*), cabbage bush, (*heterodendron oleifolim*), hakea, (*H. vitteta*) and grevillea, (*G*.spp.)[1]

Most of the species are ubiquitous and occur to some extend on all the soil types – even Murray pine is sometimes found on heavy soils such as Belar clay loam. However, abroad soil/flora relationship can be recognised and are as follow: Mallee is always dominant on the slopes; and there may be few other tree species where the soil types are Moorook sandy loam, Coomealla sandy loam or Coomealla loam, or where there is much lime in the soil; but there is frequently a proportion of velar where the soil types are Barmera sandy loam. Nookamka sandy loam, or Nookamka loam. The light soils of the ridges, viz., Murray sand, Berri sand, and Barmera sand, usually carry large mallee and Murray pine, sometimes with belar, but some situations have belar and Murray pine and less mallee. Hop bush (*Dodonaea attenuata*) grows rapidly on these soil types when they are cleared and left. Stands of large belar are characteristic of the inter-ridge corridors of Nookamka clay loam and Belar clay loam, and these situations frequently have little or no mallee. Acacia, hakea, and cabbage bush occur on all the soil types as does the principal ground flora of blue bush and salt bush. Some occurrences of Belar clay loam carry only ground species – mainly spear grass (*Stipa* spp.). This grass occurs on all the more open situations irrespective formerly cleared for cultivation.

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[*] Some of these situations have been cleared since the field soil survey was carried out.
[1] A more complete list of the trees, shrubs, and ground flora in this virgin area is given in Appendix 1

THE SOILS AND THEIR CLASSIFICATION.

1. General Characteristics of the Soils.

At the Great Soil Group level of classification, the spoils belong to the solonised brown soils (Prescott, 1944), earlier known as Mallee soils (Prescott. 1931). General features of this group are the brown colour and alkaline nature of the soil profile, the presence of calcium carbonate and soluble salts in the B and C horizons, and the presence of a significant proportion of sodium in the ions of the exchange complex. Also, there has been downward movement of clay to form alluvial horizons. This has been due to the process of solonisation whereby the mobility of the clay is increased under the influence of sodium ions. In Victoria, the soils are derived principally from aeolian calcareous materials (Crocker, 1946) and a large amount of soft and concretionary calcium carbonate is a notable feature of the subsoils. Here, also, these soils support a characteristic scrub flora, largely consisting of dwarf eucalypts.

The solonised brown soils have been classified into lower categories, namely soil series and types, at a number of locations in the Murray Valley region, and the soil types have been found to recur over a wide area. Subject to the variations that occur in the recorded morphologies of the soil types due to soil mapping by different workers and also to improvement in methods of soil classification over a period of years, the soils at Robinvale, with minor exceptions, fit into soil types recorded previously.

The lightest soil types are found on the crests of the east-west ridges, and here the textures are sand overlying sandy loam or sandy clay loam. Below the crests, the surface soils pass gradually from sandy loam texture on the upper slopes, through intermediate textures, to clay loam in the inter-ridge corridors, while the subsoils increase in texture correspondingly from sandy clay loam to medium clay. This pattern of textural graduations in the soils tends to repeat in the areas where there are sequences of parallel ridges. Coarseness is conferred on the soil textures generally by a high proportion – often exceeding 50% - of coarse sand in the sand fraction, together with a near absence of particles of silt size.

Whilst brown and re-brown are the dominant soil colours, some soils appear dull brown or even grey-brown by comparison. The more extensive areas of such soils are associated with flat situations carrying mallee, but small patches of dull soils are frequently intermingled with brown sandy loam soils on upper slopes.

The distribution of calcium carbonate is variable, but it reaches highest concentrations in the dull coloured soils and lowest in the light profile sandy soils on the ridge tips, while the bright coloured heavy soils in the depressions also contain relatively little. Much of the calcium carbonate is present as rubble in all but the lightest and the heaviest soils. The depth at which lime appears in quantity is usually related to the texture of the soil profile; the lighter the profile. The greater is the depth to the lime. The principal lime horizons appear at depths of from about 16 in to 48 in. from the surface; however, there are some soils with rubble limestone at, or just beneath the surface. Massive limestone is restricted to a few acres.

2. Key to the Soil Types.

Fairly small textural changes are considered important in the agricultural use of the irrigated, solonised brown soils; consequently, in each of the areas that has been soil surveyed, the soil types have been based on a system of classification which allows but little tolerance in the textural characteristics of the soil profile. This has made for a large number of soil types in most of the individual settlements. However, the descriptions of some soil types that recur in a number of districts show considerable divergence from their originally described profiles. Because of these variations, and because of the textural gradations between soil types, it was considered necessary to formulate a scheme which could be used in the field for distinguishing the soil types. Consequently, limits for the texture at various depths in the uppermost 72 in. of the soil profile have been fixed for most of the soil types. The criteria were arrived at from consideration of previous published work and from a preliminary survey at Robinvale, and are presented below in a form which may be used as an aid to the identification of the soil types.

A. Brown and red-brown soils.

<u>Surface</u> – texture is :-

1. Sand.

<u>Subsoil</u> – heaviest texture is :-

(a) Sandy loam.

(i) Sand or sandy loam to 62 in.; slight lime,[x] no rubble[X] — *Murray Sand.*

(b) Sandy clay loam.

(i) Occurs not before 42 on.; slight lime and rubble — Berri Sand.

(ii) Occurs before 42 in.; light lime, slight rubble.
(Sandy clay may occur below 60 in.) — *Barmera Sand.*

(c) Sandy clay.

(i) Occurs before 60 in; light or medium lime and rubble. — *"Shallow Phase" Barmera Sand.*

(ii) May occur before 60 in but not before 35 in.;
<u>Very little lime</u>. — *Type C.*

2. Sandy loam.

<u>Subsoil</u> – heaviest texture is :-

(a) Sandy clay loam.

(i) Occurs before 36 in. but light or medium lime and rubble.
(Sandy clay may occur below 60 in.) — *Barmera Sandy Loam.*

(b) Sandy clay.

(i) Occurs before 60 in but not before 36 in.; medium lime and rubble. — *"Shallow Phase" Barmera Sandy Loam*

(ii) Occurs before 36 in., light or medium line and rubble. — *Nookamka Sandy Loam*

(iii) Occurs before 36 in.; <u>very little lime</u> — *Type B.*

(c) Light clay.

(i) Occurs before 36 in. but not before 24 in.;
light or medium lime and rubble — *Nookamka Sandy Loam*

(ii) Occurs before 24 in.; light or medium lime and rubble. — *Nookamka Loam.*

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[x] Lime refers to calcium carbonate in the soft form; rubble describes concretionary calcium carbonate in the form of hard pebbles and stones.

2. Loam.

Subsoil – heaviest texture is:-

(a) Light clay.

(i) Sandy clay or light clay occurs before 36 in.; light or medium lime and rubble. — *Nookamka Loam.*

(ii) Occurs before 18 in.; light lime slight to light rubble. — *Nookamka Clay Loam.*

B. Dull brown and grey-brown soils.

Surface – texture is :--

1. Sand.

Subsoil – heaviest texture is :-

(a) Sandy clay loam (light)

(i) Occurs not before 24 in.; lime and rubble variable, frequently heavy. — *Moorook Sand*

2. Sandy loam.

Subsoil – heaviest texture is :-

(a) Sandy clay loam.

(i) Occurs not before 24 in.; medium or heavy lime and rubble. — *Moorook Sandy Loam.*

(ii) Occurs before 24 in.; lime and rubble variable, usually medium. — *"Light Deep Subsoil Phase" Coomealla Sandy Loam.*

(b) Sandy clay

(i) May occur before 30 in.; but not below 48 in.

"Light Deep Subsoil Phase" Ccoomealla Sandy Loam.

(ii) May occur before 30 in.; lime and rubble variable, usually medium (Light clay may occur below 48 in.) — *Coomealla Sandy Loam.*

3. Loam.

Subsoil – heavies texture is :-

(a) Light clay

(i) Sandy clay or light clay occurs before 30 in.; medium lime and rubble. — *Coomealla Loam.*

3. Clay loam.

Subsoil – heaviest texture is :-

(a) Heavy clay

(i) Occurs below 36 in.; lime and rubble variable often medium or heavy *Type A*

3. Description of the soil Types.

Of the fifteen soil types recorded at Robinvale, twelve have been named and reported previously in the various references listed under each soil type. The profiles described represent averages for the soil types as found at Robinvale, but notes on occurrences in other localities are included in the text. Phases and variations from the normal profile are indicated also.

Three soil types have not been investigated sufficiently to warrant naming them, although they do not appear to have been descried before. Only one – Type A – has a wide distribution in the area.

Throughout the profile description that follow, the soil colours are supplemented by Munsell notations (1948) The Munsell system of colour notation has been adapted to the soil colour nomenclature in use by the United States Department of Agriculture; however, their soil colour names do not conform entirely to those in common use in Australia and elsewhere. The Munsell notation affords a useful means of standardising colour descriptions.

The notations and colour names used below refer to the soil in the dry state and to the intrinsic colour in the absence of lime. Many of the subsoils contain large amounts of cream coloured. (7.5YR 8/6) lime which modifies the basic soil colours to give overall effects of weaker hues and lighter shades.

Murray sand. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos. 42, 45, 56, 73, 107, 123, 133 and Soil and Land Use Series No. 1).

Situation: On crests of sand – ridges.

Profile.

0 in.	Red-brown (3.5YR 4/6) to brown (5YR 4/6) sand.
18 in.	Light red-brown (3.5YR 5/6) to light brown sand.
48 in.	Light red-brown (3.5YR 5/6) or light brown sand or sandy loam; slight lime, sometimes forming weakly cemented sandy aggregates.
72 in.	

Soils of light profile were described prior to 1933 at Renmark, Woorinen and Goodnight, but were not named at the time, although later included in the Murray sand soil type. Since then Murray sand has been recorded in nearly every horticultural settlement along the Murray River downstream from Swan Hill. A feature common the all these occurrences is the absence of textures heavier than sandy loam to a depth of 72 in.; but the soils vary in colour from brown to re-brown, while soft lime is variable in amount, ranging from slight to medium concentrations. In the more recent surveys, some coherence of the sandy surface has been recognised as a property of the Murray series. Recently, Northcote and Boehm (1949) at Coomealla, giving more consideration to the compactness or otherwise of the surface soils and to differences of colour within the brown red-brown rang, have subdivided soils of the Murray sand type into the Murray and a Tiltao soil series, each with two types. The broader conception of the Murray series is retained at Robinvale.

Berri sand. (Coun. Sci. Ind. Res. (Aust.); Bull.Nos.86, 133, 137 and 141).

Situation: On crests of sand-ridges and on upper slopes below Murray sand.

Profile:

0 in.	Red-brown (3.5YR 4/6) to brown (5YR 4/6) sand.
18 in.	Light red-brown (3.5YR 5/6) to light brown sand.
30 in.	Light brown (5YR 6/6) sand or sandy loam.
42 in.	Light brown (5YR 6/6) sandy clay loam; slight to light lime, sometimes weakly cemented, rarely rubble.
72 in.	

Originally described in the Berry area. Berri sand occurs there adjoining Winkie sand and in depressions between sandy rises, and is described as having some of the characteristics of Winkie sand. However, Winkie sand has not been recorded at Robinvale and Berri sand is considered rather to be allied to Murray sand, but with a textural profile a stage heavier. It is found only on the higher levels of the sand-ridges and not in depressions between sandy rises as at Berri. At Redcliffs, the type occurs associated with both the Murray and the Winkie sands.

The heaviest texture in the profile is a light sandy clay loam which normally occurs at 42 in. or deeper, but a variety – inscribed "var" on the soil map – has been recorded in which the sandy clay loam occurs as a band at about 36 in. and revers to a sandy loam below 48 in.

Although limestone rubble has been observed in a few situations, these are regarded as abnormal; usually up to light concentrations of soft lime or lime cemented sandy pan are present.

Bamera sand. (Coun. Sci. Ind. Res. (Aust.); Bull.Nos107, 123, 133, 137 and 141).

Situation: On crests of sand-ridges and on upper slopes below Berri sand or Murray sand.

Profile.

0 in.	Red-brown (3.5YR 4/6) to brown (5YR 4/4) sand.
18 in.	Light red-brown (3.5YR 5.6) to light brown (5YR 6/6) sand or sandy loam; slight lime.
30 in.	Light brown (5YR 6/6) sandy clay loam; light lime, slight rubble.
60 in.	Light brown (5YR 6/6) sandy clay loam, occasionally sandy clay; light lime slight rubble.
72 in.	

Barmera sand was first recorded at Coomealla and later at Merbein, Mildura, and Redcliffs. The normal profile has the same textural range at all areas, including Robinvale, but the distribution of lime is variable. Light to medium concentrations are found in the normal profile as early as 16 in. at Coomealla, Mildura, and Merbein, but the depth to the principal lime horizons is usually greater at Robinvale, ranging from 21 in. to 42 in., with 30 in. the most common depth. A similar median depth is recorded at Redcliffs. Appreciable rubble in the normal profile is allowed only at Merbein, but stony phases have been defined at Mildura and Redcliffs. Lime is frequently present as sandy pan or as a soft form of rubble in this type at Robinvale, but only where much hard rubble is present between 18 in. and 48 in. has the occurrence been inscribed " rubbly."

In the shallow phase of Barmera sand, sandy clay occurs at about 40 in. instead of below the normal depth of 60 in. while rather more lime, including rubble, may be present in the profile. Some soils show a temporary increase in texture to sandy clay between 36 in. and 48 in.; these soils are considered a variety of the normal type and are indicated by the inscription "var" on the soil map

Barmera sandy loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos. 86, 107, 123, 133, and 137).

Situation: On gentle slopes below Barmera sand, sometimes on extensive low rises.

Profile:

0 in.	Red-brown (3.5YR 4/6) to brown (5YR 4/4) sandy loam.
15 in.	Light brown (5RY 6/6) sandy loam; slight lime.
24 in.	Light brown (5YR 6/6) sandy clay loam; light or medium lime and rubble.

60 in.	Light brown (5YR 6/6) sandy clay loam or sandy clay; light or medium lime and rubble.
72 in.	

First mapped in the Berri area, Barmera sandy loam was later found associated with Barmera sand in the Coomealla and Mildura districts. Robinvale occurrences conform to descriptions of the type in these areas.

The principal lime Horizon occurs in a sandy clay loam texture in considerable amount is accepted in the normal profile. A variety similar to that described for Barmera sand has been recorded as well as a shallow phase. The latter forms a linkage with Nookamka sandy loam in that sandy clay occurs at about 40 in., but passing downslope this comes closer to the surface until the soil profile ultimately possesses the characteristics of Nookamka sandy loam.

As the result of recent surveys in the Coomealla district, Northocote and Boehm (1oc.cit.) consider that too much latitude has been allowed in the morphology of the Barmera series mapped earlier at Coomealla. They do not record the Barmera series as such, but describe a Matong and a Dareton soil series, each with a sand and sandy loam member, and also an unnamed soil type, all of which would be embraced by the earlier Barmera series.

Nookamka sandy loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos 86, 107, 123, 133, 137 and 141).

Situation:	On intermediate and lower slopes and in the less pronounced depressions between sand-ridges.

Profile.

0 in.	Red brown (3.5-5YR 4/6) sandy loam.
15 in.	Red-brown (5YR 4/6) to light-brown (5YR 6/6) sandy clay loam; light lime.
27 in.	Light brown (5YR 6/6) sandy clay to light clay; light or medium lime, light rubble.
72 in.	

Nookamka sandy loam has been found in widely separated areas. As first described in the Berri area, textures in the soil profile were placed in the sandy classes, the heaviest being sandy clay, while only small amounts of lime were present. Subsequently in other districts, clay loam and light clay textures, with greater amounts of lime were recorded in the subsoils. Actually, textures in the subsoil frequently are indefinite, and may equally well be described with or without the sandy qualification. This is in accordance with the occurrence of the Nookamka series. The sandiness strongly evident in the Barmera sandy loam profile decreases down the slope, consequently it will become less apparent passing from situations of Nookamka sandy loam in proximity to Barmera sandy loam to the more remote situations of Nookamka loam.

At Robinvale, the surface soil varies from 12 in. to 21 in. in depth, while the heaviest texture and principal lime horizon occur at from 24 in. to 33 in. from the surface. As has been observed at Redcliffs, textures sometimes revert to sandy clay loam below 60 in.

Northcote and Boehm's (1oc.cit.) survey at Coomealla reveals that soils mapped there earlier as Nookamka sandy loam and Nookamka loam differ from other Nookamka occurrences in South Australia. They place the Coomealla Nookamka sandy loam partly in Matong sandy loam and partly in Boeil loam. It is unlikely that the Robinvale Nookamka sandy loam is similar to Boeil loam; however, there is some evidence that certain of the heavier soils placed in the Nookamka loam and clay loam soil types have a restricted bleached subsurface characteristic of Boeil loam.

Nookamka loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos. 107, 123, 133 and 137).

Situation:	on lower gentle slopes and in depressions between sand-ridges.

Profile.

0 in.	Red-brown (3.5-5YR 4/6); loam, occasionally sandy loam.
9 in.	Red-brown (5YR 4/6) to brown (5YR 5/6) sandy clay loam; light lime.
20 in.	Light brown (5YR 6/6) light clay to sandy clay; light or medium lime and rubble.
72 in.	

The principal difference from Nookamka loam profiles described elsewhere is in the subsoil below 48 in. This may be as heavy as medium clay in other areas, but at Robinvale it is never heavier than light clay and may even revert to sandy clay loam by 72 in.

The surface soil, although described as a loam, is sandy. It varies from 6 in to 16 in .in depth, passing to a definite sandy clay loam. The lime-rich clay horizon occurs between the limits of 15 in. and 30 in. from the surface.

Nookamka clay loam. (Coun. Sci. Ind. Res. (Aust.); Bull No. 123).

Situation: in depression between sand-ridges and on lower gentle slopes.

Profile.

0 in.	Red- brown (2.5YR 3/6) sandy clay loam or clay loam, occasionally loam.
8 in.	Red-brown (2.5YR 3/6) clay loam, or light clay.
16 in.	Red-brown (2.5YR 4/6) light clay; light lime, slight or light rubble.
72in.	

Nookamka clay loam has been recorded previously only at Merbein, although some situations of Nookamka loam at Redcliffs have a clay loam surface. At Nookamka loam at Redcliffs, the red-brown clay loam soils of the depressions are placed in the Belar clay loam. Actually the morphologies of these two series are very similar and possibly the soils have not been differentiated except at Robinvale. There Nookamka clay loam is recognised to have a slightly lighter profile with more lime than Belar clay loam, although the lime is less than in Nookamka loam.

Belar clay loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos 133 and 137).

Situation: At the lowest elevations in broad hollows between sand-ridges.

Profile.

0 in.	Red-brown (2.5YR 3/6) clay loam.
8 in.	Red-brown (2.5YR 3/8) medium clay; light lime, slight or light rubble.
48 in.	Red-brown (2.5YR 4/6) medium clay; light lime, slight or light rubble.
72 in.	

A strong re-brown colour in the upper profile and small amount of lime, particularly rubble, above 48 in. are characteristic of most occurrences. Gypsum has been recorded in the Belar clay loam at Mildura and Robinvale. A few situations showing gilgai formation are duller brown in colour but have been included in the type.

Moorook sand. (Coun. Sci. Ind. Res. (Aust.); Bull. No. 141 and Soils and Land Use Series No.1).

Situation: On crests of sand-ridges.

Profile.

0 in.	Greyish brown (7.5YR 5/4) or grey-brown sand.
12 in.	Light greyish brown sand; variable lime and rubble, often medium to heavy.
24 in.	Light brown sandy loam or light sandy clay loam; medium to heavy lime and rubble.
72 in.	

This is a very minor soil type at Robinvale and its extent is restricted to a few acres.

Moorook sandy loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos. 86, 107, 133, 137, 141, and Soils and Land Use Series No1).

Situation: On low rises and on upper moderate slopes.

Profile.

0 in.	Greyish brown (7.5YR 5/4) or grey-brown sandy loam; slight lime.
12 in.	Light greyish brown (7.5YR 6/4) sandy loam; medium or heavy lime and rubble.
24 in.	Light brown (5YR 6/6) sandy clay loam; medium to heavy lime and rubble.
72 in.	

This soil type, although lighter, closely resembles the light deep subsoil phase of Coomealla sandy loam.

In all the areas in which Moorook sandy loam has been found, the descriptions agree in the high lime content of the soil profile, and the Robinvale occurrence, although small, conforms to this. Much large rubble limestone is frequently present close to the surface.

Coomealla sandy loam. (Coun. Sci. Ind. Res. (Aust.); Bull. Nos. 107, 123, 137, and Soils and Land Use Series No.1)

Situation: On intermediate slopes.

Profile.

0 in.	Dull brown to greyish brown (7.5YR 5/4) sandy loam.
15 in.	Light brown (6.5-7.5YR 6/4) sandy clay loam; variable lime and rubble.
24 in.	Light brown (5YR 6/6) sandy clay loam or sandy clay medium lime and rubble.
48 in.	Brown (5YR 5/6) sandy clay or light clay; slight lime and rubble. (Sandy clay loam in the "light deep subsoil phase.")
72 in.	

A light deep subsoil phase similar to that recorded at Redcliffs and Coomealla is common. Its presence is indicated on the soil map by inscription, sometimes abbreviated "l.d.s." The texture is sandy clay or sandy clay loam a in the normal profile. The lighter profiles have sandy clay loam from 15 in. and are texturally similar to Barmera sandy loam with which type they frequently occur as dull brown areas showing surface rubble.

Generally in the Mallee soils, dull surface colours are associated with the highest lime contents. Both these factors are very variable and this has introduced some confusion in the description and in the mapping of such soils. Originally described as brown, the surface colour of the Coomealla series was later recorded as dull brown and later still extended to include grey-brown. The soils rarely reach a full grey-brown, although this term indicates well the relative dullness of the soils compared with the bright colours of some of the associated soils; probably dull brown is the best description of their colour as an average.

In regard to lime in the profile, an attempt has been made at Coomealla and Redcliffs to separate dull coloured soils containing much rubble – Loveday sandy loam – from those that contain not so much – Coomealla sandy loam. These two soil types are otherwise very similar. The distinction was not maintained at Merbein where soils with considerable rubble in the profile are included in the Coomealla series. At Robinvale, none of the soils appears to contain sufficient rubble to warrant mapping as the Loveday sandy loam. However, a few areas containing fairly large amounts of rubble have been allowed in the Coomealla sandy loam; as elsewhere in this soil type, soft lime may be appreciable.

Coomealla loam. Coun. Sci. Ind. Res. (Aust.); Bull.Nos.107, 123, 133, and Soil and Land Use Series No.1.).

Situation: On lower gentle slopes and on relatively flat area.

Profile.

0 in.	Dull brown to greyish brown (7.5YR 5/4) loam; slight lime and fine rubble.
9 in.	Light greyish brown (6.5YR 6/4) sandy clay loam or clay loam; light lime, light or medium rubble.

18 in.	Brown (5YR 5/6) to light brown (5YR 6/6) sandy clay or light clay; light or medium lime and rubble.
48 in.	Brown (5YR 5/6) or red-brown (2.5YR 4/6) light or medium clay; variable lime and rubble but decreasing with depth.
72 in.	

The variability in regard to colour and lime in the Coomealla series referred to under Coomealla sandy loam applies also to Coomealla loam. But where rubble reaches heavy concentrations in the profile, the case has been met by inscription on the soil map.

In the dry state the surface soil is characteristically powdery and appears to be of sandy loam texture, but it reaches a full loam when wetted. The texture builds up gradually with depth, reaching a clay – more or less sandy- within the limits of 15 in. to 27 in. from the surface. Heavier texture usually occur below 48 in., but the deep subsoil is rather variable and in some situations it may be sandy clay. This trend towards a lightening in texture in the deep subsoil is apparent in a number of soil types at Robinvale; it has been referred to previously in the Coomealla sandy loam and in the Nookamka series.

Type A.

Situation: On very gentle lower slopes and on flat situations in broad hollows.

Profile.

0 in.	Greyish brown (7.5YR 5/4) or grey-brown clay loam; slight lime and fine rubble.
8 in.	Greyish brown (7.5YR 5/4) clay loam; variable lime and rubble.
15 in.	Greyish brown (7.5YR 5/5) light clay; light or medium lime and rubble.
36 in.	Greyish brown (7.5YR 5/5) with slight grey, medium clay slight or lime.
48 in.	Greyish brown (7.5YR 5/5) with grey (5Y 8/4) mottling heavy clay.
72 in.	

In its relationship to other soil types of the area, Type A is best regarded as a heavy version of the greyish brown occurrences of Coomealla loam. It often occurs adjoining this type, but below it in the topography. The surface has the same powdery nature, but is a degree heavier and is more nearly grey-brown. The texture increases with depth in the profile, reaching a medium clay usually before 36 in., or by 48 in. at the latest. This brown clay is similar to that found at greater depth in many Coomealla loam profiles. In that type, it may sometimes show evidence of a slight grey flecking; in Type A, the flecking is always present, and may increase to a definite mottling in the deeper subsoil.

Lime is always present in considerable amount in the upper profile, but decreases rapidly below 36 in. Rubble is variable; a few profiles show small amounts only while some situations with heavy rubble close to the surface are indicated suitably on the soil map.

Type B.

Situation: On very gentle slopes fringing depressions of heavy re-brown soils.

Profile.

0 in.	Red-brown sandy loam.
18 in.	Red-brown or light red-brown sandy clay loam, cemented when dry.
30 in.	Red-brown sandy clay; hard pan of iron cemented sandy material may be present.
48 in.	

This soil type is of vary small extent. It occurs above depressions of Belar clay loam on gentle slopes normally occupied by the Nookemka series. Lime is inconspicuous in the profile, consequently bright colours are prominent. Textures are pronouncedly gritty and the horizons tend to be cemented. Iron cemented sandstone may be present in the profile as well as in the surface of these soils.

Type C.

Situation: In depressions between sand-ridges and on their lower slopes.

Profile:

0 in.	Red-brown sand.
20 in.	Light red-brown sandy loam; cemented when dry.
30 in.	Red-brown sandy clay loam, sometimes passing to sandy clay; cemented when dry; little or no lime.
60 in.	

Type C is lighter than Type B, but is similar in the bright red-brown colour, gritty texture, and low lime content if its profile. Its extent is small.

4. *Extent of the Soil Types.*

The areas of the soil types are shown in Table 2. Acreages are given for the settlement unit as well as for the whole area surveyed.

Table 2 - Areas of the Soil Types.

Soil Type	Acreage	
	Settlement	Total
Murray sand	67	108
Berri sand	103	164
Barmera sand	384	629
Barmera shallow phase	92	109
Barmera sandy loam	1,015	2,526
Barmera shallow phase	83	509
Nookamka sandy loam	913	1,740
Nookamka loam	1,061	2,697
Nookamka clay loam	503	1,360
Belar clay loam	331	671
Moorook sandy loam	72	193
Coomealla sandy loam	78	333
Coomealla loam	620	2,451
Type A	80	544
Type B	14	42
Type C	71	71
Total	**5,487**	**14,465**

Most of the soils fall into the Barmera, Nookamka, and Coomealla series, their total acreage being 12,454 or 86% of the whole area. Barmera sandy loam is the most extensive soil type, but is closely followed by Nookamka loam and Coomealla loam, while the area of Nookamka sandy loam is also appreciable. There are 2,575 acres of the heavy soil types (Nookamka clay loam, Belar clay loam, and Type A) not recommended for horticulture.

In the settlement area, inclusive of roads, yards, structures. etc., soil types recommended as suitable for vines, but not citrus, total 4,049 acres – actually in some situations of Coomealla loam. The Murray, Berri, and Barmera sands which provide the citrus planting total only 554 acres and not the whole of this recommended as suitable for citrus.

PHYSICAL AND CHEMICAL PROPERTIES OF THE SOILS.

Physical and chemical examinations have been carried out on eighteen soil profiles representing all the major soil types. Eight of the profiles were taken in virgin scrub-forest, and ten were sampled in cleared grassland areas which either had never been cultivated or had been worked only to a small extent many years ago.

The analytical methods used are indicated below under the appropriate subsections; in general, these follow the procedures described by Piper (1942).

All estimations were carried out on the air-dried fine earth, i.e., material passing through a 2 mm. round hole sieve. For calcium carbonate, nitrogen, and organic carbon estimations, samples were weighed from sub-samples which had been ground until all material passed through an eighty-mesh sieve.

1. Mechanical Analysis.

The method used was that described by Piper; it closely follows the "A" method adopted by the International Society of Soil Science. In this method, the soils are pretreated with hydrogen peroxide and hydrochloric acid, dispersed with caustic soda, and the fractions determined by a pipette and sieving technique.

The individual analyses of 120 soils are set out in Appendix 2, while the mechanical composition of the profiles to a depth of 70 in. of a representative range of the soil types is depicted in Fig. 2 by conventional diagrams. These illustrate the general textural gradient of the soil profile passing from the lightest to the heaviest soil type.

Sand is the dominant fraction – very much so in the majority of the soils – in all profiles except those of Coomealla loam, Nookamka clay loam, Belar clay loam, and Type; in these, clay exceeds sand in some horizons of the subsoil and deep subsoil. Coarse sand is greater in amount than fine sand in the lightest profiles, viz., Murray sand, Berri sand, and Moorook sandy loam; in the remaining profiles, fine sand is usually slightly greater, but the relationship is not consistent.

Silt is of the very low order commonly found in Mallee soils. Values of less than 5% are most frequent and only in the Belar clay loam profile is more than 10% present.

Clay seldom exceeds 20% (the maximum value recorded is 25.7%) in the profiles of the sand and sandy loam surface soil types. Contents are slightly higher in the Nookamka and Coomealla loam profiles, but most horizons above 4 ft. have less than 26% of clay; below this depth, the recordings range from 19.1% to 44.4%. The clay content of the Type A profile differs from that of these types mainly in the higher amount at 3 ft. (42.0%). In the Nookamka clay loam profiles, surface contents of less than 20% clay increase to about 36% before 12 in., while in the Belar clay loam the increase is approximately from 30% to 40%.

Large quantities of calcium carbonate are recorded in the subsoils, but the amount are very variable; however, the following general trends can be observed between the soil types :- The principal lime horizons occur below 48 in. in the Murray and Berri sands and the amount are relatively low (5-12%) in these soil types. With few exceptions, the zone of maximum concentration is reached before 48 in. in the remaining soil types. Based on the amounts present in this zone of the recorded profiles (Appendix 2), Moorook sandy loam, Coomealla sandy loam, Coomealla loam, and Type A are the most calcareous oil types (25 – 33%), followed by the Barmera and Nookamka series (9-28%) and then the Belar clay loam (5.3%).

Hard rubble limestone is high – up to 47.4% - only in certain horizons of the Coomealla loam profiles. Moorook sandy loam, Coomealla sandy loam, and Type A also may contain appreciable amounts of rubble, although the analysed profiles of these soil types contain but little (0 – 3.1%). Rubble is absent from, or slight in the profiles of the Murray, Berri, and Barmera series, while there is up to 19% in the horizons of maximum concentration in the Nookamka and Belar profiles. Whilst hard rubble is sometimes present in the light soil types, e.g., the Berri and Barmera sands, the nodular calcium carbonate sometimes found in these types is usually relatively soft. This material is considered not to be rubble and the calcium carbonate in it has been included with the soft lime content of the soil.

The composition of the mineral fraction of the soils is further illustrated by the scatter diagrams of Fig. 3. In addition, the textural classes suggested by Marshall (1947) are superimposed in order to show the relationship between the mechanical composition and the field texture of the soils.

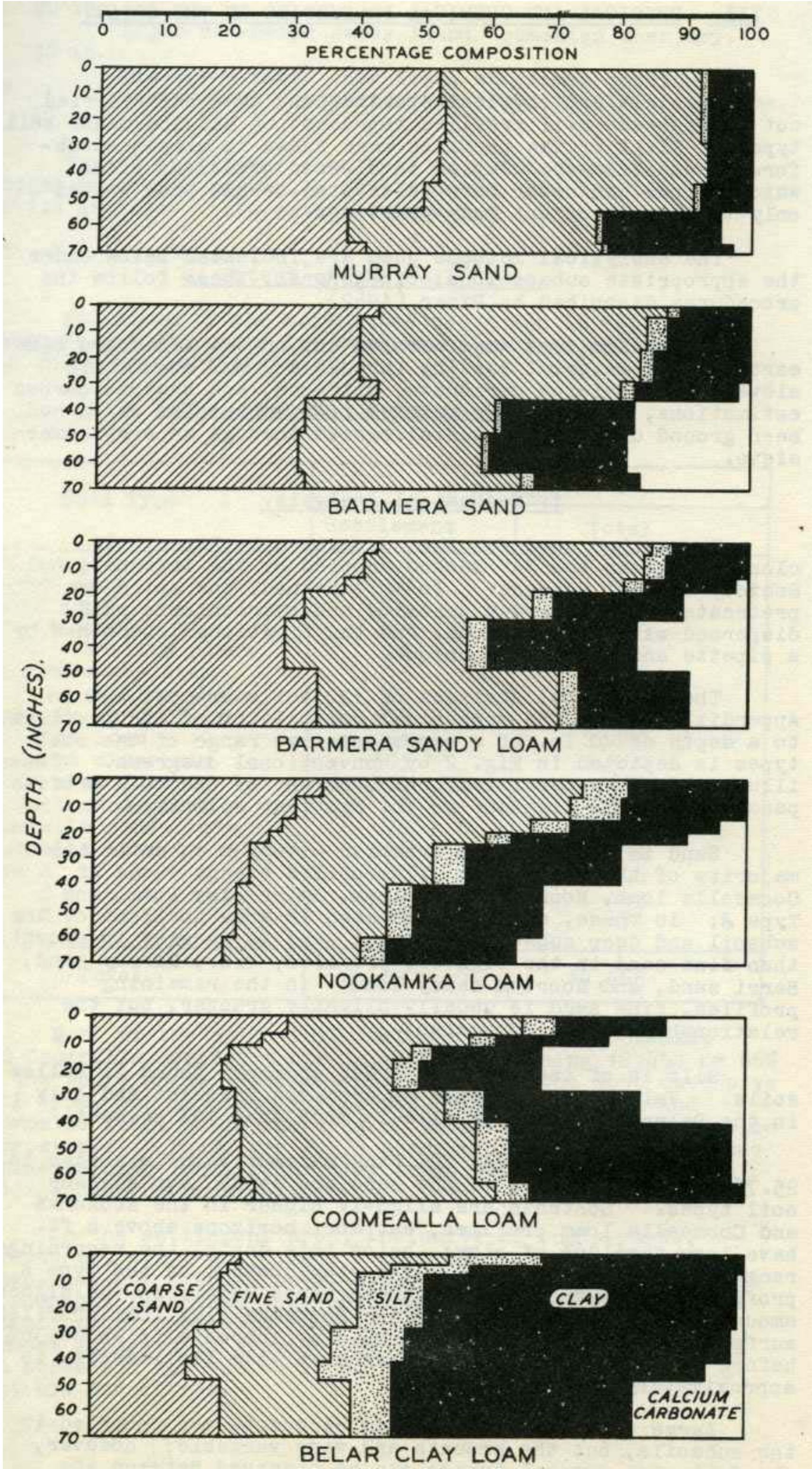

Figure 2 – Mechanical Composition of Profiles of Major Soil Types

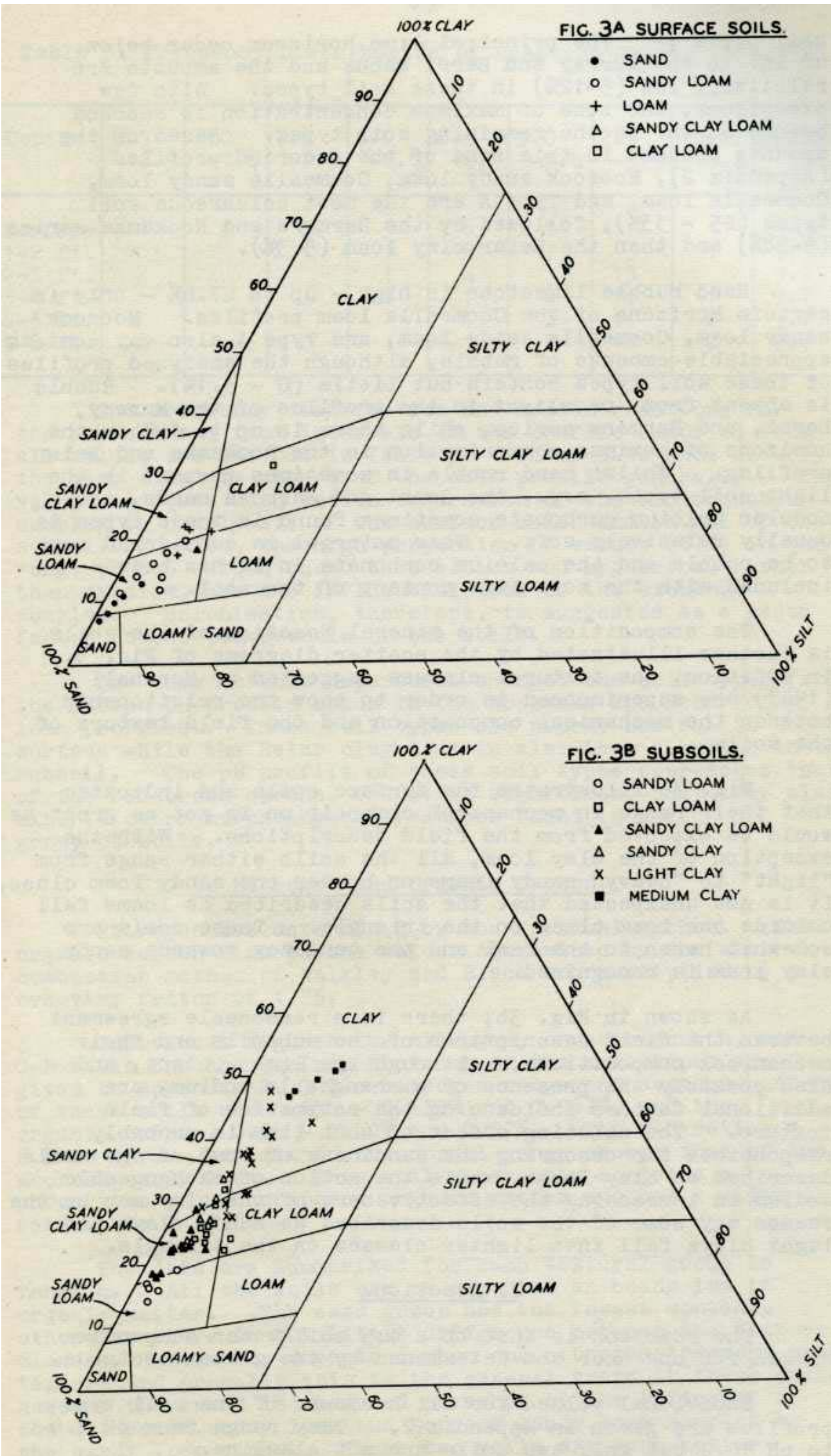

Figure 3 – Mineral Composition of Soils and Relationship with Field Texture

Fig. 3a illustrates the surface soils and indicates that their range in mechanical composition is not as great as would be expected from the filed descriptions. With the exception of the clay loam, all the soils either range form "light " to "heavy" sandy loams or border the sandy loam class. It is not unexpected that the soils described as loams fall outside the loam class on the triangle. These soils are somewhat harsh to the fell and the tendency towards sandy clay loam is recognised.

As shown in Fig.3b, there is a reasonable agreement between the field descriptions of the subsoils and their mechanical compositions; although the lime content, and also possibly the presence of exchangeable sodium, are additional factors influencing the estimation of field texture. The diluting effect of soft lime is probably responsible for obscuring the sandiness of some of the soils described as clay loams, while the action of exchangeable sodium in increasing the effectiveness of the clay may be the reason why some of the soils described as sandy clays and light clays fall into lighter classes on the triangle.

Reaction.

The reaction is that of a 1:5 soil-water suspension shaken for one hour and determined by the glass electrode.

Individual values for all horizons of the soil type profiles are given in Appendix 2. They range pH 6.4 to pH 10.2 but only two soils are not alkaline.

Table 3. - Frequency Distribution of Reaction Values of Soils.

Depth	6.5 - 6.9	7.0 -7.4	7.5 – 7.9	8.0 – 8.4	8.5 – 8.9	9.0 – 9.4	9.5 – 9.9	10.0 – 10.4	Median pH
Surface	1	1	4	5	6	1			8.3
1-2 ft.			1	1	5	7	3	1	9.1
2-3 ft.				1	4		13		9.7
3-4 ft.				1	1	4	11	1	9.7
4-5 ft.					1	3	11	2	9.7
5-6 ft.					1	3	10	2	9.7

The frequency distribution and median reactions for the surface and foot intervals of the profile compiled from all values are set out in Table 3. These data show clearly the very alkaline nature of the soil profile generally. The values indicate high cation saturation of the exchangeable complex in nearly all of the surface soils and in all of the subsoils. Also, the high proportion of values (87%) in the range pH 8.5 – 10.4 shows that sodium and magnesium, rather than calcium, are the influential ions of the exchange complex. Solemnisation, therefore, is suggested as a major a factor in the pedogenesis of the soils.

The only notable departures amongst the soil types from the median pH profile occur in the Nookamka and Belar clay loam profiles. These soil types are nearly neutral in the surface while the Belar clay loam is also less alkaline in the subsoils. The pH profile of these soil types approaches that of the red-brown earths, and it is significant that they also exhibit other morphological features found in that group of soils.

3. *Nitrogen and Organic Carbon.*

Nitrogen was determined by the Kjeldalhl method. The organic carbon figures are values determined by the wet combustion method of Walkley and Black and multiplied by a recovery factor of 1.25.

Individual figures for nitrogen, organic carbon, and C-N ratio for the surface horizons of the soil types are given in Appendix 2. The nitrogen range and average content of these soils are 0.034 – 0.130% and 0.067%, and the organic carbon, 0.34 – 2.42% and 0.77%. The C-N ratios – 8.8 to 13.4 – are within the normal range except that of the Moorook sandy loam. This soil apparently contains a proportion of undecomposed organic matter and has a wider ratio, viz., 18.8.

The data are summarised for each textural group in Table 4. All the soils can be regarded as being low in organic matter. The sand group has the lowest content, otherwise there is but little difference between the textural classes. Normally organic carbon and nitrogen increase with texture and probably this is the general trend in these soils; however the trend is obscured somewhat by the influence of the Coomealla sandy loam and Moorook sandy loam samples on the sandy loam class. These two soils are much better supplied with organic matter than the other sandy loam types; but there are not sufficient analyses to assess the relative status of the soil types other than in a broad way.

Table 4. - Average Nitrogen and Organic Carbon in Surface Soils.

(Air-dry basis)

Textural Class	No of Soils	N%	C%	C/N
Sand	4	0.043	0.46	10.7
Sandy loam	6	0.080	1.02	12.8
Loam	4	0.065	0.72	11.1
Clay loam	3	0.074	0.77	10.4
All soils	17	0.067	0.77	11.6

4. *Phosphoric Acid.*

The phosphoric acid in the hydrochloric acid extract of six surface soils, representing a range of soil types, is given in Table 5.

Table 5. - Phosphoric Acid in Hydrochloric Acid extract.

(Percentages of air-dried soil).

Soil Type	Soil No.	Depth (in.)	P_2O_5
Murray sand	10191	0-12	0.022
Barmera sandy loam	2021	0-3	0.037
Nookamka sandy loam	6477	0-8	0.037
Nookamka loam	10205	0-6	0.048
Coomealla loam	2034	0-5	0.054
Belar clay loam	2047	0-3	0.058

The phosphoric acid contents are low, but are of the order usually found in Mallee soils. The values follow texture directly which suggests a relationship with clay content.

5. *Exchangeable Cations.*

Significant horizons form three of the soil type profiles have been analysed for exchangeable metal ions as shown in Table 6. The method used was that of Piper for coils containing soluble salts and appreciable calcium carbonate. After leaching with 40% alcohol to remove soluble salts, the soils were extracted with normal ammonium chloride which was analysed for exchangeable sodium and potassium, and for calcium and magnesium in the case of soils 2013 and 6477. The remaining soils contained calcium carbonate and were leached with normal sodium chloride followed by second and similar leaching. Calcium and magnesium were both determined in each sodium chloride leachate, the differences giving the exchangeable forms of these cations.

The exchangeable data of the three soil types shown in Table 6 may be regarded as typical of Mallee soils generally and the solonised character of this soil group is well illustrated. Exchangeable sodium is very low in the surface soils in which calcium is the dominant cation and represents about 70% of the total exchangeable metal ions. With increase in depth calcium, at first, is partially replaced by magnesium, and this becomes the dominant ion in the upper zone of clay accumulation. However, at the some time sodium also begins to enter the exchange complex to a greater extent, and with increasing depth comprises ¼ or even over 1/3 of the total exchangeable metal ions. Sodium clay of this character occurs before 3 ft. In the Nookamka sandy loam and Coomealla loam profiles, but is relatively low, although much calcium carbonate is present.

Table 6. - Exchangeable Metal Ions.

Soil Type	Soil No.	Depth (in.)	pH	Clay %	Total Ex. Mr. ions [x]	% of total metal ions as			
						Ca	Mg	K	Na
Barmera sand	2013	0-4	7.7	10.9	7.3	70	19	10	1
	2017	36-48	9.0	19.9	10.2	37	50	7	6
	2019	68-90	9.8	15.5	7.2	22	39	13	26
Coomealla loam	6447	2-7	8.7	15.9	14.3	69	28	2	1
	6449	11-17	9.5	16.5	13.3	33	54	3	10
	6451	27-40	9.9	22.2	15.5	16	45	7	32
Nookamka sandy loam	6477	0-8	8.0	13.8	12.2	69	22	6	3
	6479	18-29	9.5	25.1	16.3	35	39	5	21
	6481	41-69	9.8	22.5	13.1	24	41	6	29

[x] Total exchangeable metal ions as milligram equivalents per 100 g of air-dried soil.

Whilst exchange capacity and percentage saturation have not been determined, the date in Table 6 provide a guide to these values. The very alkaline reactions indicate a very high percentage saturation of the exchange complex, particularly in the subsoils. In fact, all the soils in Table 6 are more than 100% saturated with reference to the neutral point; also are most of them with reference to pH 8.4 - the approximate reaction of soils in equilibrium with excess calcium carbonate and in which calcium is the dominant exchangeable ion. However, although free calcium carbonate is present in the subsoils illustrated, sodium and magnesium are influential ions in the exchange complex and these are responsible for reactions greater than pH 8.4. Since the subsoils may be regarded as fully saturated, the values for total exchangeable metal ions of these soils also provide an approximation of their exchange capacities. These values are moderate because of low clay contents, [x] but, if t his factor is taken into consideration, the range for total exchangeable metal ions per 100 g. for clay is from 46 m.3. in soil 2019 to 80 m.e. in soil 6449, while the average value for the six subsoils is 62 m.e. This compares with average values of 61, 61, and 60 m.e. per 100 g clay for base saturated soils (pH range 8.5 –10.0) at Redcliffs (Hubble and Crocker, 1941), Mildura (Penman et al., 1940), and Merbein (Penman at al., 1939), respectively. Such values indicate that the exchange capacity of the clay colloid of Mallee soils is moderately high suggesting a montmorillonitic type of clay mineral.

As a source of plant nutrients, exchangeable calcium and magnesium are in adequate amounts in all the soils analysed. Exchangeable potassium is at a satisfactory level in the Barmera sand and Nookamka sandy loam profiles, but there is only.36 m.e. per 100 g of soil in the 2-17 in. horizons of the Coomealla loam profile. This value approaches a deficiency level; however, there are adequate reserves of exchangeable potassium (1.01 m.e./100g) in the horizon below 24 in. to satisfy the potassium requirements of vines grown on this soil. General experience with citrus and vines in the various irrigation settlements along the Murray River to date has not shown the need for added potash on Mallee soils, and the Robinvale soils are unlikely to be any different in this respect.

6. *Soluble Salts.*

A guide to the general level and composition of the soluble salts in the soils is provided by the specific conductivity and chloride values of the type samples reported in Appendix 2; and, in Table 7, by more detailed analyses of the soluble salts present in specific horizons of the major soil types.

Soluble salts[*], calculated from the specific conductivity values, [x] are low in all the surface horizons of the soils listed in Appendix 2 except those of the Moorook sandy loam and Coomealla sandy loam; these two soil types contain moderate amounts, viz., 0.12%. In all profiles except those of t he Murray and Berri sands, total salts increase with depth to four feet, at which depth contents are low – less than 0.10% - in the Barmera sand, and Belar clay loam profiles; moderate – 0.15% to 0.33% - in the profiles of the Moorook sandy loam, Coomealla sandy loam, Barmerra sandy loam, and Nookamka series; and high – 0.36% to 0.50% 0 in two of the Coomealla loam and the Type A profiles. There is a further increase in soluble salt content at the 6 ft. indicate that the concentration present at 6 ft. is increased or maintained with further depth.

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[*] % Total Salts = Specific Conductivity x 10^5 (i.e. values as reported) x 0.0033

The chloride contents follow the same general trend with depth in the soil profile as the specific conductivity values. Also, these values, when interpreted in terms of sodium chloride and total water soluble salts show broadly that in the soils with low totals salts less than half is sodium chloride; in those of moderate total salt content, roughly half is sodium chloride; and in those of high salt content, about two thirds is sodium chloride. Further evidence of this relationship is afforded by the detailed analyses of soluble salts set out in Table 7. These data also show that calcium and magnesium salts occur in only very small amounts, but that small to moderate quantities of sodium carbonate and sodium sulphate are present. The maximum concentration of sodium carbonate recorded is 0.053% in soil 2025, while the greatest amount of sodium sulphate present is 0.094% in soil 2038.

Table 7. - Analysis of Soluble Salts.

Soil Type	**Soil No.**	**Depth (in.)**	**K^x**	**Total Soluble Salts %**	**Milliequivalents per 100g of air dried soil.**						
					Cl	**$S0_4$**	**HCO_3**	**CO_3**	**Ca**	**Mg**	**Na^+**
Berri sand	10203	66-96	24	0.105	0.10	0.10	1.11	0.03	0.06	0.09	1.19
Barmerra sand	2018	48-68	49	0.170	1.27	0.29	0.88	0.08	0.07	0.14	2.31
Barmera sandy loam	2025	29-45	65	0.215	1.01	0.31	0.83	0.50	0.09	0.07	2.49
Nookamka sandy	6481	41-69	89	0.285	2.37	1.00	0.61	0.24	0.14	0.09	3.99
loam	10210	40-60	74	0.255	1.57	0.88	1.22	0.02	0.11	0.10	3.48
Nookamka loam	2035	5-11	119	0.352	4.48	0.38	0.78	0.00	0.17	0.20	5.27
Coomealla loam	2038	24-42	136	0.450	4.82	1.33	0.77	0.18	0.12	0.18	6.81
Coomealla loam	6451	27-40	89	0.315	2.21	0.75	0.92	0.39	0.09	0.11	4.06
Coomealla loam											

^{x} Specific conductivity of 1:5 soil:water suspension at 20^0C in mhos $x10^5$.

\+ Determined by difference – is mainly sodium

SALINITY OF THE SOIL TYPES.

Experience has shown that soluble salts, and sodium chloride in particular, may be present in sufficient amounts in Mallee soils to exert a profound influence on the growth of horticultural crops under irrigation. For this reason the assessment of the inherent salinity of the soils has been an important part of the soil survey, and has enabled soils with an undue salt hazard to be excluded from irrigation.

The systematic evaluation of salinity within the surveyed area has entailed analyses for chloride content of more than 2,500 soils samples collected from the bores put down for soil examination. Most of these samples were taken from the 3-4 ft. zone since it is considered that this zone provides a reliable estimate of the inherent salinity of the soil profile; however, many samples were taken also from the 102 ft. and 5-6 ft. zones. From the salt survey data, it has been possible to assess the salinity hazard over the area and to guide settlement into those localities where the risk is at a minimum. Whilst factors of soil texture and topographic situation must be considered in conjunction with the degree of salinity of the soil when assessing the salt risk under irrigation, in general, all areas in which a majority of the soils examined show more than 0.2% of sodium chloride in the 304 ft. zone have been avoided

Table 8. - Average Sodium Chloride Content of the Soil Types.

Soil Type	Depth (ft.)	Mean Sodium Chloride %	No. of Samples
Murray sand	3-4	0.019^{+}.0051ǿ	31
	5-6	0.028^{+}.0071	26
Berri sand	3-4	0.030^{+}.0052	48
	5-6	0.038$^{+\cdot}$0063	40
Barmera sand	3-4	0.050$^{+\cdot}$0041	147
	5-6	0.066$^{+\cdot}$0052	80
Barmera sandy loam	3-4	0.088^{+}.0033	376
	5-6	0.132^{+}.0060	133
Nookamka sandy loam	3-4	0.095^{+}.0040	246
	5-6	0.121^{+}.0086	50
Nookamka loam	1-2	0.031^{+}.0110	27
	3-4	0.124^{+}.0039	358
	5-6	0.163^{+}.0098	60
Nookamka clay loam	1-2	0.087^{+}.0187	14
	3-4	0.120^{+}.0066	148
	5-6	0.168+.0211	11
Belar clay loam	1-2	0.030^{+}.0074	23
	3-4	0.085^{+}.0081	85
	5-6	0.106^{+}.0240	14
Coomealla loam	1-2	0.100^{+}.0078	85
	3-4	0.162^{+}.0036	323
	5-6	0.196^{+}.0079	48
Type A	1-2	0.137^{+}.0200	24
	3-4	0.193^{+}.0121	53
	5-6	0.248^{+}.0260	6

ǿ Standard error of mean

The relative salt status of the principal soil types is shown by the mean values in Table 8. The figures are of interest in that they indicate a salinity level for unirrigated Mallee soils which are either virgin or have been sparingly cultivated in the past. The trend of increasing salt content with depth in the soil profile, evident from the analyses of the type samples, is substantiated at a statistically significant level for most of the soil types. Using the salt content of the 3-4 ft depth as an index of the inherent salinity of each soil type, the mean values show that the salinity level in the soil types listed is in the following order: Murray sand, Berri sand < Barmera sand < Barmera sandy loam, Nookamka sandy loam, Belar clay loam[*] < Nookamka loam, Nookamka clay loam < Coomealla loam < Type A.

Excepting the Murray sand and Berri sand, and possibly the Barmera sand, all the soil types in their natural state contain salt concentrations unfavourable for the growth of horticultural crops. This condition is accepted for Mallee soils generally and leaching of salt into the deep subsoil is necessary to reduce the natural salt content within the root-zone to a safe level. Normally this is an early effect under irrigation and takes place most readily in the light soils situated high in the topography, e.g., Murray sand, Berri sand and Barmera sand. Although initially of moderate salt content, reduction by leaching should be satisfactory in the Barmera sandy loam, Nookamka sandy loam, Mookook sandy loam and Coomealla sandy loam soil types. The average salt contains in the soil types with loam and clay loam surface textures are fairly high (Table 8) and this has been taken into consideration in excluding the Nookamka clay loam and Type A soil types from irrigation. Also, the more saline situations of Nookamka loam and Coomealla loam have been excluded, consequently the general salinity level of these types within the area selected for settlement is lower than the general means indicated in Table 8. However, Coomealla loam in particular is inherently a rather saline soil type and will require careful management in order to avoid salt troubles.

It cannot be over-emphasised that, whilst water is necessary to reduce the initial salinity of most of the soil types, ultimately it may build up in the soil to form a saline water-table from which salt may rise into the root management are the counters to this.

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[*] The means of grouped soil types are not significant different

SOIL ASPECTS OF SETTLEMENT DESIGN, IRRIAGATION, AND DRAINAGE.

1. District and Block Design.

The Robinvale settlement is fortunate in being able to draw upon an extensive background of district experience in irrigated horticulture, derived under very similar conditions of soils and climate. This experience has been applied in planning, firstly, the overall design of the settlement and, secondly, the details of internal layout of the blocks.

Early in the survey it was evident that the soil pattern was similar to that in other horticultural settlements along the mid-Murray River, consequently it was possible from the outset to direct development into areas comprised largely of soil types of known suitability for vines and citrus under irrigation.

Generally the heavy soil types have been found to be inferior for horticulture under irrigation. They are sometimes difficult to maintain in good production, while they occur in the topography in low situations which are subject to considerable frost hazard. The Nookamka clay loam and Belar clay loam are in this category. In addition at Robinvale, Nookamka clay loam has an additional drawback in that it possesses a fairly high degree of inherent salinity. The unnamed soil, Type A is also a heavy soil type with an even higher salinity level. Subsoil drainage is not feasible in these soil types. Because of such factors these three soil types have been excluded from irrigation. Large areas have been avoided entirely, but, where they necessarily occur within the subdivision, adjustment has been made in the size of the holdings. A few blocks consisting largely of heavy soil types have been reserved from allocation.

Utilisation of the soils texturally unsuitable for horticulture would be desirable, but there are difficulties associated with putting these soils to irrigation in other ways. Some situations of Nookamka clay loam and Belar clay loam may be suitable for vegetable-growing, while no doubt they should also be capable of supporting good pastures under irrigation; however, economic considerations, and difficulties attendant to supplying water to crops with high water requirements from a district scheme designed for horticultural crops, make utilisation of the soils in this way difficult or impracticable.

The remaining soil types[2] in the area, viz., Murray sand, Berri sand, Moorook sand and sandy loam, Barmera sand and sandy loam, Coomealla sandy loam and loam and Nookamka sandy loam and loam all have provided satisfactory soils for vines when under suitable management; in addition, Murray sand, Berri sand, and sometimes Barmera sand, have been found to support citrus well. Settlement has been directed towards these soil types, except where soil salinity has been found to be excessive.

The area of soils in the settlement suitable for citrus is disappointingly small. The Murray sand, Berri sand and Barmera sand, excluding its shallow phase, were originally recommended for citrus; but latest plantings have been only on areas re-examined for suitability, resulting in some situations, mainly of Barmerra sand, being discarded for citrus.

The lay-out of the individual blocks is designed to allow the most effective application of irrigation water practicable under the particular conditions prevailing. Irrigation is by the furrow system and plantings are intended to give optimum slope and length of run in the furrows, having regard to the absorptive capacity of the soil and the topography. As far as possible soil types with dissimilar infiltration rates are not irrigated in the some run.

2. Soil and Water Usage.

Control of water is important to the success of the individual block holder and to the settlement as a whole. Many of the water-logging and salinity troubles of the older horticultural settlements can be attributed to the irrational use of water. In the past, there have been far more cases of excessive use of water than there have been of under-irrigation. Lack of knowledge of the water properties of the soils and the water requirements of the growing crop have been chiefly responsible. Frequently, excessively large quantities of water have been applied simply to make sure of giving enough, while efficient irrigation has been impossible in many cases because of mixed soil types, unsuitable slopes, and over long runs. Plant-water relationships in Mallee soils are now better understood, and block layouts at Robinvale should enable better control of water within the

[2] Types B and C are additional soil types of minor importance

holdings. However, water has to be applied intelligently to obtain efficient distribution and, in this, the onus is on the settler himself.

The application of results derived from investigations into the filtration characteristics of Mallee soils to the furrow irrigation of vines and citrus is dealt with by Lyon and Tisdall (1942) and Lyon and Pennefather (1946). Only general considerations are discussed below.

The object in applying water to the soil is to create an optimum moisture environment for crop growth by replenishing the water losses of transpiration and evaporation. This usually entails raising the moisture content of the soil from the vicinity of its wilting point to that of its field capacity over the depth of soil explored by the roots of the crop. Application of water in large excess over this requirement is to be avoided as a general rule. Exceptions may be in the reclamation of salted land by underground drainage, although in practice drains almost invariably run after normal irrigation, and sometimes in the early stages of developing new land to irrigation, where it may be necessary to wash soluble salts from the upper to lower layers in the soil profile. Soil types which may benefit by an initial leaching for this purpose are the Barmera sandy loam, Nookamka sandy loam, Nookamka loam, and particularly the Mookook sandy loam, Coomealla sandy loam and Coomealla loam. But caution in the use of water is necessary in the absence of underground drains to carry away the surplus water.

There is no doubt that water can be applied to the sandy soils, such as the Murray sand and Berri sand, most efficiently by the spray system of irrigation; however, with care these soil types can be watered satisfactorily by the furrow method. The heavier soil types are generally watered effectively by furrow irrigation. The greatest drawback of the furrow system is the liability of over-irrigation of the headlands, since water has to be held longer there than on the footland, the headland soils are frequently more permeable, and soakage reduces the flow rate down the slope. The risk can be reduced by irrigating only soils of similar infiltration capacities in the same run, and by adopting the most suitable slopes and run lengths having regard to the absorptive capacity of the soil. Sometimes, the topography and the soil pattern make attainment of the ideal arrangement impracticable.

Given suitable conditions of layout, efficiency of irrigation then depends on control of the flow rate per furrow. This is easiest with flat grades. Increasing the flow rate reduces the quantity of water applied and also the time of irrigation, consequently the sandy soil types are best watered using large streams for short times. The over-watering of light soil types which is prevalent in the older districts is usually due to using too small furrow streams. A larger initial flow which can be cut down to a smaller soakage rate when the water reaches the end of the furrow most often gives the best results with all soil types. For example in South Australia, sixteen sandy and sandy loam soils of the Mallee type, having slopes of from 11/2 in. to 4 in per chain, were effectively irrigated with 4 ac in. using an average initial flow rate per furrow of 0.047 cusec. (171/2 gall/min.) cut down to a soakage rate of 0.024 cusec. (Lyon and Pennefather, 1946)

The soil types can be watered efficiently with surface applications of from 2 to 4 inches per acre in most circumstances. Slightly larger quantities may be justified for leaching purposes in the early stages, but at all times, large applications exceeding 9 in. are to be deprecated. The sandy soil types require less water per irrigation than the sandy loams, and these less than the loams.

Once the optimum quantity of water is determined for a particular soil type, then theoretically the some amount should be applied at all irrigations, since ideally water will always be added to the soil when its moisture is depleted to the some point, i.e., just before wilting point is reached. However, under a community system of irrigation, it is impossible always to supply water at the ideal time, consequently some variation from the normal irrigation rate may be necessary according to the moisture content of the soil when water is made available.

This may be the case during the period of spring rains and then less than the normal summer irrigation should be given if soil moisture indicates this treatment.

Climate and soil type are the factors determining the optimum period between irrigations. Water usage by plants increases with the onset of hot weather, therefore, closer spacing of irrigations is necessary in summer than in spring.

Soils vary in their ability to meet the moisture demands of the plant; usually, but not always, heavy textured soils can hod out longer than light soils. These considerations are taken into account when fixing the spacing of irrigations on the settlement roster. Normally the settler is required to take water only in his turn on the roster, hence such a system is unlikely to meet all conditions satisfactorily. Inter-irrigation periods may be considered too long in some situations, but the practice of watering heavily will not compensate for this. Such irrigations merely wet the soil to greater depths than can be reached by the plant roots, and may even develop a rising water-table with the attendant risk of salt injury.

3. *Drainage of the Soils.*

Up-to-date, underground drainage has not been installed within the blocks, nor has a district scheme progressed beyond the design stage. However, the delay has been due to circumstances beyond control. It is recognised that underground drainage is essential to guard against water-logging and salinity troubles in Mallee soils under irrigated horticulture.

Of the irrigated soils types at Robinvale, Coomealla loam appears to be the soil most likely to give trouble if drainage is delayed for long. This soil type has a fairly high inherent salinity, is situated relatively low in the topography, and has a rather low permeability. Nookamka loam is in much the same category, but is favoured by a naturally lower salt content.

Much is now known about the reaction of individual Mallee soil types to underground drainage. District experience at Mildura, Redcliffs and Merbein, and experimental work carried out through the Commonwealth Research Station at Merbein have enabled recommendations to be made regarding the optimum depth and spacing of drains for the major soil types (Tisdall, 1942). These recommendations are set out in Table 9 for the soil types that occur at Robinvale. The suggested depths are approximate, but with the aid of the soil map should serve as a guide for drainage installations in the district. Modifications of these depths may be advisable where exploratory borings reveal textural variations from the normal profile of the soil type, while, in some cases, slopes and outfall may over-ride soil type in determining the depth at which drains shall be laid.

Table 9 - Depth and Spacing of Drains for the Soil Types.

Soil Type	Depth Ft.	Spacing Ft.
Murray sand	6-7	132
Berri sand	6-7	132
Barmera sand	51/2	99-132
Barmera sand shallow phase	41/2-51/2	88-99
Barmera sandy loam	51/2-6	99-132
Barmera sandy loam shallow phase	41/2-51/2	88-99
Moorook sandy loam	51/2-6	99-132
Coomealla sandy loam	41/2-5	88
Coomealla sandy loam light deep subsoil	51/2-6	99-132
Coomealla loam	4	44
Nookamka sandy loam	4-5	44-88
Nookamka loam	4	44

In Table 9, spacing should be read in conjunction with depth since the spacing advocated for each soil type implies that the drains are laid at the recommended depth for the particular type; if this is varied the appropriate spacing for the altered depth should be used. The above recommendations are considered adequate to guard against the onset of salt injury in unaffected soils; where damage is already apparent the distances between drains may need to be reduced by about one third.

There are strong reasons why drainage should be installed at an early date. First plantings are now in bearing and additional areas are coming into production each year, with consequent increase in the water usage of the district. The effect of this is already apparent by the presence of water table in far too many situations; rise of salt can be expected to follow. Then instead of drainage for prevention, the prospect is one of drainage for reclamation – a more difficult and costly matter.

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APPENDIX 1 - VIRGIN FOREST FLORA.[3]

Acacia colleticides	"Wait-a-while."
Acacia Oswaldii	"Umbrella Wattle."
Amyema Preissii	"Wire-Leaf Mistletoe."
Atriplex Muelleri	"Lagoon Saltbush."
Bassia paradoxa	"Curious Bassia."
Bassia pantenticuspis	"Spear-fruit Saltbush."
Bassia unifilar	"Two-spined Saltbush."
Callitris glauca	"Murray Cyprus Pine."
Cassia Sturtii	"Dense Cassia."
Casuarina lepidophloria	"Belar."
Chenopodium microphyllium	"Small-Leaf Goosefoot."
Chenopodium nitrariaceum	"Nitre Goose-foot."
Codonocarpus cotinifolius	"Bell-fruit."
Dodonaea attenuata	'Slender Hop-bush."
Eremophila oppositifolia	"Twin-leaf Emubush."
Eucalyptus angulosa	"Red-fruited Mallee."
Eucalyptus oleossa	"Oil Mallee."
Exocarpus aphylla	"Leafless Ballarat."
Grevillea Huegelii	"Comb Grevillea."
Grevillea pterasperma	"Desert Grevillea."
Hakea vittatta	"Striped Hakea."
Heterodendron oleifolium	"Cattle-bush."
Kochia brevifolia	"Short-leaf Bluebush."
Koshia Geprgei	"Handsome Bluebush."
Kochia triptera var. erlocade	"Sort-leaf Bluebush."
Lysiana exocarpi	"Harlequin Mistletoe."
Myoporum platycarpum	"Sandalwood."
Nicotiana glauca	"Tree Tobacco."
Olearia Muelleri	"Dusky Daisy-bush."
Olearia pimelioides	"Pimelea Daisy-bush."
Pimelea microcephala	"Small-head Riceflower."
Salsola Kali	"Prickly Saltwort."
Santalim scuminatium	"Sweet Quandong."
Stipa variagilis	"Variable Spear Grass."
Teucrium racemosum	"Grey Germander."
Vittadinia triloba	"New Holland Daisy."
Zygophyllum apiculatum	"Pointed Twin-leaf."
Zygophyllum fruticulosun	"Shrubby Twin-leaf."

[3] The specimens were collected by Mr W. I Walbran and identified by courtesy of the National Herbarium.

APPENDIX 2 - MECHANICAL ANALYSES AND OTHER DATA FOR THE SOIL TYPES.

Limestone rubble is expressed as a percentage of the field sample and specific conductivity as that of a 1:5 soil:water suspension at 20^{o}C in reciprocal ohms x 10^{5}; while all other figures, except those for depth, reaction, and C:N ration, are percentages of air dried soil passing a 2 mm. sieve.

The following abbreviations are used to describe field texture:-

S = sand; SL = sandy loam; L = loam; CL = clay loam; SCL = sandy clay loam; SC = sandy clay; LC = light clay; MC = medium clay; HC = heavy clay.

	MURRAY SAND						BERRI SAND					
Soil No.	**10191**	**10192**	**10193**	**10194**	**10195**	**10196**	**10199**	**10200**	**12001**	**10202**	**10203**	**10204**
Depth (in.)	**0-12**	**12-28**	**28-43**	**43-54**	**54-66**	**66-84**	**0-14**	**14-27**	**27-45**	**47-66**	**66-96**	**96-120**
Texture	**S**	**S**	**S**	**S**	**SL**	**S**	**S**	**S**	**S**	**SL-SCL**	**SL-SCL**	**SCL**
Grave (Calcium carbonate)												**Tr**
Coarse sand	51.7	52.4	51.0	49.0	37.5	41.1	54.8	53.0	46.9	40.4	38.6	34.4
Fine sand	38.8	38.1	40.2	41.0	37.9	35.6	33.4	33.6	38.6	28.6	30.8	26.3
Silt	1.0	1.1	0.4	0.9	1.0	1.2	1.7	1.7	1.6	1.2	1.2	1.0
Clay	7.1	7.1	7.0	8.3	17.3	18.3	8.0	9.4	10.6	16.3	14.7	14.0
Moisture	0.7	0.8	0.7	0.8	1.7	1.7	0.8	0.9	1.1	1.6	1.6	2.1
Loss on acid treatment	0.4	1.1	0.5	0.5	4.6	2.5	0.9	1.9	2.0	12.6	13.5	23.9
Loss on Ignition	1.4	1.6	1.2	1.1	3.9	2.8	1.8	2.2	2.2	7.1	7.0	12.1
Calcium carbonate					4.9	3.0				12.4	12.2	25.5
Specific conductivity	8	8	9	10	21	30	9	9	11	13	24	30
Chlorides (Cl)	0.003	0.002	0.005	0.003	0.005	0.005	0.001	0.004	0.005	0.005	0.004	0.009
Nitrogen	0.034						0.049					
Organic carbon	0.38						0.53					
C-N ratio	11.2						10.8					
Reaction (pH)	8.5	8.8	8.9	9.0	9.3	9.9	8.7	8.7	8.7	9.2	9.7	9.9

SOIL TYPE	BARMERA SAND								BARMERA SAND					
Soil No.	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**6464**	**6465**	**6466**	**6447**	**6468**	**6469**
Depth (in.)	**0-4**	**4-17**	**17-29**	**29-36**	**36-48**	**48-68**	**68-90**	**90-126**	**0-7**	**7-14**	**14-20**	**20-41**	**41-66**	**66-82**
Texture	**S**	**S**	**S**	**SL**	**SCL**	**SCL**	**SCL**	**SCL**	**S**	**S-SL**	**SL**	**SCL**	**SL**	**SCL**
Gravel (Calcium carbonate)						**Tr.**	**1.0**	**1.0**						
Coarse sand	42.3	39.2	39.6	42.0	30.2	30.5	31.1	29.1	43.2	38.9	34.6	28.8	35.0	29.4
Fine sand	44.0	44.2	41.7	36.5	27.7	27.4	31.5	36.7	35.6	36.1	38.9	24.2	31.4	23.9
Silt	2.4	2.5	2.1	1.9	0.9	1.0	1.5	1.8	3.8	4.6	3.2	1.6	2.7	1.6
Clay	10.9	12.9	14.1	15.6	19.9	20.9	15.5	15.5	12.7	13.1	14.4	16.1	15.9	17.7
Moisture	1.2	1.6	1.9	2.2	2.7	2.6	1.9	2.1	2.2	2.5	2.6	2.6	2.8	2.7
Loss on acid treatment	0.6	0.7	2.1	2.8	20.1	20.7	19.8	15.9	3.5	5.8	9.1	28.6	13.4	26.7
Loss on ignition	1.9	1.8	2.3	2.5	8.6	8.8	10.1	8.6	3.5	4.4	5.8	12.2	7.3	13.1
Calcium carbonate				2.0	16.9	18.7	16.8	13.4	2.8	4.9	8.4	28.6	13.6	25.6
Specific conductivity	6	6	12	15	30	49	63	72	9	11	10	18	49	58
Chlorides (Cl)	0.002	0.001	0.004	0.008	0.029	0.045	0.045	0.052	0.002	0.001	0.001	0.004	0.022	0.030
Nitrogen	0.051								0.038					
Organic carbon	0.50								0.42					
C-N ratio	9.8								11.1					
Reaction (pH0	7.7	7.8	8.7	8.7	9.0	9.6	9.8	9.7	8.7	8.8	8.9	9.9	10.2	10.1

SOIL TYPE	BARMERA SANDY LOAM							BARMERA SANY LOAM						
Soil No.	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**10168**	**10169**	**10170**	**10171**	**10172**	**10173**	**10174**
Depth (in.)	**0-3**	**3-13**	**13-18**	**18-29**	**29-45**	**50-72**	**72-90**	**0-1**	**1-18**	**19-24**	**24-36**	**36-47**	**47-61**	**61-80**
Texture	**SL**	**SL**	**SL**	**SCL**	**SC**	**SCL**	**SCL**	**S**	**SL**	**SCL**	**SC**	**SCL**	**SCL**	**SCL**
Gravel (Calcium Carbonate)				**Tr**	**Tr**	**Tr**	**6.0**					**2.1**	**10.5**	**tr**
Coarse sand	42.2	40.3	37.1	30.9	28.3	34.8	35.4	45.2	30.2	30.4	28.3	28.8	25.1	24.6
Fine sand	41.4	41.9	41.5	33.9	26.9	34.2	31.5	40.8	44.7	32.3	25.8	27.8	25.2	26.5
Silt	2.7	3.1	2.4	2.4	3.0	2.6	1.8	1.7	2.5	3.2	2.3	2.6	2.8	1.0
Clay	11.2	12.0	13.5	19.8	21.8	17.0	18.9	10.1	19.1	25.7	23.0	20.7	18.9	19.6
Moisture	1.4	1.7	2.1	2.8	3.1	2.4	2.5	1.0	2.3	3.3	3.1	2.9	2.7	2.7
Loss on acid treatment	0.9	1.1	2.9	10.8	17.9	10.3	11.3	0.5	0.9	7.3	17.9	18.7	28.0	25.2
Loss on ignition	2.4	2.1	2.7	6.3	9.3	4.9	5.9	2.5	2.6	5.4	9.8	9.8	11.4	13.7
Calcium carbonate			2.0	9.4	16.3	8.2	8.0		0.1	6.1	16.8	16.6	26.4	25.0
Specific conductivity	6	11	12	26	65	101	111	5	10	25	57	80	93	106
Chlorides (Cl)	0.002	0.002	0.001	0.004	0.036	0.106	0.109	0.003	0.007	0.010	0.037	0.063	0.091	0.109
Nitrogen	0.062							0.063	0.041					
Organic carbon	0.55							0.57	0.34					
C-N ratio	8.9							9.1	8.3					
Reaction (pH)	8.0	8.6	8.8	9.7	9.9	9.7	9.7	7.7	8.5	9.5	9.7	9.8	9.5	9.3

SOIL TYPE	MOOROOK SANDY LOAM					COOMEALLA SANDY LOAM "light deep subsoil"						
Soil No.	**6454**	**6455**	**6456**	**6457**	**6458**	**6470**	**6471**	**6472**	**6473**	**6474**	**6475**	**6476**
Depth (in.)	**0-5**	**5-11**	**11-24**	**24-41**	**41-72**	**0-6**	**6-14**	**14-21**	**21-40**	**40-75**	**75-98**	**98-116**
Texture	**SL**	**SL**	**SL-SCL**	**SL-SCL**	**SL**	**SL**	**L**	**SCL**	**SCL**	**SCL**	**SL+SCL**	**SCL**
Gravel (Calcium carbonate)	**1.6**	**2.3**	**Tr**					**3.1**	**1.2**	**Tr**	**2.0**	**0.9**
Coarse sand	40.2	33.0	29.4	35.6	39.9	29.6	25.4	24.6	23.0	22.0	21.8	25.4
Fine sand	29.3	30.4	24.8	22.3	30.0	33.9	35.2	31.8	26.9	36.4	47.3	43.8
Silt	2.4	2.6	1.6	1.7	1.8	5.6	5.1	3.7	2.8	2.3	3.1	3.8
Clay	11.8	11.8	13.0	13.2	13.5	17.2	16.8	18.6	16.5	11.8	14.2	22.8
Moisture	2.9	3.3	2.8	2.3	2.4	3.5	3.6	3.8	3.1	2.3	2.5	4.0
Loss on acid treatment	11.5	18.1	28.7	24.0	13.5	10.8	14.3	17.5	27.0	26.6	12.8	1.3
Loss on ignition	9.5	11.1	14.5	12.2	7.1	8.5	8.7	9.6	13.5	13.2	7.2	2.7
Calcium carbonate	9.4	16.1	27.8	23.7	13.1	9.1	13.8	16.5	27.8	27.4	12.5	1.0
Specific conductivity	38	76	80	74	75	36	85	106	100	85	87	108
Chlorides (Cl)	0.037	0.094	0.086	0.069	0.066	0.016	0.097	0.114	0.098	0.079	0.073	0.094
Nitrogen	0.129					0.130						
Organic carbon	2.42					1.59						
C-N ration	18.8					12.2						
Reaction (pH)	8.4	8.7	9.7	9.8	9.9	8.4	9.4	10.0	9.9	10.0	9.9	9.3

SOIL TYPE	COOMEALLA LOAM								COOMEALLA LOAM							
Soil No.	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**6446**	**6447**	**6448**	**6449**	**6450**	**6451**	**6452**	**645 3**
Depth (in.)	**0-5**	**5-11**	**11-15**	**15-24**	**24-42**	**42-51**	**51-57**	**59-63**	**0-2**	**2-7**	**7-11**	**11-17**	**17-27**	**27-40**	**40-63**	**63-78**
Texture	**L**	**L-CL**	**CL**	**LC**	**LC**	**LC**	**MC**	**LC**	**SL-L**	**L**	**CL**	**CL**	**SC**	**LC**	**LC-MC**	**LC**
Gravel (Calcium carbonate)	**1.0**	**2.0**	**20.0**	**28.0**	**16.0**	**16.0**	**6.0**	**36.0**	**Tr**	**2.3**	**47.4**	**34.3**	**23.8**	**10.0**	**2.7**	**Tr**
Coarse sand	31.8	26.4	24.7	22.6	19.8	19.0	19.2	10.6	33.1	28.3	25.2	21.1	19.6	21.0	22.1	23.6
Fine sand	30.4	29.3	26.6	23.0	25.4	30.1	32.0	28.3	38.6	34.7	31.2	27.2	26.4	30.3	34.2	35.3
Silt	8.7	8.1	7.6	5.8	6.3	6.9	6.8	7.4	4.9	4.3	3.5	3.2	3.6	5.5	4.3	5.0
Clay	19.0	19.0	18.9	19.7	23.4	25.6	31.1	21.2	17.0	15.9	16.0	16.5	18.4	22.2	32.1	30.9
Moisture	2.3	3.3	3.2	3.0	3.4	3.8	4.5	2.8	2.5	3.2	3.5	3.2	3.4	4.6	5.8	5.3
Loss on acid treatment	9.3	14.7	19.6	25.8	22.7	13.9	6.2	27.6	4.3	14.3	21.1	29.8	30.0	17.7	3.0	1.2
Loss on ignition	7.2	8.9	10.9	14.0	11.9	8.1	5.0	14.7	4.3	9.1	11.8	15.4	15.4	10.2	4.1	3.3
Calcium carbonate	6.1	14.5	18.3	24.6	19.2	11.8	6.8	25.3	3.6	13.1	20.4	29.8	30.0	15.6	1.3	0.1
Specific conductivity	19	119	142	132	136	125	136	97	9	11	25	43	61	89	108	99
Chlorides (Cl)	.014	.159	.211	.199	.171	.152	.165	.116	.001	.002	.014	.044	.057	.078	.097	.095
Nitrogen	.079								.053							
Organic carbon	0.92								0.53							
C-N ration	11.6								10.0							
Reaction (pH)	9.1	9.2	9.2	9.2	9.5	9.7	9.5	9.7	8.6	8.7	9.3	9.5	9.8	9.9	9.9	9.6

SOIL TYPE	COOMEALLA LOAM								NOOKAMKA SANDY LOAM					
Soil No.	**10183**	**10184**	**10185**	**10186**	**10187**	**10188**	**10189**	**10190**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Depth (in.)	**0-6**	**6-15**	**15-24**	**24-36**	**36-43**	**43-56**	**56-68**	**68-80**	**0-9**	**9-16**	**16-22**	**22-34**	**34-50**	**50-66**
Texture	**L**	**CL**	**CL**	**LC**	**LC**	**MC**	**HC**	**HC**	**SL**	**SCL**	**SCL**	**SC**	**SCL**	**SC**
Gravel **(Calcium carbonate)**		**13.9**	**8.6**	**6.4**	**8.6**	**Tr**	**Tr**				**Tr**	**6.0**	**4.0**	**2.0**
Coarse sand	32.7	23.4	20.8	20.2	18.0	17.3	21.6	25.6	46.5	37.9	35.1	29.5	30.1	35.3
Fine sand	26.9	26.0	21.1	17.9	15.8	16.1	16.8	16.7	30.1	35.3	32.7	23.5	27.6	30.3
Silt	4.9	4.0	3.7	4.0	3.9	5.1	5.9	5.9	4.0	4.5	4.0	2.4	3.3	3.0
Clay	18.1	19.2	21.5	24.7	26.4	33.9	44.4	43.7	15.5	49.0	22.0	22.9	18.3	19.1
Moisture	2.2	2.2	2.3	2.5	2.8	3.7	4.7	4.5	2.1	2.5	3.0	3.4	2.4	2.2
Loss on acid treatment	14.3	23.3	31.6	30.9	33.6	25.0	6.5	5.7	1.2	2.3	4.4	18.8	20.2	12.4
Loss on ignition	8.8	12.9	14.2	16.5	17.6	13.8	6.7	5.0	3.2	3.2	4.2	10.1	10.5	7.2
Calcium carbonate	11.5	21.4	28.5	30.0	32.8	24.6	5.9	5.4			3.9	18.3	18.4	11.1
Specific conductivity	13	64	115	126	123	151	175	170	8	15	41	53	53	60
Chlorides (Cl)	0.007	0.065	0.135	0.134	0.135	0.180	0.214	0.199	0.003	0.013	0.049	0.059	0.051	0.051
Nitrogen	0.071								0.050					
Organic carbon	0.85								0.55					
C-N ratio	13.4								11.0					
Reaction (pH)	8.5	9.4	9.7	9.7	9.7	9.5	9.4	9.4	7.9	8.6	8.6	8.7	9.3	9.7

SOIL TYPE	NOOKAMKA SANDY LOAM						NOOKAMKA LOAM								
Soil No.	**6477**	**6478**	**6479**	**6480**	**6481**	**6482**	**10205**	**10206**	**10207**	**10208**	**10209**	**10210**	**10211**	**10212**	**10213**
Depth (in.)	**0-8**	**8-18**	**18-29**	**29-41**	**41-69**	**69-82**	**0-6**	**6-14**	**14-20**	**20-24**	**24-40**	**40-60**	**60-76**	**76-94**	**94-108**
Texture	**SL**	**SCL**	**SC**	**SC**	**SC**	**SCL**	**SL**	**SCL**	**SCL**	**SCL**	**SC-LC**	**SC-LC**	**SC**	**LC**	**MC**
Gravel (calcium carbonate)	**Tr**			**5.3**	**11.0**										
Coarse sand	32.8	27.0	22.2	21.6	25.4	27.6	33.7	30.2	27.7	25.7	22.8	22.0	18.8	19.2	22.3
Fine sand	42.9	40.1	31.8	26.1	28.0	36.1	39.4	40.2	36.4	31.8	26.4	22.9	19.8	22.3	27.6
Silt	5.9	6.7	4.1	3.1	2.4	2.6	6.8	7.6	5.6	4.4	4.9	3.8	4.5	3.4	5.1
Clay	13.8	21.2	25.1	25.7	22.5	20.4	17.0	18.8	23.1	26.2	23.0	19.5	19.1	25.9	37.5
Moisture	2.5	4.2	5.2	5.3	4.0	3.6	2.3	2.7	3.3	3.7	3.1	2.4	2.4	3.2	4.6
Loss on acid treatment	0.9	1.4	12.4	18.7	19.1	11.1	2.1	1.5	4.5	9.3	22.2	31.0	37.3	27.0	4.6
Loss on ignition	2.8	3.3	7.7	10.5	10.4	6.7	2.8	2.5	3.6	5.6	5.2	14.7	18.5	14.1	4.8
Calcium carbonate	0.1	0.3	10.8	17.8	18.4	10.9			3.7	8.1	18.4	30.3	34.0	26.0	3.9
Specific conductivity	10	35	72	92	89	84	7	11	13	17	34	74	99	121	142
Chlorides (Cl)	0.004	0.034	0.085	0.101	0.078	0.079	.008	0.006	0.009	0.009	0.025	0.056	0.160	0.200	0.22
Nitrogen	0.048						0.057								
Organic carbon	0.46						0.49								
C-N ratio	9.6						8.8								
Reaction (pH)	8.0	9.3	9.5	9.6	9.8	9.8	8.3	8.5	8.5	9.0	9.8	9.7	9.5	9.4	9.2

SOIL TYPE	NOOKAMKA CLAY LOAM					NOOKAMKA CLAY LOAM "light surface"				
Soil No.	**2042**	**2043**	**2044**	**2045**	**2046**	**6459**	**6460**	**6461**	**6462**	**6463**
Depth (in.)	**0-9**	**9-17**	**18-26**	**26-48**	**48-54**	**0-7**	**7-8**	**8-17**	**17-24**	**24-42**
Texture	**SCL**	**LC**	**MC**	**MC**	**LC**	**SL**	**S**	**LC**	**LC**	**LC**
Gravel (Calcium carbonate)			**7.0**	**7.5**	**13.0**				**0.9**	**2.8**
Coarse sand	34.3	23.3	22.6	26.5	31.4	45.2	49.1	30.2	24.5	23.3
Fine sand	34.4	24.8	17.8	18.0	23.2	34.5	35.7	23.4	18.4	20.5
Silt	8.8	7.0	4.2	4.6	3.8	6.9	6.6	4.7	3.6	5.4
Clay	17.1	37.8	36.6	30.3	27.3	11.8	7.6	35.2	42.5	34.8
Moisture	2.0	5.1	5.0	3.7	3.4	1.7	1.2	6.0	7.8	6.7
Loss on acid treatment	1.1	1.4	12.0	14.7	11.3	0.6	0.4	1.2	4.7	11.3
Loss on ignition	3.4	4.8	8.6	9.1	7.1	2.5	1.5	3.8	5.3	7.3
Calcium carbonate			9.6	13.0	11.9			0.2	3.5	9.1
Specific Conductivity	6	13	31	46	54	6	8	49	80	80
Chlorides (Cl)	0.003	0.007	0.015	0.024	0.031	0.002	0.007	0.041	0.073	0.061
Nitrogen	0.046									
Organic carbon	0.43									
C-N ratio	9.4									
Reaction (pH)	7.7	8.4	9.4	9.8	9.7	6.9	7.1	8.9	9.6	9.7

SOIL TYPE	BELAR CLAY LOAM						TYPE A						
Soil No.	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**10176**	**10177**	**10178**	**10179**	**10180**	**10181**	**10182**
Depth (in.)	**0-4**	**4-7**	**7-28**	**28-42**	**42-48**	**48-72**	**0-4**	**4-9**	**9-13**	**13-24**	**24-35**	**35-46**	**46-80**
Texture	**CL**	**LC**	**MC**	**HC**	**HC**	**MC**	**L**	**CL**	**CL**	**SC**	**LC-MC**	**HC**	**HC**
Gravel (calcium carbonate				**Tr**	**6.0**	**19.0**		**Tr**	**Tr**	**Tr**			
Coarse sand	21.9	19.5	18.3	15.4	13.8	18.8	31.6	23.2	24.0	24.8	18.7	15.9	13.9
Fine sand	30.3	23.0	18.9	20.0	18.4	19.0	32.3	32.2	30.1	26.7	21.3	24.2	21.2
Silt	12.7	11.7	*.3	10.7	10.6	5.4	6.0	4.6	5.0	4.4	4.8	6.6	8.9
Clay	29.9	40.1	45.2	47.6	45.7	36.0	19.1	19.2	18.5	20.3	25.6	42.0	49.2
Moisture	3.3	4.3	6.3	6.4	6.6	4.8	2.2	2.5	2.4	2.5	3.0	4.5	5.3
Loss on acid treatment	1.5	2.5	3.0	2.7	5.9	18.4	8.8	16.7	19.1	20.4	26.2	6.2	2.2
Loss on ignition	5.1	5.4	5.1	5.7	5.8	11.1	6.7	10.0	10.8	11.4	14.1	6.1	4.6
Calcium carbonate			1.1	1.4	5.3	16.3	9.3	15.3	18.1	18.0	26.5	5.0	1.5
Specific conductivity	8	6	12	20	20	20	11	29	104	126	139	181	196
Chlorides (Cl)	0.003	0.002	0.002	0.005	0.004	0.005	0.005	0.023	0.122	0.149	0.164	0.219	0.243
Nitrogen	0.072						0.105						
Organic carbon	0.78						1.09						
C-N ration	10.8						10.4						
Reaction (pH)	7.1	6.4	7.5	8.2	8.5	8.7	8.7	9.2	9.2	9.3	9.6	9.4	9.0