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Soil Survey of Part of County Moira, Victoria

Including the Parishes of Boosey, Cobram, Katamatite, Naringaningalook, Katunga, Yarroweyah, and Strathmerton

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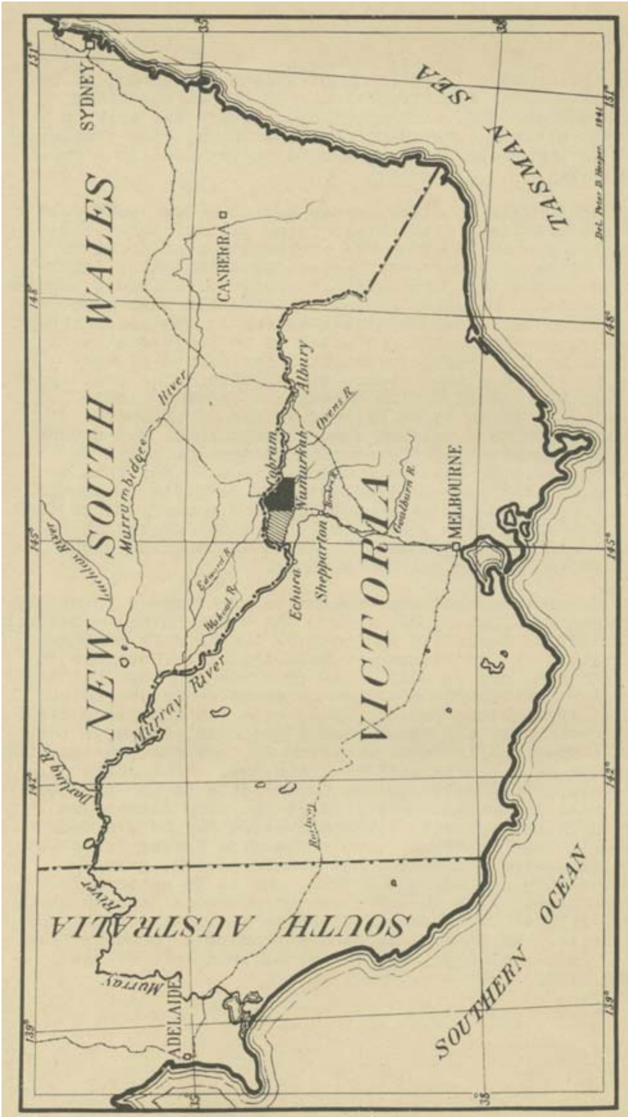
War time economy requires reduction in the Council's expenditure on publication. It is hoped that the adoption of the photo-lithographic process will be for a brief period only.

SUMMARY.

A soil survey of part of County Moira, Victoria, to be supplied with water for irrigation from the Murray River, was commenced in 1938. This bulletin covers the work on the eastern portion comprising seven parishes; the remaining parishes of the projected area are to be included in a subsequent survey.

The country is a uniform plain having a few sand hills as its most prominent feature and forms part of the flood-plain of the Murray River. The conformation of areas of sediments of varying degrees of coarseness indicates fairly definitely an earlier physiographic system of effluent streams and periodically inundated plains. The soils that have formed on these alluvial materials belong to the zonal group of red-brown earths. The character of an individual soil is governed by its stage of maturity, the nature of the sediment, and the drainage status at the site. The soil types established and mapped by the survey are shown in their relationship to these three influences and to present topography. Certain catenas can be recognised, but a more useful simplification of the complex pattern of soils is achieved by grouping into soil associations. For this purpose the soil types are associated as complete landscape groups as suggested by their most frequent occurrence in the field. For the farmer, justification for the segregation of the soils into soil types will be found in their physical rather than their chemical differences.

The present agricultural scheme is one devoted primarily to wheat and fat lamb production. The soils have a moderately high standard of fertility and most of the land is arable. An examination of the climate reveals that from November to March conditions are so arid as to preclude growth; but it is estimated that by the addition of about 24 inches of irrigation water, this period may be made the most productive of the year. With the water rights proposed, it is anticipated that when the irrigation system is completed one-quarter to one-sixth of the area will be irrigated. The soils of the area are low in salt and the water-table deep; provided care is taken in irrigation practices the more disastrous ills often associated with irrigated areas may be avoided. An aggregate area of about 1,000 acres near Cobram township has been irrigated for some considerable period, growing lucerne, peaches, pears, and citrus, and it is anticipated that these crops, with the addition of perennial and annual pastures, will be found to suit certain soils throughout the area at large. An attempt is made to indicate the crop best suited to each soil type, and the broad principle of the watering policy necessary.



NEW SOUTH WALES
VICTORIA
SOUTH AUSTRALIA
SYDNEY
CANBERRA
MELBOURNE
ADELAIDE
TASMAN SEA
SOUTHERN OCEAN
Murray River
Murrumbidgee River
Lachlan River
Darling R.
Edward R.
Wakool R.
Owens R.
Goulburn R.
Albury
Cobram
Numurkah
Shepparton
Echuca
Railway
Murray
River

Fig. 1

Soil Survey of Part of County Moira, Victoria

Including the Parishes of Boosey, Cobram, Katamatite, Naringaningalook, Katunga, Yarroweyah, and Strathmerton

Note: The soil survey was begun in 1938 at the request of the Victorian Department of Agriculture as a co-operative enterprise by the Soils Section of that Department with the Division of Soils of the Council for Scientific and Industrial Research, and with the assistance of the State Rivers and Water Supply Commission of Victoria. Part or all of each of the seven parishes surveyed will be served by the Murray Valley Irrigation Scheme now under construction. The remaining parishes in the Scheme are to be surveyed at a later date.*

I. GENERAL DISCUSSION OF THE AREA.

1. Introduction.

The Murray Valley Irrigation Scheme is in the Northern District of Victoria adjacent to the Murray River in the County of Moira. It embraces an area measuring approximately 45 miles from east to west fronting the river, with a depth of 20 miles from north and south. Portion or all of fifteen parishes are included; the area covered by the survey described in this Bulletin includes the seven parishes of Boosey, Cobram, Katamatite, Yarroweyah, Naringaningalook, Strathmerton, and Katunga where irrigation works are now in course of construction. The geographic position is shown in the locality plan (Fig. 1). A total area of 197,470 acres has been surveyed, of which 158,460 acres are within the irrigation area.

Prior to 1876 the area was leased as large pastoral runs carrying sheep and cattle at low stocking rates equivalent to 1 sheep to 10 acres. In that year country to the north and west of the present site of Numurkah was opened for selection, and before 1890 the whole of the area was allotted. Land was generally taken up in blocks of 320 acres, which was the maximum allowable. Initially wheat alone was grown, and, on the virgin soil, yields of 25 bushels were obtained without fallowing or the use of superphosphate. By 1900, sheep had become of equal importance to wheat in the agricultural system, and production approximated to its present level with the exception that in the past 20 years, although the number of sheep has not altered considerably, the emphasis has changed from wool to fat-lamb production.

In 1936-37 the occupied land totalled 190,608 acres, of which 38,446 acres were sown to wheat and 7,393 acres to oats. A fair yield of wheat in recent years has been 25 bushels; crops are generally sown on fallow with the application of superphosphate. In addition 82,820

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* The field survey was carried out by B. E. Butler, J. Baldwin, and R.G. Downes, and the preparation of the maps by P.D. Hooper, all of the Division of Soils, Council for Scientific and Industrial Research. The analyses were done in the State Laboratories of Victoria under the direction of F. Penman.

sheep, 2,475 dairy cattle, and 3,820 other cattle were maintained chiefly on stubble and volunteer pastures on which top-dressing is exceptional. In 1940, 52,357 ewes were mated to rams of British breeds and 1,545 to Merino, Corriedale, and Polworth rams, indicating the dominance of the fat lamb industry.[*]

Concurrently with other changes in the agricultural pattern, there has been a continuous tendency to an increase in the size of holding until at the present time the average is about 800 acres. In part, the explanation of this trend lies in the inadequate size of the original holding at the productivity values then obtaining, and the aggravation of the condition by the effects of later depressions in the value of primary products.

Since 1890, some areas near Cobram township have been irrigated, citrus, pome, and stone fruits and lucerne being successfully grown.

Under the amended River Murray Agreement between the Commonwealth of Australia and the States of Victoria, New South Wales, and South Australia, a weir was constructed in 1936-9 in the Murray River at Yarrawonga to control the diversion of water through one offtake to the Murray Valley Irrigation District in Victoria, and through another to areas in New South Wales. The Victorian irrigation scheme is designed to serve the area with a limited supply, the minimum water right being 3-acre-inches of water per acre of land commanded and deemed suitable for irrigation. Additional rights have been allotted to the horticultural settlement at Cobram. Control of water supply and distribution is exercised by the State Rivers and Water Supply Commission of Victoria.

The irrigation made available will largely mitigate the losses caused by droughts, and facilitate still further expansion of fat-lamb, beef, dairy, and horticultural production. A relative decrease is expected in the importance of wheat farming, and the drift towards larger holdings should be allayed and probably reversed.

2. Climate.

The climate of the area is warm temperate with maximum rainfall in the winter. Meteorological data for Numurkah, which is considered typical of the district, are summarised in Table 1.

The rainfall is not very reliable and consequently monthly and annual averages alone do not signify much. More useful information is the expectation of rainfall in the April-September and the October-March periods governing winter and summer crop yields. It has been calculated that once in a 20-year period the April-September rains will equal or exceed 16.62 inches, and once in the same period equal or fall short of 5.42 inches. In the same period the October-March rains will exceed or equal 14.4 inches once, and fall short or equal 2.81 inches once. Similar calculations for a 10- and a 5-year period are given in Table 2.

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[*] Figures kindly supplied by Miller, Department of Agriculture, Victoria.

TABLE 1 - Meteorological data for Numurkah.

Figures for temperature, humidity, and rainfall supplied by courtesy of the Commonwealth Meteorological Bureau. Saturation-deficit and evaporation have been calculated.

	Rainfall in.	Temperature deg. F			Mean Humidity % at 9 am	Saturation Deficit in. of Mercury	Evaporation in.	Rainfall Evaporation
		Mean max	Mean min	Average				
Jan	0.99	87	58	73	51	0.40	8.8	0.11
Feb	1.02	88	59	74	53	0.39	7.4	0.13
Mar	1.12	82	55	69	60	0.29	6.4	0.18
Apr	1.48	72	48	60	68	0.17	3.6	0.41
May	1.60	64	43	54	79	0.08	1.8	0.89
Jun	2.02	57	40	49	86	0.05	1.1	1.84
Jul	1.56	56	38	47	87	004	0.9	1.73
Aug	1.77	59	40	50	81	0.07	1.5	1.18
Sept	1.57	65	43	55	74	0.11	2.3	0.68
Oct	1.63	72	47	60	67	0.17	3.7	0.44
Nov	1.11	81	52	67	58	0.28	5.9	0.19
Dec	1.10	85	56	71	54	0.35	7.7	0.14
Year	16.97	72	48	60	68		51.1	
No of years	55	19			26	-	-	

TABLE 2 - The expectation of seasonal rainfall.

Probability	Expected rainfall (in.)	
	April – September	**October - March**
Once in 20 years = or > Once in 20 years = or <	16.62 5.42	14.44 2.81
Once in 20 years = or > Once in 20 years = or <	14.66 6.15	12.02 3.38
Once in 20 years = or > Once in 20 years = or <	12.61 7.15	9.65 4.21

Calculations by E. A. Cornish, Section of Biometrics, Council for Scientific and Industrial Research.

Notwithstanding the vagaries of individual seasons, the weather throughout an average season may be examined further. The evaporation for Numurkah is not available, but approximate monthly figures have been calculated from temperature and humidity by the formula derived by Prescott (1938). By taking into account both rainfall and evaporation as the ratio R/E - a better picture of the degree of humidity or aridity is obtained than by examining rainfall alone. Davidson (1936) considers that in those periods when = or < 0.25 conditions are arid and preclude growth. Further, by embodying the temperature element with R/E a rough picture of suitability-for-growth may be obtained. Applying Davidson's standard for R/E set out above and tentatively assuming that below 50°F a check to growth becomes increasingly significant, the season, for annual crops or pastures, may be interpreted as follows:-

Throughout the summer months moisture is the factor limiting growth. Towards the end of March or in April R/E rises above 0.25 and growth commences. With increasing humidity in May and June growth is accelerated until lowering temperatures in June and July exert an increasing check again. During June, July, and August, temperature is the limiting factor and, growth being retarded, the moisture status of the soil is built up. During August, September, and October, temperatures become increasingly favourable and growth is accelerated until decreasing humidity and the depletion of soil moisture reserves in October and early November lead to a rapid diminution and final cessation of growth. By this time the season's crops have come to maturity and the grass has dried off. November, December, January, February, and usually March are too arid to sustain growth, though temperatures are very favourable. Where irrigation is available to make conditions sufficiently humid to favour growth, these months are the most productive of the year.

The amount of irrigation water necessary to achieve this plenitude will need to be the subject for research. It may be inferred from the monthly evaporation figures that the greatest need for water will occur in December, January, and February. The soil will contain a considerable store of moisture in spring (October), and evaporation being then still inconsiderable the demand for irrigation water is not great. Also, it will be inadvisable to make heavy applications in late summer and autumn (March), for not only is the demand, as indicated by evaporation for that month, decreasing, but to leave the soil saturated at the beginning of winter will be to court excessive wetness in July and August. The heaviest waterings of the season should be in January with decreasing applications towards November and March. The application of quantities of water in excess of those that will be immediately used by the crop is to be avoided as not only uneconomic but as leading to the evils associated with high water tables. These suggestions are in agreement with experience at Merbein (Thomas, 1939) and Swan Hill (Penman et. al., 1937).

Local irrigation practice suggests that an application of 18-24 inches of water per season is sufficient for horticultural crops. Results obtained at Werribee, Victoria, for irrigated lucerne (Richardson, 1923) and pastures (Bartels et. al., 1932) indicate that the most economical application of water is 24 inches per season; for Griffith, N.S.W., the corresponding figure for lucerne is 24-30 inches.[*] Information for the adjacent Goulburn River valley derived from Shepparton and from the Horticultural Research Station at Tatura, should be of even more value. How far such material will apply in the local climate will need to be discovered.

In this district, where water and not land is in limited supply, annual pastures may be preferred to perennial pastures or lucerne. In the moderate temperatures of spring and autumn a greater amount of fodder is produced from an equal supply of water than at the height of summer (Richardson 1923). Annual pastures watered only in autumn and spring to prolong the growing season will exploit this water economy and provide a substantial improvement to carrying capacity at times well adapted to the fat-lamb industry. In the Wakool Irrigation District in south-western New South Wales, pastures of this kind - midseason strain of subterranean clover with Wimmera rye-grass - are being successfully grown with a total application of 12 inches of water per season.[*]

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[*] E.S. West, Research Station, Griffith, private communication.

[*] Information from the soil survey of Wakool Irrigation District supplied by R. Smith of the Council's Division of Soils.

3. Vegetation.

The greater part of the native vegetation has been removed from the area but there remain some associations only slightly modified, chiefly on the river bends, on some sandhills, and in a few swampy areas. From these incomplete data the original vegetation may be reconstructed.

Originally the area was under savannah woodland, having grey box *(Eucalyptus* hemiphloia) as the dominant tree, with Murray pine *(Callitris* robusta) yellow box *(E.* melliodora), and buloke *(Casuarina luehmanni)* as dominants in certain areas.

Pure stands of grey box probably occurred on quite extensive areas. It is found associated with pine and yellow box on lighter soils and with buloke on heavier less well drained soils, but the correlation of vegetation with soil type is not very well maintained and in individual cases the vegetation cannot be considered a reliable guide to soil character. Sandhills and well drained high country generally support an association of pine and yellow box. North of the Strathmerton-Cobram railway line in the parishes of Yarroweyah and Strathmerton, black box *(E. bicolor*) partly displaces grey box on the heavy, poorly drained soils. Red gum *(E. camaldulensis)* grows in the river bends and in the adjoining low country which, before the construction of levees, was subject to periodic flooding from the Murray River. Red gum is also found along the Boosey and Broken Creeks; it grows on either heavy or light soils provided the moisture regime is suitable.

Species of *Stipa* and Danthonia with a few ephemeral herbs formed a thin ground cover under all associations.

4. Physiography.[†]

The area forms part of the flood plain of the Murray system and consists of extensive plains of unconsolidated Recent deposits. There are no outcrops of stone within the area and, as far as is known, no bedrock has been reached by bores, although those for stock water often exceed 100 feet. The borings made during the soil survey were rarely deeper than 7 feet. The limited information available from deep bores and wells indicates that sediments of the same kind and range are found in the vertical as in the horizontal plane. The sediments forming the substrata vary from sandy gravels to medium-clays, with a preponderance in the fine sandy clay and silty clay range. No pattern has been traced in the conformation of the deep sediments, but it is considered that the system of sediments at the surface is only the latest of a succession of buried comparable systems.

The surface system extends to a depth of from 5 to 12 feet; this Bulletin deals only with the first 7 feet, though for irrigation purposes the influence of deeper layers on water movement can be expected, particularly in the more permeable types.

[†] Dr. E.S. Hills of the University of Melbourne assisted materially in the interpretation of the physiography of the district.

The disposition of sediments of various textures throughout the area can be explained as the result of stream activity and normal flood-plain deposition. Here the normal flood plain deposit is so fine as to be comparable with lacustrine deposits. Coarser sediments are channel deposits and they mark the course of old effluent streams. Under the conditions at present prevailing, these streams can still be traced but they only carry water in times of exceptional flooding. They are presumed to have been active at a time when the Murray River, in this part of its course, was less stable than it is at present. These streams flowed from the Murray River or its predecessor, across the plain which they helped to build up, eventually rejoining the river or its tributaries. The largest one flowed from a point 4 miles south-east of Cobram township in a west-south-westerly direction to the south-west corner of the parish of Yarroweyah and then south-west to the western boundary of the parish of Katunga. Another stream branched from the first in the south-west of the parish of Cobram and flowed north-west through the village of Yarroweyah to Mywee, thence westerly to the western boundary of the parish of Strathmerton. The progress of both of these streams further westward has not yet been traced, but they are expected to rejoin the Murray River or merge with the Broken Creek. The third and smallest stream was independent and flowed round the northern edge of the township of Cobram, thence to Koonoomoo and back to the river again. In and adjoining the courses of these streams, coarse, variable sediments accumulated. The large expanse of such sediments in Cobram, Strathmerton (southern portion), and Katunga (northern portion) suggests that besides those described, earlier alternative courses existed in these parts. Sandhills were formed by wind action at various points along these water courses.

A large part of the area consists of flood plain deposits which have accumulated by the flooding of the country from its various watercourses, from the Murray River and from the Boosey and Broken Creeks. Some areas of such country are drained by channels which, however, must be distinguished from the channels of effluent streams mentioned above. These are drainage channels only and have not produced sedimentation of any kind; they carry water for a few weeks each winter.

The channel sediments of the Boosey and Broken Creeks are as fine as the flood plain sediments of the Murray system, and the absence of coarse channel material here indicates that the breakaway streams referred to above were more vigorous than the Broken Creek. It even appears that sedimentation from the Broken Creek may have impeded the natural drainage of the adjoining country. Gravelly deposits occurring north and south of the Broken Creek near Numurkah indicate that a breakaway stream belonging to a system existing prior to the one described above antedated the present Broken Creek.

As a result of the above processes, a great diversity of sediments occur, varying from very fine to coarse ones containing gravel. A closer investigation shows the possibility of a further subdivision of the groups.

<u>The flood-plain deposits.</u>

The fine, uniform group is divisible into:-

1. A normal group.
2. A group differing from the normal in that it gives rise to soils with friable subsoils.

This may be due to its greater age or to some difference in the composition of the sediment. These sediments occur in areas which would have been free from periodic flooding for the greatest length of time.

3. A group differing from the normal in that it gives rise to a group of heavy, immature soils. These sediments occur in an area which would have been most recently subject to periodic flooding from the Murray River.

<u>The channel deposits.</u>

The coarse, variable group is divisible into:-

1. A normal group
2. A group younger than normal, found adjoining the Murray River and in stream lines approaching it.
3. A group coarser than normal, containing gravel.

In the examination of the soils (*vide infra)* the influence of the sediments will be apparent.

The topography of the district is simple and subdued, the area consisting of a uniform plain which has a slope of 2 feet per mile toward the west. The contours are roughly parallel and run north and south. Excluding sandhills, which are a unique feature and may be up to 50 feet in height, the differences in level between various physical features are small. Terms such as depression, creek, swamp, high plain, and rise have a particular meaning when used to describe country with such subdued topography. Creeks are more or less continuous depressions usually two, and never exceeding ten, feet below the level of the plains. They are the natural drainage channels of the country but only occasionally carry water. Isolated depressions and low plains may be only a foot below the general level. A swamp is lower by two or three feet and usually receives drainage from creeks; it generally has an outlet and is dry for all but a few months each winter. Rises and high plains are only two or three feet above the average level.

There is quite an involved system of minor depressions covering the whole country, draining into deeper depressions which in turn may lead into creeks or swamps. By this means a drainage system of some capacity is produced, although in some sections the system is ineffective and leads only to local depressions more or less swampy. The country being so flat, the removal of surface water is slow, and small differences in relief have a considerable effect in the drainage regime; in consequence a wide range of drainage conditions is found, notwithstanding the low relief. The system of rises, high and low plains, creeks, depressions and swamps is reflected in the pattern of soil types. through the influence of drainage in pedogenesis.

Permanent water-tables are not a pedogenic factor. The first permanent ground-water is at about 70 feet, except within reach of the Murray River, when it is shallower depending on underlying sand drifts and the seasonal conditions.

II. THE SOILS AND THEIR CLASSIFICATION.

1. Definitions.

Before discussing the soils a few of the terms used are defined.

A soil type is a group of soils having the same general colour, texture, structure and arrangement of horizons in the profile and formed from a particular parent material. It is the unit used in soil mapping.

A phase is a modification of a soil type showing minor variations from the normal form of the type. The variation may be in such characteristics as depth or texture or structure of the horizons, but it does not alter the main character of the profile.

Profile is a vertical section of the soil through all its horizons and extending into the parent material or substrata.

Horizon is a layer of soil approximately parallel to the land surface, with more or less well defined characteristics that have been produced through soil-forming processes. The horizons mentioned in this bulletin are:-

> A_1 - surface layer containing organic matter. A variable amount of clay and soluble material has been leached out from this layer.
>
> A_2 - a light coloured layer, representing the zone of maximum leaching.
>
> B_1 - a zone of accumulation of some of the material, chiefly clay, leached from A horizons.
>
> B_2 - a zone of accumulation of some of the material notably calcium carbonate, leached from A and B_1 horizons.
>
> C - a layer of material representing the unchanged material from which the upper layers have formed.

Hardpan is a hardened or cemented soil horizon; the soil may be cemented by lime, silica, or other substances.

Catena is a group of soil types developed from similar parent material, differing from one another only by features that are the result of different drainage conditions.

Lime is calcium carbonate either in an incoherent form or as concretions, when it is also described as rubble.

2. Description of Soil Types.

In the field the soils show considerable diversity. The nature of the soil is governed by the character of the alluvium on which it has formed, by the drainage conditions operating during its genesis, and by its stage of maturity. The relationship between the soil types defined during the survey and the sediment from which they have been derived, and the drainage status has been set out in Table 3.

<u>TABLE 3 - The relationship of soil type to drainage and sediment.</u>

Drainage Status	FINE SEDIMENT GROUP		
	More recent sediments with immature soils	Normal sediments	Sediments giving rise to soils with friable subsoils
Very good			Katamatite loam
Good		Moira loam	Friable subsoil phase of Moira loam
Fair	Ulupna clay	Naringaningalook loam	Friable subsoil phase Naringaningalook loam
Poor	Mywee clay	Boosey clay	Friable subsoil phase of Boosey loam
Undrained	Muckatah clay-loam	Muckatah clay-loam	

Drainage Status	COARSE SEDIMENT GROUP		
	More recent sediments with immature soils	Normal sediments	Very coarse sediments
Very good		Cobram sandy-loam	Katunga gravelly-loam
Good	Koonoomoo Suite Type 3	Cobram loam	
Fair	Yarroweyah loam		
Poor	Koonoomoo Suite Types 1 and 2		

Excluded from Table 3 are Sandmount Sand which is formed on aeolian deposits and the "well drained depression soils" which are not homogeneous but grouped together because of similar topographic position and permeability of their profile.

A full description of each soil type is given below. The soil maps (see folder at end of bulletin) show the soils of the seven parishes classified into these types.

MOIRA LOAM.

Brown plains, generally fairly well drained.

A_1	0-6"	Brown loam, sometimes clay-loam; cloddy when dry, mellow to sticky when wet; sometimes with buckshot gravel.
A_2	6-8"	Light brown loam to sandy clay-loam; weakly cemented, slightly platey to structureless; sometimes with buckshot. (In some cases this "bleached layer" has been destroyed by cultivation).
B_1	8-27"	Brown to red-brown heavy clay; hard and brittle when dry, stiff and intractable when wet, with a blocky hard fracture; a few permanent cleavage lines through the mass.
B_2	27-40"	Mottled yellow-brown and brown or grey-brown heavy clay; slightly granular structure, compact and hard when dry, plastic and stiff when wet; with light lime and limestone rubble.
C	40-72"	Mottled grey-brown and yellow-grey medium clay tending to light clay with depth; granular structure, plastic when wet, crumbly when dry; trace of limestone rubble.

In those areas of Moira loam that have "light profile" on the soil map, light clay comes in at 36".

MOIRA LOAM - FRIABLE SUBSOIL PHASE.

Brown plains, well drained.

A_1	0-6"	Brown loam; hard but friable when dry, mellow to plastic when wet; sometimes with slight buckshot.
A_2	6-8"	Light brown loam to sandy clay-loam; weakly cemented, slightly platey to structureless; sometimes with buckshot. (This bleached layer has sometimes been destroyed by cultivation).
B_1	8-27"	Warm brown to red-brown heavy clay; hard and massive when dry, stiff to slightly friable when wet; with a blocky hard fracture and a few permanent cleavage lines through the mass.
B_2	27-40"	Greyish yellow-brown clay, with a few black specks; slightly cemented, with slight platey structure; readily breaks down to yellow friable mass.
B-C	40-58"	Transition between B_2 and C - with slight stoney rubble.
C	58-72"	Mottled yellow-grey-brown light to medium clay; friable to granular, plastic when wet, crumbly when dry; with slight stoney rubble.

In those areas of friable phase of Moira loam that have "light profile" on the soil map, the friable B_2 comes in at 21".

NARINGANINGALOOK LOAM.

Grey-brown plains or depressions, slightly lower and less well drained than Moira loam.

A_1	0-5"	Grey-brown loam, sometimes clay-loam; structureless, cloddy when dry, mellow to sticky when wet; sometimes with slight buckshot.
A_2	5-7"	"Bleached layer", light grey-brown sandy clay-loam; weakly cemented, slightly platey structure; sometimes with light buckshot. Boundary between this and next horizon ill-defined. (In some cases this horizon has been destroyed by cultivation).
B_1	7-24"	Dark brown to grey-brown heavy clay; hard and brittle when dry, stiff and intractable when wet; with a blocky ham; fracture, a few permanent cleavage lines through the mass.
B_2	24-40"	Mottled grey-brown and yellow-grey heavy clay; compact and hard when dry, plastic and stiff when wet, structure becoming slightly granular; with light lime and rubble.
C	40-72"	Yellow-grey mottled with grey-brown medium clay, tending to light clay with depth; granular structure, plastic when wet, crumbly when dry; trace of limestone rubble.

In those areas of Naringaningalook loam that have "light profile" on the soil map, light clay comes in at 36".

NARINGANINGALOOK LOAM - FRIABLE SUBSOIL PHASE.

Grey-brown depressions in plains of friable phase of Moira loam.

The sequence of texture and structure as in the friable phase of heirs. loam.

The sequence of colour is the same as for the Naringaningalook loam.

BOOSEY LOAM

Brownish-grey low plains, depressions and creeks, lower and not so well drained as Naringaningalook loam, sometimes slightly crab-holey, surface slightly cracked when dry.

A_1	0-5"	Brownish grey loam, or frequently clay-loam; hard cloddy when dry, sticky to mellow when wet; sometimes with slight buckshot.
A_2	5-7"	Light grey clay-loam or sandy clay-loam; weakly cemented slightly platey structure; sometimes with light buckshot. (This horizon has sometimes been destroyed by cultivation).
B_1	7-15"	Grey-brown to yellow-grey heavy clay; hard and massive when dry, stiff and intractable when wet;
	15-21"	Yellow-grey heavy clay.
B_2	21-36"	Yellow and grey mottled heavy clay; compact and hard when dry, plastic and stiff when wet; structure becoming slightly granular; with light lime and rubble.
C	36-72"	Mottled yellowish-grey and grey medium clay tending to light clay with depth; granular structure, plastic when wet, crumbly when dry; trace of limestone rubble.

In those areas of Boosey loam that have "light profile" on the soil map, light clay comes in at 36".

BOOSEY LOAM - FRIABLE SUBSOIL PHASE.

In rather low swampy localities in plains of friable subsoil phase of Moira loam.

A_1	0-5"	Brownish grey loam; hard cloddy when dry, plastic when wet; often with slight buckshot.
A_2	5-9"	Light grey-brown sandy clay-loam; often with light buckshot; structureless, slightly cemented.
B_1	9-24"	Yellow-grey heavy clay; hard and massive when dry, stiff to slightly friable when wet, with a hard blocky fracture.
B_2	24-36"	Greyish yellow clay; slightly cemented, with slightly platey structure; readily breaks down to yellow friable mass.
B-C	36-48"	Transition between B_2 and C.
C	48-72"	Mottled brown-yellow-grey light to medium clay; granular, mellow; with slight rubble.

MUCKATAH CLAY-LOAM.

Lowest and poorest drained member in Moira - Naringaningalook - Boosey - Muckatah catena. Grey depressions or swamps or creeks, generally crab-holey; soil deeply cracked when dry.

A_1	0-2"	Grey clay-loam or sometimes clay with rusty mottling; hard and blocky when dry, plastic to stiff when wet.
A_2	2-4"	Light-grey clay-loam or light clay; hard and brittle when dry, plastic to stiff when wet. Ill-defined horizon fingering into B_1.
B_1	4-24"	Grey heavy clay, with slight yellowish or brownish mottling; hard and massive when dry, stiff and intractable when wet.
B_2	24-40"	Mottled grey and yellow-grey heavy clay; may be slightly granular but otherwise as for B_1; slight diffused lime and rubble.
C	40-72"	Mottled yellowish-grey and grey medium clay, tending to light clay with depth; granular structure, trace of rubble.

KATAMATITE LOAM.

Plains and as slight depressions in plains of Moira loam friable subsoil phase; frequently has buckshot on surface.

A_1	0-5"	Brown loam; hard friable when dry, mellow to plastic when wet; sometimes with slight buckshot.
A_2	5-10"	Light-brown loam to sandy clay loam; weakly cemented, slightly platey to structureless; sometimes with buckshot. (This bleached layer has sometimes been destroyed by cultivation).
B_1	10-18"	Yellowish-brown clay; with slight nutty structure; easily breaks down to a brown-yellow mellow mass.
B_2	18-36"	Greyish yellow-brown clay, with a few black specks; slightly cemented, with slight platey structure; readily breaks down to yellow friable mass.
B-C	36-54"	Transition between B_2 and C - with slight stoney rubble.
C	54-72"	Mottled yellow-grey-brown light to medium clay; friable to granular, plastic when wet, crumbly when dry; with slight stoney rubble.

ULUPNA CLAY.

Dark brown-grey heavy plains, fair drainage, cracked when dry.

A_1	0-3"	Rather dark brown-grey clay; lumpy to nutty structure, hard brittle when dry, plastic when wet.
A_2	3-5"	Ill-defined bleached layer of mottled light grey and brownish-grey light clay; slightly cemented, with less structure than A_l; rusty inclusions; merges into B_1.
B_1	5-22"	Dark yellowish or brownish grey heavy clay; hard and brittle when dry, stiff and intractable when wet; lumpy structure.
B_2	22-36"	Dark yellowish grey heavy clay; structure more massive and less developed than in B_1; trace of limestone rubble.
B-C	36-48"	Yellowish gley heavy clay; hard when dry, stiff and plastic when wet; slightly crumbly; slight limestone rubble.
C	48-72"	Grey with yellowish and brownish mottling, heavy clay; slightly crumbly.

MYWEE CLAY.

Dark-grey heavy relatively low plains with poor drainage, sometimes crab-holey and deeply cracked when dry.

A	0-4"	Dark-grey medium clay with organic matter rusty mottling; nutty structure slightly developed; hard and brittle when dry, mellow to plastic when wet.
B_1	4-18"	Dark grey or dark brownish-grey heavy clay; hard and brittle when dry, mellow to plastic when wet; showing a degree of lumpy to coarse nutty structure.
B_2	18-36"	Heavy clay not so dark in colour as B_1, yellowness coming in with mottling; more massive and intractable than in B_1; trace of limestone rubble towards bottom of horizon.
C	36-72"	Mottled grey and yellow-grey heavy clay; tending to granular structure but massive and intractable.

COBRAM LOAM.

Well drained brown plains.

A_1	0-6"	Brown loam frequently fine sandy to silty; hard and crumbly when dry, plastic to mellow when wet.
A_2	6-9"	Bleached layer, light brown sandy loam to sandy clay loam; slightly cemented, slightly platey structure. (This horizon sometimes destroyed by cultivation).
B1	9-27"	Warm brown to red-brown heavy clay; hard and massive when dry, stiff to slightly friable when wet; with a blocky, hard fracture, and a few permanent cleavage lines through the mass. From 21-27" a transition of brown rather mellow clay to B_2.
B_2	27-36"	Yellowish grey-brown, slightly mottled, light clay passing to micaceous fine sandy clay; platey formation; granular structure, mellow to plastic when wet; slight limestone rubble.
B-C	36-72"	Mottled yellow-grey-brown micaceous fine sandy clay tending to fine sandy loam, sometimes with strata of fine sandy loam; platey formation; mellow to plastic. slight limestone rubble.

In those areas of Cobram loam marked "grey-brown" on the soil map, the sequence of textures is normal but the sequence of colours is more grey-brown throughout the profile.

LIGHT PHASE OF COBRAM LOAM.

Well drained high plains or ridges.

A_1	0-6"	As for Cobram loam.
A_2	6-9"	As for Cobram loam.
B_1	9-18"	Warm brown to red-brown heavy to medium clay; slightly granular structure, plastic when wet, hard crumbly when dry; passing by transition of light clay to -.
	18-27"	Yellowish grey-brown micaceous fine sandy clay, mellow to plastic.
B-C	27-72"	Strata of yellowish grey-brown fine sandy clay, fine sandy clay-loam and fine sand, all micaceous; trace of limestone rubble throughout with greater accumulation at 30-39".

COBRAM SANDY-LOAM.

Low sandy rises, frequently adjoining creeks, or as sandy plains.

A_1	0-8"	Brown sandy loam; structureless, hard crumbly when dry, free plastic when wet.
A_2	8-18"	Light brown sandy loam similar to A_l, gradually working up through sandy clay-loam to:-
B_1	18-27"	Brown to red-brown sandy clay going to sandy medium clay; structureless, massive and hard when dry, plastic when wet.
B_2	27-36"	Greyish brown sandy clay or fine sandy clay; mellow to plastic; with slight limestone rubble.
B-C	36-72"	Stratified yellow-grey-brown sandy clay, sandy clay loam, micaceous fine sandy clay or fine sandy clay-loam with trace of limestone rubble.

KATUNGA GRAVELLY LOAM.

Gritty or gravelly rises.

A_1	0-6"	Greyish brown sandy loam with gravel; loose, incoherent.
A_2	6-21"	Light brown sandy loam with gravel; upper 9" slightly cemented, lower 6" lighter in colour and incoherent.
B_1	21-27"	Brown to red-brown light clay with yellowish mottling and with gravel; hard, crumbly when dry, mellow, plastic when wet.
B_2	27-48"	Cemented hard-pan: mottled grey brown, brown and yellow with black inclusions; with gravel.
C	48-72"	Stratified light sediments - micaceous fine sandy clay- loam; clayey sand, sandy clay-loam.

KATUNGA LOAM.

Brown plains, generally adjoining or near areas of Katunga gravelly loam.

A_1	0-6"	Brown loam with slight grit; cloddy when dry, mellow to sticky when wet.
A_2	6-9"	Light brown sandy clay-loam with slight grit; slightly cemented.
B_1	9-24"	Brown heavy clay with some gravel; hard and brittle when dry, stiff and intractable when wet; with blocky hard fracture.
B_2	24-36"	Hard-pan; grey brown mottled with brown and yellow; with some gravel.
C	36-72"	Mottled yellow-grey-brown stratified sandy clay, micaceous fine sandy clay and fine sandy clay-loam.

YARROWEYAH LOAM.

Grey low country; found mostly between Cobram association and Koonoomoo Suite Type 2.

A_1	0-5"	Grey loam or silty loam; tends to form crust, hard crumbly when dry, plastic to mellow when wet.
A_2	5-9"	Light grey-brown sandy or silty clay loam; structureless, compact and cloddy; with soft rusty concretions.
B_1	9-24"	Warm brown to grey-brown medium to heavy clay; hard and brittle when dry, stiff and intractable when wet; blocky fracture with a few permanent cleavage lines through mass.
B-C	24-36"	Grey-brown with yellowish mottling, light clay, becoming micaceous fine sandy clay; mellow to plastic.
	36-72"	Stratified mottled yellow grey-brown micaceous fine sandy clay, fine sandy clay-loam and fine sand; mellow, granular to plastic.

KOONOOMOO SUITE.

<u>Type 1.</u> This is the unnamed Type 1 of the Boosey-Cobram-Katamatite soil map. It occurs as light grey low areas or in creek lines, frequently associated with Boosey and Broken Creeks.

A_1	0-4"	Grey silty clay loam; structureless, hard and lumpy when dry, plastic and sticky when wet.
A_2	4-10"	Light grey silty clay loam; slightly cemented, structureless with soft rusty concretions.
B_1	10-24"	Yellowish grey heavy clay; hard and massive when dry, stiff and intractable when wet; with infiltrations of A_2.
B-C	24-36"	Light grey, with yellowish mottling, silty clay, with black and white inclusions.
	36-72"	Yellowish grey, with brownish mottling, silty clay-loam, with bands of silty clay.

KOONOOMOO SUITE. (Contd.)

Type 2. Light grey flats adjoining the Murray River and as creek lines in the adjoining heavy country. The profile is immature.

A	0-5"	Grey, with a slight grey-brown mottling, silty clay loam; with some soft buckshot.
A-B	5-14"	Light grey with yellowish-brown mottling, silty light to medium clay; with soft buckshot and charcoal.
B-C	14-27"	Light grey with yellowish-brown mottling silty medium clay; structureless, plastic and sticky when wet, hard but powdery when dry; with charcoal.
27-72"		Light grey and greyish-brown mottled silty clay, texture varying in bands; fairly mellow.

Areas of this type marked "heavy subsoil" on the soil map rest on a substratum of mottled yellowish grey, intractable heavy clay at 48".

KOONOOMOO SUITE. (Contd.)

Type 3. Brown or grey-brown higher country associated with Type 2; profiles ere immature and variable.

A_1	0-8"	Grey-brown silty loam.
A_2	8-12"	Light grey-brown silty clay loam.
B	12-24"	Grey-brown light clay.
	24-72"	Grey-brown sandy Clay loam with alternating strata of micaceous fine sandy clay loam and silty clay.

SANDMOUNT SAND.

Sand hills.

A_1	0-7"	Greyish brown incoherent coarse sand.
A_2	7-54"	Light red-brown incoherent sand.
B	54-60"	Brown with red and yellow mottling sandy clay loam.
C	60-72"	Brown clayey sand.

SANDMOUNT SAND - SHALLOW PHASE.

Smaller sand hills or fringing larger ones.

A_1	0-7"	Greyish brown incoherent sand.
A_2	7-36"	Light red-brown incoherent sand.
B	36-42"	Brown with red and yellow mottling sandy clay-loam.
	42-72"	Stratified clayey sand, sandy clay-loam, fine sandy clay-loam etc.

WELL DRAINED DEPRESSION SOILS.

Type A. Grey-brown depressions, light but not sandy.

A_1	0-6"	Grey-brown loam; cloddy when dry, mellow to sticky when wet.
A_2	6-10"	Light brown loam; slightly cemented, passing by gradual transition to -
B	10-30"	Brown clay; granular structure, plastic when wet, hard crumbly when dry.
B-C	30-48"	Grey-brown with yellowish mottling light clay or micaceous fine sandy clay; mellow; granular structure; trace of limestone rubble.
	48-72"	Mottled yellow-grey-brown stratified silty clay, micaceous fine sandy clay and fine sandy clay-loam.

Type B. Grey-brown depressions, light and sandy.

A_1	0-5"	Grey-brown sandy loam; hard crumbly when dry, free plastic when wet.
A_2	5-12"	Light brown sandy loam; slightly cemented passing by gradual transition to -
B	12-27"	Brown to greyish brown sandy clay-loam becoming sandy clay.
	27-72"	Mottled grey-brown and yellow-brown sandy clay-loam, fine sandy clay-loam etc. stratified.

Type C. Grey light depressions.

A_1	0-5"	Grey sandy loam or loam.
A_2	5-12"	Light grey sandy loam or loam with soft rusty concretions.
B	12-24"	Grey with greyish brown mottling, sandy clay loam going to sandy clay, or light clay; with soft buckshot.
	24" +	Mottled light-yellow-grey, light grey and grey-brown silty clay, fine sandy clay or sandy clay-loam stratified.

Type D. Brown light depressions.

The profile is similar to the Katamatite loam, but the soil occurs only in depressions and creeks.

It is important to realise that the soil type rarely signifies a rigidly uniform condition throughout the area on the map enclosed by a certain boundary and given a certain symbol and colour. For practical mapping purposes a soil type may be considered as a group of soils having characteristics approximating to a normal or ideal soil which represents the type, but varying in some degree from that normal and merging towards adjoining types. There is a zone of transition where soil types adjoin; also entire areas may consist of soils intermediate to the categories adopted in the classification. As an example of the latter case, a series of soils on sediments intermediate in texture between the normal fine group and the normal coarse group was placed with the former rather than in a new category. The soils formed on this intermediate sediment have been placed in the Moira catena (see below) with "light profile" printed on the map over the area. Another intermediate group of soils is the friable subsoil phase of Moira loam as found in the southern part of the parish of Strathmerton, and the northern part of the parish of Katunga. These soils, having developed from a somewhat coarser sediment, are not identical with but are closely related to soils classified as the same type in the parish of Katamatite.

3. Soils and Soil Relationships.

The soils of the district fall within the major zonal group of red-brown earths (Prescott, 1931). Typical soils from this survey may be compared with those of other parts of the red-brown earth zone of Victoria, in particular with types described from the adjacent Goulburn Valley. The Bamawm and Ballendella soils (penman, 1936b) are slightly solonised and rest at four or five feet on a bed of impervious grey clay, but otherwise they form a series loosely parallel to those described below. Some of the soils from the Tatura Horticultural Research Station (Penman, 1936a) conform fairly closely to types defined in this survey. For example, the soil described from Tatura as Type A is similar to Moira loam and Types D and E compare with Light Phase of Cobram loam and Cobram sandy-loam respectively. Soils with as much buckshot as Types B and C are not common on this survey, but probably Boosey loam would be most comparable.

From the descriptions available (Penman, 1940) it seems likely that the soils of the State Research Farm at Werribee are also comparable with the types of this district.

Jewell (1931) in an article on some typical soils from the irrigation districts of Victoria describes a soil "encountered at a number of places such as Tongala, Kyabram, Merrigum, Shepparton etc." which is like the Light Phase of Cobram loam, a soil "examined at Kyabram and Merrigum" which is similar to Moira loam, and one chosen from Shepparton similar to Cobram sandy-loam.

(a) Soil Catenas.

The depressions and drainage lines have an effect on the configuration of soil types and, in mapping, micro-relief was used in delineating soil boundaries. The stages reached under conditions of slight to considerable surface flooding lead to the evolution of a series of soils with internal drainage varying from good to poor. On a common sediment such a series constitutes a catena, the members of which are rather arbitrarily separated as they grade into one another according to the drainage of the profile.

The best illustration of the catena is the sequence Moira loam - Naringaningalook loam - Boosey loam - Muckatah clay-loam. An examination of their profiles shows that there has been leaching of the clay from the surface horizon and a partial podsolising effect in the lighter coloured A_2 horizon. The immediate capping of the B_1 horizon is denser and darker than the rest of B_1 and sharply defined from the partly bleached A_2. These features are least marked in the Muckatah clay-loam. In the Naringaningalook loam and Boosey loam the boundary between A2 and B1 horizons is uneven, fingers of A_2 penetrating irregularly into a degraded capping several inches thick on the B1 horizon. The zone of illuviation of $CaCO_3$ is at 24-30 inches in all soils.

The sequence Ulupna clay - Mywee clay - Muckatah clay-loam constitutes a similar catena. All these soils have a profile less mature than those of the Moira catena. There has been little eluviation of clay from the surface; the A_2 or "bleached layer" is absent or poorly developed, but is apparently developing with the degradation of the surface of B_1 as in the case of Naringaningalook loam. The B_1 is shallow and not well differentiated.

The friable sub-soil phases of Moira loam - Naringaningalook loam - Boosey loam constitute a catena of phases closely parallel to the normal Moira sequence. There does not seem to be any equivalent to the Muckatah clay-loam as the poorly drained member. The friable nature of the subsoils of this sequence of soils is its only important difference from the normal Moira catena. The subsoils of the phases, when analysed by the standard methods of mechanical analysis, appear no different from those of the normal types, but though there is no distinction in ultimate particle size, there is a pronounced difference in the structure of the clay.[*] The material has a slightly platey to granular structure and readily breaks down into a mellow, friable mass which, only on prolonged kneading, begins to reveal its high clay content. The Katamatite loam is of considerable interest because the friable characteristic is developed in B_1 as well as in B2 horizons.

Soils formed on the coarser sediments do not form well developed catenas. They represent in most cases the well drained member of different catenas, the other members of which are missing.

(b) Soil Association

Because of the incompleteness of the catena groups, some other simplification of the complex of soil types which characterises the soil map was sought. It was found in practice that any part of the area could be classified into one or other of several generalised landscapes. Because of the influence of drainage on the development of soils, a given soil type occupies a fixed topographical position in any landscape in which it occurs. Consequently in each particular landscape there is a characteristic group of soils. For the purposes of this report each such soil group in its particular landscape has been called a soil association. The soils within the association will bear a hydrographic relationship to one another according to their respective positions in the landscape, but they need not necessarily form a single catena nor conform to any other system of grouping.

Classification by association is to some extent a utilitarian conception and to that degree the broadness of the categories can be governed by the purpose to be served.

[*] A similar condition has been observed in certain soils of the Murrumbidgee Irrigation Area, N.S.W. (See Coun. Sci. Ind. Res. (Aust.) Bull. 118, 1938).

The soil associations recognised in this survey are:-

(i)	Moira association	(v) Cobram association	
(ii)	Boosey "	(vi) Katunga	"
(iii)	Katamatite "	(vii) Koonoomoo	"
(iv)	Ulupna "	(viii) Sandmount	"

A map* shows the seven parishes classified into these associations, which the farmer may recognise as types of "country".

(i) The Moira association is made up chiefly of medium to heavy soils.

Dominant soil type:- Moira loam.

Subdominant soil types:- Naringaningalook loam, Boosey loam, and Muckatah clay-loam.

Minor soil types:- Cobram loam, Cobram sandy loam, well drained depression soils, and Type 1 of the Koonoomoo Suite.

The landscape is dominated by plains, a network of slight depressions cover the plains connecting deeper depressions, creeks, and swamps. The system of creeks provides a moderately effective drainage system; temporary swamps are a significant element.

Moira loam is the soil of the plains, Naringaningalook loam is in the slight depressions, Boosey loam in deeper depressions and creeks, and Muckatah clay-loam in creeks and swamps. Cobram loam sometimes occurs on high plains, Cobram sandy-loam as low ridges, often adjoining creeks, while some creek formations are included as well drained depression soils. Type 1 of Koonoomoo Suite is found in a few swamps and creek lines.

The vegetation is dominantly, often exclusively grey box, with buloke on the heavier, and yellow box and pine on the lighter soils.

(ii) The Boosey association has a different landscape pattern and differs from the Moira association also in the relative importance of its component soils.

Dominant soil types:- Boosey loam and Muckatah clay-loam.

Subdominant soil types:- Moira loam and Naringaningalook loam.

Minor soil types:- Ulupna clay, Mywee clay, and Type 1 of Koonoomoo Suite.

The landscape is dominated by low plains and swampy areas; higher plains and rises are subordinate. There are few well-developed drainage lines, water finding its way from the low plains into local swamps which may in turn overflow into more definite channels.

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* See folder at back of bulletin.

Boosey loam is the soil of the low plains and Muckatah clay-loam of the swamps. Naringaningalook loam and Moira loam occur on slightly higher plains and rises; Ulupna clay and Mywee clay occur on some poorly drained flats, with Type 1 of Koonoomoo Suite in depressions or swamps.

The vegetation is grey box with buloke subdominants while red gum is found near the Boosey and Broken Creeks.

(iii) The Katamatite association is composed chiefly of soils having friable subsoils.

Dominant soil type:- Friable subsoil phase of Moira loam.

Subdominant soil types:- Katamatite loam, friable subsoil phase of Naringaningalook loam, and friable subsoil phase of Boosey loam.

Minor soil types:- Moira loam, Naringaningalook loam, Boosey loam, Muckatah clay-loam, Cobram loam, Cobram sandy loam, and well drained depression soils.

The landscape consists almost exclusively of plains, so that depressions, creeks, and swamps are minor elements.

In spite of a poorly developed creek system the country is quite well drained, indicating good internal drainage of the soils.

On the plains the friable subsoil phase of Moira loam occurs and to a much lesser degree Katamatite loam, Cobram loam, and Moira loam. In depressions Naringaningalook loam and Boosey loam and their friable subsoil phases occur.

Of the minor types, well drained depression soils are found in a few creek lines, Cobram sandy-loam on low rises, and Muckatah clay-loam occasionally in temporary swamps.

The vegetation is grey box with pine subdominant; yellow box sometimes occurs on the lighter soils.

(iv) The Ulupna association is dominated by the heaviest soils.

Dominant soil type:- Ulupna clay.

Subdominant soil types:- Mywee clay and Muckatah clay-loam.

Minor soil types:- Boosey loam, Naringaningalook loam, and Type 2 of Koonoomoo Suite.

The landscape is an almost featureless plain. A few shallow watercourses provide a not very effective drainage system.
Ulupna clay occurs on the plains with Mywee clay in the lower areas and Muckatah clay-

loam in the lowest areas and swamps, although there are only slight differences in relief. Both the Naringaningalook loam in some higher localities and the Boosey loam on the plains are represented by individuals heavier than normal. Type 2 of Koonoomoo Suite occurs in some of the watercourses.

The vegetation consists of red gum with black box and grey box in transition areas.

(v) The Cobram association consists largely of light permeable soils.

Dominant soil type:- Cobram loam.

Subdominant soil types:- Cobram sandy loam, light phase of Cobram loam, Muckatah clay-loam.

Minor soil types:- Moira loam, Boosey loam, Yarroweyah loam, well drained depression soils and, in the parishes of Strathmerton and Katunga, the friable subsoil of Moira loam.

The landscape is less regular than in the preceding associations, although plains still dominate it. Rises and high plains are important and so too are depressions and swamps. The creek system is not well developed although, owing to the porous nature of the soil and the presence of light subsoil drifts, the country is well drained.

Cobram loam with its light phase occurs on the plains and Cobram sandy loam on rises and high plains. Boosey loam, Yarroweyah loam, and Muckatah clay-loam occur in depressions and swamps with well drained depression soils in creek lines. Moira loam and its friable subsoil phase are sometimes found on the plains associated with Cobram loam.

The vegetation is chiefly grey box but yellow box and pine are of increasing importance on the lighter soils.

(vi) The Katunga association is a variant of the Cobram association and differs from it by the presence of gravelly ridges in its landscape and by more erratic light subsoil drifts. These two factors will distinguish this from the Cobram association for management under irrigation.

The soil of the gravelly rises is the Katunga gravelly loam. A minor type not found in the Cobram association is the Katunga loam occurring on plains. In other components and their occurrence the two associations are similar.

The vegetation is also the same.

(vii) The Koonoomoo association consists of the immature silty soils adjoining the Murray River and in former stream lines leading into it.

Dominant soil types:- Type 2 of Koonoomoo Suite and Yarroweyah loam.

Subdominant soil types:- Muckatah clay-loam, Type 3 of Koonoomoo Suite.

Minor Soil Types:- Well drained depression soils.

The landscape consists of irregular flats traversed by deserted watercourses, swampy areas, and low rises.

On the flats, Type 2 of Koonoomoo Suite and Yarroweyah loam occur - the former being dominant near the river, the latter further from it. Swamps are of a silty Muckatah clay-loam, and slight rises are of Type 3 of Koonoomoo Suite.

The vegetation is dominantly red gum with yellow box in well drained positions and grey box on Type 3 of Koonoomoo Suite.

(viii) The Sandmount association consists of sandy rise soils of aeolian origin.

Dominant soil type:- Sandmount sand.

Subdominant soil type:- Shallow phase of Sandmount sand.

Minor soil types:- Cobram sandy-loam, Cobram loam, Type 2 of Koonoomoo Suite, and various well drained depression soils.

The landscape consists of wind-blown sand hills with intervening areas of minor components at lower levels.

The higher areas are of Sandmount sand with its shallow phase on the lower rises and fringing areas of the sand hills.

The vegetation is pine and yellow box.

4. The Relation of the Soil Types to Agriculture.

The area forms part of one of the important wheat and fat lamb districts of Victoria; yields of 36 bushels of wheat to the acre are not rare, and developed land generally carries one wet sheep to the acre. Most of the soil types are equally fertile but each succeeds best in a particular kind of season.

The soils of the whole area, more particularly such types as Moira loam, and Naringaningalook loam, in common with other soils in the Goulburn Valley (Penman, 1936a) are conspicuous among agricultural soils for their shallow surface and underlying "clay pan" (B horizon). In the practice of wheat farming, the condition is met by careful cultivation without the productivity of the soils being impaired; but it is thought that in irrigation husbandry their unique character may necessitate some considerable departure from normal watering and cultural technique.

Chemical analyses, discussed below, show a considerable degree of uniformity among the soils. With the exception of Yarroweyah loam, Sandmount sand, and the soils of the Koonoomoo Suite, they are all slightly acid to neutral at the surface, slightly alkaline in the B_1 and quite strongly alkaline in the B_2 and C horizons.

All soils are deficient in phosphates; the usual application for wheat and oats is 60 to 100 lb. of superphosphate per acre, but the pastures are not generally top-dressed. The nitrogen content is normal for such soils in Australia; in an average season a crop grown on fallow has its requirements adequately supplied, though it is expected that those grown on stubble would be improved by nitrogenous manures. The soils are well supplied with potash.

The physical characteristics of the soil types show considerable variation which determines their agricultural significance and value. The physical characteristics involved are internal and external drainage capacity, texture, and structure.

Cultivation has caused a general though not very serious deterioration in the structure of the surface soils, with a resultant loss in productivity. The deterioration is characterised under wet conditions by greater stickiness with a liability to run together, and under dry conditions by cracking and the formation of hard clods. Repeated cropping accentuates this deterioration in structure, while resting the soil at pasture for a period allows a reversion to a more favourable state. Irrigation offers more potent means of improving or depreciating soil structure than does dry farming. The growth of pastures and lucerne with irrigation will provide conditions favourable to improvement in the physical condition of the soil. In horticultural areas, where the soil is clean cultivated and frequently saturated, heavy traffic and constant stirring tend to destroy structure. Soils of this area suited to horticulture are considered liable to this deterioration.[*]

In the absence of local experiments and trials the value of the soil types for irrigation purposes cannot be assessed with any certainty, and until trials are conducted results from Tatura Horticultural Research Station and Werribee Research Station, Victoria, and Griffith Research Station, N.S.W., must be adapted, where possible, to local conditions. From the examination of the soils and local practices and from comparisons with adjoining irrigation districts a few general principles may be formulated.

With the intensification of culture implied by irrigation husbandry, a heavier manuring policy will be necessary, Experiments are desirable to define the requirements more precisely, but on present information (Bartels *et. al.* 1928, 1933) it is expected that it will pay to add 400 lb. of superphosphate per acre to lucerne and permanent pastures and 200 lb. to annual irrigated pastures. Six cwt. of superphosphate per acre is applied to horticultural crops at Cobram. Nitrogenous manures will be required for all except leguminous crops; 6 cwt. of sulphate of ammonia, in two applications, is added to peaches at Cobram. Potash may even be found to produce a favourable response.

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[*] Observations on comparable soils in the Murrumbidgee Irrigation Area, N.S.W., confirm this opinion.

Under irrigation the soil types will stand in greater contrast to one another than they do under extensive dry farming; it is expected that the contrast will be reflected in different cultural techniques rather than in different productivity levels. Irrigation technique will be simplified if the area watered consists of a single soil type; where there are two or more soils of widely differing permeability within the same run or bay, serious overwatering is liable to occur and the ultimate waterlogging of the more permeable type may result.

The building up of high water tables is a latent evil in all irrigated areas, to be countered by a conservative watering policy, and, if necessary, by drainage. In this area, where the general ground-water level is at 70 feet and not more than a quarter of the area will be irrigated, the danger is not imminent. It cannot be assumed however that water table troubles are impossible; at best they are improbable, and their cumulative character makes forethought in the matter necessary even at this early stage. It is clear too that the problem must be treated as a community one. The numerous sandy and gravelly drifts in some localities can well lead to seepage effects unless precautionary measures are taken, while in a few places the pre-irrigation water table is as shallow as 20 feet. In the design of the area there may be portions with much more than the average concentration of 25 per cent irrigated land surface. Where any of these conditions obtain, and still more where they coincide, a judicious watering policy is imperative.

The soils of the area do not contain sufficient salt to affect the growth of crops, and normal irrigation practice should not cause any aggravation of this condition. It will be only in localities where high water tables are established that salt accumulation can possibly reach concentrations prejudicial to crops. A discussion of the salt content of the soils will be found in a later section.

In describing the soils in relation to agriculture it is convenient to consider types rather than associations.

Moira loam is the important soil of the Moira association occurring as brown uniform plains. It is a strong growing soil, fairly compact and tending to cloddiness; it becomes sticky when wet, but works up to a good tilth under favourable moisture conditions. Moira loam absorbs water fairly slowly, and in a wet winter, because of its shallow "clay-pan" and low relief, may become over-wet. When irrigated it will need a watering technique suited to its restricted permeability and some surface drainage system to remove the excess water in a wet winter. A system using two small applications with a short interval between may be successful. In normal seasons it produces good crops of wheat and natural pasture. Lucerne may not persist as a profitable stand for a prolonged period on this soil, but sown pastures should do well. Pears would be the only suitable horticultural crop.

Those areas of Moira loam marked "light profile" on the soil map, being lighter soils than the normal Moira loam, are expected to react to irrigation in a manner intermediate between that set out above and that given for Cobram loam.

Naringaningalook loam is a grey-brown soil rather similar to the Moira loam but differing from it in its greater tendency to wetness because of its lesser permeability and lower topographical position. Under dry farming, it hardly differs from the Moira loam except that it will do better in a dry season and suffer sooner in a wet one. Similarly, when irrigated it will absorb water more slowly and be more inclined to surface water logging in winter.

Boosey loam carries the tendencies of Naringaningalook loam a step further from Moira loam. It is more compact and less amenable to cultivation, and, because of its slower permeability and lower topographical position, more inclined to wetness than these soil types. Notwithstanding these defects, it produces good crops of wheat in a suitable season, and should do satisfactorily under irrigation, provided excess water can be drained away and a suitable watering system evolved. Pasture seems to be the most suitable crop for irrigation.

Muckatah clay-loam is found in the lowest topographical position in the landscape, so that it is generally inundated for some months each winter. However, it is not infertile, since good catch crops have been taken from it in suitable seasons. The soil, for irrigation purposes, has several handicaps, being usually "crab-holey", liable to inundation, difficult to drain and physically unattractive.

Friable subsoil phase of Moira loam is a medium to light soil, less compact and more permeable than the normal Moira loam. It can be worked up to a good tilth under favourable moisture conditions but becomes cloddy or sticky at other times. The soil absorbs large amounts of water easily but becomes boggy; it has not as great a water holding capacity as Moira loam and consequently dries out earlier. In normal seasons it yields good crops of wheat and pasture but is not quite as high a producer as Moira loam. It should be easily irrigated with success, although its easy permeability may lead to overwatering and eventual waterlogging. Lucerne and stone fruits should do well under irrigation on this soil.

Katamatite loam is a minor type of considerable theoretical importance, as in it the property of friableness is more fully developed than in any other type. In its response to farming practice it resembles the friable subsoil phase of Moira loam, but it is more permeable.

Friable subsoil phase of Naringaningalook loam is a greyish-brown soil, less well drained and structured than the friable subsoil phase of Moira loam. The same relationship exists between these two phases as exists between normal forms of the soil types.

Friable subsoil phase of Boosey loam is found in low situations where it receives surface drainage from surrounding country. The physical condition of this soil is less favourable than in the friable subsoil phases of other types, but in this feature, as in its permeability, it is superior to the normal Boosey loam. In its response to either irrigation or dry farming, it may be considered as blending the virtues of a permeable subsoil with the defects of the Boosey loam.

Ulupna clay is a heavy soil but structured to some degree and consequently amenable to cultivation and moderately permeable. When dry it cracks freely into coarse nutty aggregates and when wet it is sticky, but at favourable moisture contents is also mellow. In the dry state it absorbs water rather freely up to a certain point, when it becomes waterlogged at the surface due to slow internal drainage. In seasons with good rains it grows heavy crops of wheat and natural pasture, but excessive rainfall causes a rapid deterioration in yields. It should be possible with careful management to irrigate this soil type successfully. The soil has a good water holding capacity but, owing to poor surface drainage and slow permeability, it is liable to swamping. The growing of pasture is the most promising use for this soil when irrigated; lucerne will not persist here as it does on brown, lighter soils.

Mywee clay is similar, agriculturally, to the Ulupna clay. It is at least as fertile as that type, but being at lower levels will suffer from wetness more quickly. It is sometimes crab-holey.

Cobram loam is a light to medium-textured soil, moderately compact at the surface though light and permeable in the subsoil. There is a tendency for the soil to become cloddy when dry, boggy and sticky when wet, but it works up to a good tilth under favourable moisture conditions. Under dry farming its culture and yields are similar to those of Moira loam; it has however, greater adaptability to wet seasons, and dries out earlier. It absorbs water readily and will be easily irrigated. The permeable subsoil facilitates the percolation of water, but this feature makes overwatering a danger and consequent water table trouble a possibility. Peaches and lucerne, have been successfully grown with irrigation on this soil.

Light phase of Cobram loam is a lighter soil than the Cobram loam, more permeable to water, and drying out earlier, It will be easily irrigated but even more liable to overwatering than the normal type, and the light subsoil drifts characterising this phase may dispose it more readily to eventual serious waterlogging.

Cobram sandy loam is similar to the Cobram loam but somewhat lighter and with a sandy surface. It is an early soil, porous and easily worked, but it dries out quickly, having a comparatively low waterholding capacity. It will be easily irrigated, but susceptible to overwatering. Citrus is successfully grown on this soil near Cobram.

Katunga gravelly loam has little agricultural importance as the total area is small, and it is considered a poor and droughty soil. Owing to its extreme porosity this type, in irrigated country, will be liable to cause serious seepage troubles.

Katunga loam has been found in such small areas that little can be said about its agricultural significance at this stage.

Yarroweyah loam has similar internal drainage qualities to the Cobram loam. It is found in rather low areas where it receives drainage water from higher country and, when close to the Murray River, has obviously been subject to flooding from that source. If surface water can be drained away the soil may be expected to react to irrigation like the Cobram loam except that its high silt content may tend to cause setting of the surface. It is an acid soil and for that reason probably unsuited to lucerne.

Koonoomoo Suite.

Type 1 is found in topographical positions corresponding o those occupied by Muckatah clay-loam. It is more permeable than that type, is not crab-holey, and its surface, being silty, is liable to set. Its agricultural significance is slight.

Type 2 a more important soil, is moderately permeable and up to the general level of fertility of the district.

The soil has an acid reaction, and lucerne is not expected to thrive on it for this reason, though pastures should do well. The soil is silty and 'liable to surface compaction.

Type 3 is a minor type, unimportant from an agricultural point of view. It is similar to Type 2 but occurs in higher positions; it generally has a very compacted surface.

Sandmount sand has characteristics general to sandy soils - high permeability, low water holding capacity, free drainage, and a low fertility status. It warms up quickly in the spring and cools quickly in the autumn, and makes the most effective use of light rains. When irrigated it calls for a special watering technique and frequent applications of manure, organic manures being particularly useful. Oranges are grown successfully on this soil at Cobram, where it is found that spray irrigation is more satisfactory than the furrow system of application.

Shallow phase of Sandmount sand has a heavier texture in the subsoil than the above soil and will behave in a manner intermediate between Sandmount sand and Cobram sandy-loam.

The well drained depression soils are significant in the drainage of the country rather than of importance in the growing of crops.

III. LABORATORY EXAMINATION OF SOILS.

1. Mechanical Analysis.

The procedure for mechanical analysis followed closely the standard International A pipette method; caustic soda was used as the dispersing agent. Representative analyzes are given in the Appendix covering the major types.

Coarse sand is the dominant fraction in the aeolian soils of the Sandmount sand and its shallow phase, but in most other soils it is present in negligible amounts. Fine sand is the important sand fraction in most cases, being present in the Cobram soil types in sufficient amounts to influence texture. Silt is of some significance in many soils, frequently exceeding 20 per cent. In the Koonoomoo Suite it is above 40 per cent. and these soils are referred to as silty clays and silty clay-loams. Silt is also important in the Cobram loam, rising to 30 per cent. in the surface soils. Clay is the controlling component in the texture of the subsoil horizons of all soils except the Sandmount sand.

In mature types such as the Moira loam and Cobram loam there has been marked eluviation of the clay from the surface; in immature types, as Mywee clay and Ulupna clay, the movement is not so obvious. the upper portion of the B_1 horizon is slightly higher in clay content than the underlying subsoil.

The soils formed on the fine group of sediments have a consistent composition of the C horizon as shown by a comparison of sample No. 10011 - Moira loam; and its friable phase - No. 9966; No. 3429 - Boosey loam; No. 5630 - Muckatah clay-loam; and No. 5637 - Ulupna clay. The distinction between coarse and fine sediments is indicated by the comparison of the above samples with No. 3397 - Cobram loam and its light phase - No. 3405. The Katunga gravelly-loam, Sample No. 9945, is unique in coarseness, particularly in its high percentage of gravel.

Fig. 2 shows summation curves of particle size for the C horizon of five representative soil types which indicate the range in composition of parent material in the surveyed area.

It was thought that the differences of structure shown in the field by the B_2 horizons of several types, such as Moira loam and its friable subsoil phase, could be confirmed by certain laboratory tests. Apparent specific gravity and the state of aggregation of the soils were studied, but only slight and probably insignificant differences were found. The data for Katamatite loam were more significant when compared with those for Moira loam. From limited tests it is thought that a study of pore-size-distribution curves for the soils will show that, although the percentage of total pore space is almost the same, the percentage of pores with a diameter greater than 0.02 mm. may be considerably higher in the friable as compared with the normal soil.

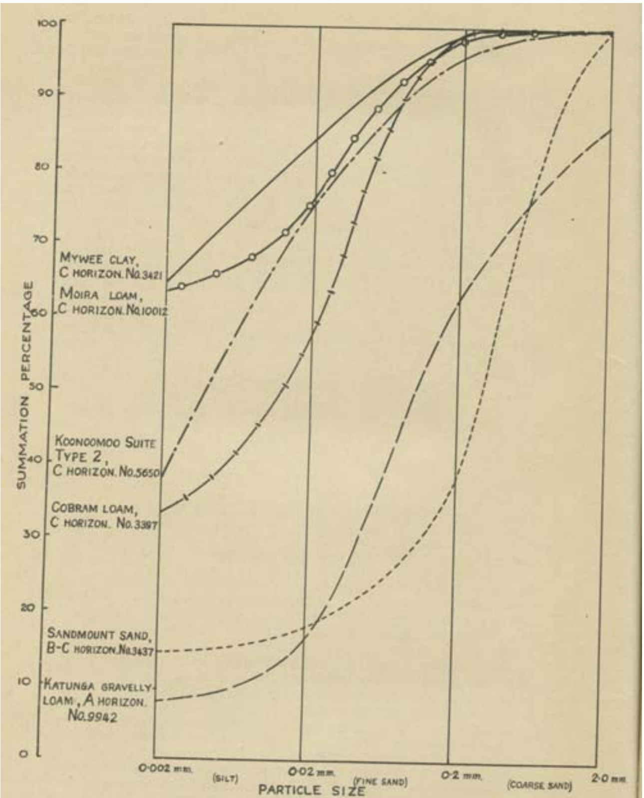

FIG. 2.

Summation Curves of Representative Textures.

Fig 2 – Summation Curves of Representative Textures

The $CaCO_3$ figures in the tables are the amount in the fine earth fraction, but most of the "rubble and gravel" noted in subsoils is also calcareous. The zone of lime illuviation is approximately 20-39 inches in most soils. There is not a wide variation in lime content between the red-brown earth types, but Mywee and Ulupna soil types are low, and Sandmount, Yarroweyah, and Koonoomoo types very low or lacking in free lime. Gypsum is rarely encountered.

2. Soil Reaction.

pH values were determined with the glass electrode in 1:5 soil - water suspension which had been previously shaken for one hour. The results for typical profiles are given in the tables of Mechanical Analyses (Appendix). The results of all of the samples so far analysed are summarised in Table 4.

TABLE 4 - Distribution Table of soil reaction values.

Soil Group	pH						
	6.0 to 6.5	6.5 to 7.0	7.0 to 7.5	7.5 to 8.0	8.0 to 8.5	8.5 to 9.0	9.0 to 9.5
The less permeable red-brown earths							
A horizons	3	5	7	-	-	-	-
B horizons	-	-	2	1	6	9	2
C horizons	-	-	-	-	7	16	18
The more permeable red-brown earths							
A horizons	7	6	6	-	-	-	-
B horizons	3	3	-	6	6	4	2
C horizons	-	-	-	1	2	18	28
The recent sediment soils							
A horizons	5	1	-	-	-	-	-
B horizons	3	3	-	-	-	-	-
C horizons	2	2	3	-	2	-	-
The grey-brown soils							
A horizons	-	3	1	1	-	-	-
B horizons	-	-	-	1	2	4	1
C horizons	-	-	-	-	5	8	1

For the purpose of this table the red-brown earths are divided into two groups, a less permeable and a more permeable group. The former comprise Moira loam, Naringaningalook loam, Boosey loam, and Muckatah clay-loam; the latter Cobram loam and its light phase, friable phase of Moira loam, Katamatite loam, Katunga loam, and Katunga gravelly loam.

It will be seen that the more permeable group is slightly more acid in the A horizons and in the B horizons; of the latter, Bi is most distinct in this tendency. In the C horizon the deeper samples tend to be least alkaline. The soils included in "the recent sediment soils" comprise the Koonoomoo Suite Types and Yarroweyah loam; these soils are acid throughout excepting in the deep subsoil where some become neutral or alkaline. The soils included in "the grey-brown soils" are Mywee clay and Ulupna clay; these soils are less acid at the surface and less alkaline in the C horizon than are the red-brown earths corroborating the view that they are less mature.

The Sandmount sand is not included in Table 4, it is neutral throughout its profile which is free of lime.

3. Replaceable Bases.

The soils were leached with 40 per cent, alcohol to remove soluble salts before extraction with normal NH_4Cl and NaCl. Sodium was determined by the magnesium-uranyl-acetate method, potassium by the chloroplatinate method, calcium by precipitation as oxalate, and magnesium as pyrophosphate.

Exchangeable hydrogen was not estimated. The results are given in Table 5.

TABLE 5 - Replaceable bases soils.

Soil type	Soil No*	Depth in	pH	Clay %	Total Replaceable† Bases	Percentage of total cations as			
						Ca	Mg	Na	K
Sandmount sand	3434	0-6	7.0	5.6	2.7	57	35	5	3
Cobram loam	(3392)	0-6	636	25.5	9.0	47	42	5	8
	(3409)	0-4	6.3	17.1	8.4	59	29	3	9
	(3400)	0-4	6.5	20.4	9.3	39	46	7	8
	(3401)	4-13	6.1	42.7	14.3	20	59	19	2
Moira loam, friable subsoil phase	(9960)	2-5	7.1	23.6	9.2	60	27	3	10
	(9961)	5-9	6.9	22.6	6.5	53	33	5	9
	(9962)	10-20	8.1	67.1	19.0	31	52	7	10
	(9963)	20-28	8.5	65.7	24.1	24	51	7	18
	(9983)	0-6	5.8	22.0	7.3	48	31	3	18
	(10452)	0-5	7.0	13.1	6.3	50	31	6	13
	(10455)	20-28	9.1	56.9	22.5	31	47	6	16
	(9970)	20-27	7.0	56.0	17.1	31	42	6	21
Moira loam	(9994)	0-6	6.5	22.3	8.0	52	33	5	10
	(9995)	6-15	8.2	65.6	21.7	37	50	6	7
	(9996)	15-21	8.5	64.5	23.2	33	54	7	6
	(9997)	21-27	9.0	59.4	24.5	22	51	8	19
	(10459)	0-5	7.0	21.4	11.4	59	25	6	10
	(10462)	23-33	9.2	56.8	26.4	35	52	8	6
	(10005)	0-3	6.4	25.1	8.9	48	39	3	10
	(9976)	21-28	9.0	55.1	20.9	25	46	11	18
Boosey loam	3425	0-5	7.0	22.2	8.0	59	32	4	5
Mywee clay	(3418)	0-6	7.2	60.7	23.6	41	49	6	4
	(10447)	0-6	8.0	57.1	25.2	39	45	13	3
Koonoomoo Suite Type 2	(5647)	0-2	5.7	37.3	16.8	52	38	6	4
	(5649)	5-14	5.6	34.6	10.1	19	68	7	6
	(5650)	14-27	5.7	36.7	12.4	18	69	5	8

* Soil numbers are those of State Laboratories of Victoria.
† As milligramme equivalents per 100 grammes of soil: sum of Ca, Mg, Na, and K.

The absorbing complex in most of the surface soils is slightly unsaturated and in the subsoils completely saturated. Calcium and magnesium together make up 80 per cent. or more of the total replaceable bases in the surface soils and 75-85 per cent, in the subsoil horizons. Calcium is present in highest proportion in the surface horizon and decreases with depth, while magnesium has an opposite and complementary distribution. In the grey heavy soils the magnesium is somewhat higher than the calcium in the surface horizon. Sodium is unimportant in all but one sample. The exchangeable potassium is high in the red-brown soils but low in the grey. The surface of Mywee clay has a notably high replaceable cation content associated with a high clay figure. The soils of the Koonoomoo Suite are exceptional. The figure for replaceable bases is relatively high at the surface but lower than normal in the subsoil, while in the subsoil magnesium represents an exceptionally high percentage of the total.

4. Chemical Analysis.

For the estimation of phosphoric acid, potash, lime, and magnesia the soils were extracted with concentrated hydrochloric acid. The results are shown in Table 6.

TABLE 6 - Chemical analyses of soils.
(expressed as percentage of air-dry soil).

Soil type	Soil No*	Depth in	P_2O_5	K_2O	CaO	MgO	N	Organic Carbon
Sandmount sand	3434	0-6	0.03	0.19	0.09	0.10	0.029	0.48
Cobram loam	(3392)	0-6	0.08	0.81	0.17	0.41	0.118	1.24
	(3400)	0-4	0.07	0.78	0.15	0.37	0.120	1.38
	(3409)	0-3	0.07	0.47	0.20	0.41	0.099	1.08
Moira loam subsoil phase	(9960)	0-5	0.07	0.52	0.20	0.25	0.085	1.09
	(9961)	5-9	0.11	0.38	0.12	0.17	-	-
	(9962)	10-20	0.07	1.37	0.21	0.57	-	-
	(9968)	0-9	0.07	0.48	0.28	0.28	0.085	1.10
	(9983)	0-6	0.06	0.45	0.13	0.21	0.083	1.23
	(10452)	0-5	0.058	0.41	0.11	0.19	-	0.19
Moira loam	(9973)	0-5	0.06	0.54	0.12	0.30	0.092	1.15
	(9994)	0-6	0.07	0.55	0.14	0.26	0.089	1.11
	(9995)	6-15	0.05	1.28	0.31	0.70	-	-
	(10005)	0-3	0.07	0.54	0.15	0.25	0.114	1.34
	(10006)	3-7	0.07	0.47	0.15	0.30	-	0.97
	(10459)	0-5	0.06	0.31	0.24	0.26	-	-
Boosey loam	3425	0-5	0.05	0.40	0.20	0.25	0.085	1.09
Mywee clay	(3418)	0-6	0.04	1.13	0.28	0.35	0.091	0.62
	(10447)	0-6	0.04	0.97	0.31	0.22	-	
Muckatah clay-loam	(5618)	0-1	-	-	-	-	0.093	1.10
	(5619)	1-5	-	-	-	-	0.076	0.88

In those paces where no figure is given the analysis has not been done.
* Soil Numbers are those of State Laboratories of Victoria.

Phosphoric acid was estimated by Lorenz's method, organic carbon was determined by the wet combustion method of Walkley and Black (1934) and nitrogen by the Kjeldahl method. For the remaining estimations the same methods were used as for the replaceable bases.

Apart from odd samples there is considerable uniformity in the phosphoric acid content which averages 0.07 per cent. in the red-brown earths, somewhat lower - 0.04 per cent. -in the grey heavy soils, and again lower - 0.03 per cent. -on a single sandhill type. Potassium varies more or less directly with the clay content, although there is a considerable range in the amount present in the surface soils; the Cobram loam has definitely higher figures per unit of clay. The calcium content is not high but a large proportion is in the exchangeable form. The nitrogen content is reasonably high, the Cobram loam again being somewhat better than the other soils, averaging 0.112 per cent. in the surface soil. Certain grey heavy soils contain high amounts in the surface one or two inches. The Koonoomoo Type is very high in the surface soil, one profile analysed yielding 0.33 per cent. at 0-2 in. and 0.10 per cent. at 2-4 in. All the other heavy types fall close to 0.09 per cent. There is no difference in organic carbon or nitrogen contents between the red-brown earths and the grey heavy soils (typified by Mywee clay) as might be expected from the darker colour of the latter in the field. The Sandmount sand is markedly low in nitrogen.

5. Soluble Salts - Chlorides.

Chlorides were determined by Best's electrometric titration method (Best 1939). In addition to those values given in the tables of mechanical analyses 340 bores were made by the State Rivers and Water Supply Commission and the soils analysed for chlorides at the Victorian State Laboratories.

96% of the 0-6"	samples	contained	<0.030% chloride (as Cl)
86% of the 6-18	"	"	< 0.030% and 96% < 0.060% chloride
48% of the 18-36	"	"	<0.030%, 79% <0.060% and 93% <0.100%

There is some variation in the chloride content of the soils from one district to another. The content of chlorides shows some correlation with the texture of the soil in that the lighter soils contain least. Those soils most free of salt are: Sandmount series, Katunga gravelly-loam, Koonoomoo Suite soils, Yarroweyah loam, and Katamatite loam. For the medium and heavy soils there is a fair correlation between the salt content and the depth of sample; the surface contains least, at 3-4 feet the concentration is about 8 times as high, at 6-7 feet 10 times. At greater depths the concentration sometimes decreases slightly.

In this connection the analyses of 162 samples of bore water are of interest. Most of the bores are about 100 feet deep; the opinion that shallower bores are more salty is general among farmers of the district. The distribution of the content of <u>total salts</u> in the bore waters is:-

Total salt content	<0.05%	0.051-0.100%	0.101-0.150%	0.151-0.200%	>0.200%
No. of bore samples	121	26	9	2	4

Total salts consist mainly of chlorides in all cases; traces of carbonate are present in about 4 per cent, of the samples.

In addition to those figures discussed above, 1,850 samples have been analysed for chlorides in a salt survey of the area; of these samples, 1,600 are from 3-4 feet and 250 from 6-7 feet. An analysis of the results shows:-

Depth		3-4 ft	6-7ft
Average salt content of all soil borings (chlorides as Cl)		0.047%	0.055%
		%	**%**
	(<0.050% chlorides (as Cl)	63	54
Proportion of all soil	(0.051-0.100% “	25	30
Bores with	(0.101-0.150% “	10	11
	(0.151- 0.200% “	2	5

The general conclusion is that there is no inherent danger of salt accumulation in the soils affecting crop growth unless concentration at the surface is produced by a rising water table created through development of the area under irrigation.

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APPENDIX.
TABLES OF MECHANICAL ANALYSES.

All figures with the exception of pH express percentage; those for rubble and gravel are the percentage of the field sample, all others the percentage of the fine-earth.

Texture is indicated by the following symbols:-

S = sand
CS = coarse sand
FS = fine sand
SL = sandy loam
SCL = sandy clay-loam
ClS = clay-sand
CL = clay-loam
LC = light clay
ClFS = clay-fine sand
FSC = fine sandy clay
MC = medium clay
HC = heavy clay

As a prefix Si = silty, gr = gravelly, Fb = friable structure.

Figures for loss on ignition have been omitted from the tables, and loss on acid treatment is only quoted when figures for calcium carbonate are not available.

Where figures are not given the analysis has not been made.

SOIL TYPE	**MOIRA LOAM**								
Lab No.	10005	10006	10007	10008	10009	10010	10011	10012	10013
Depth (in)	0-3	3-7	7-15	15-22	22-33	33-48	48-60	60-70	70-80
Texture	L	SCL	HC	HC	HC	MC	MC	MC	LMC
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	0.4	0.5	-	0.1	0.4	0.4	0.1	-	2.5
Coarse sand	7.3	6.7	3.1	1.8	.2	2.2	2.0	1.3	1.2
Fine sand	44.8	43.1	21.0	16.2	21.1	23.1	22.4	20.9	22.0
Silt	20.5	20.7	11.0	17.7	10.7	12.2	13.4	12.3	14.2
Clay	25.1	27.5	60.6	58.9	58.7	58.1	58.7	59.7	58.4
Moisture	1.6	1.6	3.6	4.3	3.9	3.8	5.0	5.2	5.3
Calcium carbonate	0.00	0.00	0.00	0.01	3.25	0.57	0.13	0.03	0.02
Chlorides (as Cl)	0.004	0.005	0.005	0.015	0.024	0.033	0.037	0.038	0.035
Reaction pH	6.4	6.4	7.4	8.5	9.2	9.0	8.9	8.6	8.5

SOIL TYPE	BOOSEY LOAM								
Lab No.	3425	3426	3427	3428	3429	3430	3431	3432	3433
Depth (in)	0-5	5-18	18-27	27-54	54-84	84-96	96-120	120-138	138-156
Texture	L	HC	HC	HC	MC	MC	LMC	LC-SCL	CLS
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	0.2	0.1	-	1.1	2.1	1.3	0.5	tr	-
Coarse sand	12.1	3.5	3.0	3.2	5.4	8.0	12.2	17.5	20.7
Fine sand	41.9	16.8	16.1	19.8	23.3	26.6	34.8	40.5	42.9
Silt	20.7	12.4	14.0	17.6	17.4	18.9	14.1	12.9	10.1
Clay	22.2	62.5	63.0	55.0	50.0	44.2	36.5	27.7	24.5
Moisture	1.4	4.1	3.9	3.4	3.3	3.0	2.6	1.7	1.7
Calcium carbonate	0.01	0.02	0.03	0.60	1.44	0.25	0.05	-	-
Chlorides (as Cl)	0.004	0.017	0.035	0.062	0.055	0.049	0.037	0.036	0.032
Reaction pH	7.0	8.3	8.7	9.0	9.1	8.8	8.6	8.3	8.4

SOIL TYPE	MUCKATAH CLAY-LOAM							
Lab No.	5624	5625	5626	5627	5628	5629	5630	5631
Depth (in)	0-1	1-3	3-11	11-21	21-32	32-48	48-63	63-84
Texture	HC	HC	HC	HC	HC	HC	HC	SiMC
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	-	-	-	0.2	0.5	3.8	2.0	0.6
Coarse sand	1.5	1.2	0.5	0.5	0.8	1.3	1.6	2.1
Fine sand	19.1	10.2	7.0	8.7	14.0	25.2	26.0	29.2
Silt	14.8	12.3	10.3	11.3	13.8	16.9	18.4	22.6
Clay	56.8	70.1	77.3	75.0	68.5	53.4	51.1	44.2
Moisture	3.4	3.7	5.1	4.5	3.6	3.1	2.6	2.0
L. on acid treatment	1.3	1.8	1.8	2.0	1.2	2.1	1.9	1.7
Reaction pH	6.6	7.1	8.0	8.8	93	8.7	9.3	9.2

SOIL TYPE	KATAMATITE LOAM				
Lab No.	9928	9929	9930	9931	9932
Depth (in)	0-5	5-10	10-16	16-33	33-48
Texture	L	CL	MC	FbMC	FbLMC
	%	%	%	%	%
Rubble and gravel	0.9	0.4	-	-	0.4
Coarse sand	12.2	14.9	6.2	2.3	2.3
Fine sand	46.6	44.8	20.8	13.3	19.0
Silt	15.9	15.8	5.9	5.0	8.5
Clay	23.5	1.3	3.7	5.0	5.8
Moisture	1.7	1.3	3.7	5.0	5.8
L. on acid treatment	0.7	0.5	0.7	1.2	2.0
Chlorides (as Cl)	0.003	0.002	0.002	0.002	0.003
Reaction pH	6.7	6.9	7.5	8.1	9.0

SOIL TYPE	FRIABLE SUBSOIL PHASE MOIRA LOAM							
Lab No.	9960	9961	9962	9963	9964	9965	9967	9967
Depth (in)	0-5	5-9	10-20	20-28	28-33	33-57	57-66	66-80
Texture	L	SCL	MC	LMC	MC	FbLC	FbLC	LC
	%	%	%	%	%	%	%	%
Rubble and gravel	0.4	0.3	-	tr	0.7	1.2	0.1	9.9
Coarse sand	11.3	12.5	3.4	3.1	3.0	2.6	2.4	2.0
Fine sand	45.2	48.4	17.1	18.6	19.7	19.2	20.4	25.2
Silt	17.3	16.8	7.8	9.0	10.9	8.8	11.7	18.8
Clay	23.6	22.6	67.1	65.7	61.8	65.5	62.8	50.0
Moisture	1.2	0.8	3.3	3.6	3.7	3.8	4.0	3.7
L. on acid treatment	0.01	0.00	0.02	0.03	0.83	0.29	0.05	1.20
Chlorides (as Cl)	0.004	0.005	0.006	0.005	0.004	0.004	0.004	0.007
Reaction pH	7.1	6.9	8.1	8.5	9.0	9.0	9.0	9.4

SOIL TYPE	MYWEE CLAY					ULUPNA CLAY				
Lab No.	3418	3419	3420	3421	3422	5632	5633	5634	5635	5636
Depth (in)	0-6	6-30	30-48	48-66	66-92	0-5	5-22	22-36	36-48	48-60
Texture	HC	HC	HC	MHC	MC	LMC	HC	HC	HC	HC
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	-	-	0.2	-	-	tr	-	tr	0.9	0.4
Coarse sand	1.7	1.4	1.6	0.6	0.6	3.3	1.9	2.1	2.7	3.3
Fine sand	15.1	15.3	16.9	13.9	15.6	38.4	24.0	22.8	24.0	23.6
Silt	15.6	14.6	18.4	20.0	20.7	20.1	16.9	18.7	17.6	16.8
Clay	60.7	63.6	57.9	61.5	58.1	34.9	5.6	52.8	51.7	53.3
Moisture	6.1	4.2	4.0	4.4	4.7	2.3	3.2	3.3	3.4	2.9
L. on acid treatment	0.5	1.3	1.3	1.1	1.4	1.1	1.5	2.2	2.6	2.1
Calcium carbonate	0.01	0.01	0.22	0.05	0.03					
Chlorides (as Cl)	0.005	0.013	0.037	0.061	0.069					
Reaction pH	7.2	8.1	8.6	8.3	8.3	6.5	7.7	8.5	8.9	8.8

SOIL TYPE	COBRAM LOAM							
Lab No.	3392	3393	3394	3395	3396	3397	3398	3399
Depth (in)	0-6	6-17	17-24	24-48	48-72	72-102	102-120	120-156
Texture	L	MHC	MC	FSC	FSC	FSCL	FSL	FS-FSL
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	-	-	-	2.3	0.9	tr	-	-
Coarse sand	1.6	0.5	0.4	1.3	1.9	1.0	0.2	0.3
Fine sand	36.6	19.9	13.7	21.7	25.5	40.6	52.1	62.2
Silt	31.6	24.0	29.1	32.7	32.6	24.0	20.6	17.2
Clay	25.5	52.1	52.1	40.8	36.3	32.4	26.1	19.4
Moisture	1.9	3.9	4.8	3.8	3.7	2.5	2.0	1.7
L. on acid treatment	0.02	0.01	0.00	0.23	0.18	0.16	-	-
Chlorides (as Cl)	0.004	0.006	0.008	0.021	0.053	0.051	0.049	0.043
Reaction pH	6.6	6.3	8.0	9.1	9.0	9.0	8.8	8.6

SOIL TYPE	COBRAM LOAM LIGHT PHASE								
Lab No.	3400	3401	3402	3403	3404	3405	3406	3407	3408
Depth (in)	0-4	4-13	13-21	21-36	36-56	56-84	84-110	110-126	126-140
Texture	L	MC	LC	FSC	FSCL	ClFS	ClFS	FS	CS
	%	%	%	%	%	%	%	%	%
Rubble and gravel	0.5	-	1.8	6.2	2.4	2.6	0.1	0.2	6.4
Coarse sand	1.5	0.6	0.5	0.2	0.2	0.2	1.5	3.6	74.5
Fine sand	48.0	30.7	32.4	40.0	57.4	61.2	68.6	75.0	16.6
Silt	25.4	24.1	23.7	21.2	17.0	16.6	16.2	13.8	4.4
Clay	20.4	42.7	40.3	31.9	23.6	20.7	13.2	8.2	5.0
Moisture	1.5	2.8	2.9	3.1	2.3	1.8	1.5	0.8	0.4
L. on acid treatment	0.00	-	0.80	3.69	0.87	-	-	-	0.01
Chlorides (as Cl)	0.009	0.020	0.057	0.092	0.080	0.088	0.057	0.027	0.011
Reaction pH	6.5	6.1	9.0	9.4	9.5	9.2	9.2	9.3	9.2

SOIL TYPE	SANDMOUNT SAND				KATUNGA GRAVELLY LOAM		
Lab No.	3434	3435	3436	3437	9942	9943	9945
Depth (in)	0-6	6-54	54-84	84-115	0-6	6-15	20-27
Texture	S	S	ClS	ClS	grSL	grSL	grSL
	%	%	%	%	%	%	%
Rubble and gravel	-	tr	tr	-	13.2	24.2	18.0
Coarse sand	69.3	68.5	64.3	62.0	27.0	28.0	19.5
Fine sand	20.4	21.9	22.2	20.1	52.1	52.9	29.7
Silt	4.1	3.9	3.7	3.5	9.4	10.0	9.1
Clay	56	6.1	9.8	14.5	8.8	8.0	37.4
Moisture	0.3	0.3	0.5	1.0	0.9	0.6	3.3
L. on acid treatment	0.1	0.2	0.2	0.1	0.4	0.3	1.0
Calcium carbonate	0.00	0.00	-	0.00			
Chlorides (as Cl)	0.001	0.004	0.002	0.003	0.003	0.003	0.001
Reaction pH	7.0	7.0	7.5	6.9	6.4	7.6	8.4

SOIL TYPE	KOONOOMOO SUITE								
	TYPE 2							TYPE 1	
Lab No.	5647	5648	5649	5650	5651	5652	5653	9915	9917
Depth (in)	0-2	2-5	5-14	14-27	27-46	46-56	56-84	0-4	10-18
Texture	SiCL	SiCL	SiLMC	SiMC	SiLC	SiMC	SiLMC	SiCL	HC
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Rubble and gravel	-	0.7	0.9	1.1	0.1	-	-	0.6	-
Coarse sand	0.7	2.8	4.4	3.8	2.9	2.1	1.4	4.7	2.9
Fine sand	10.7	16.8	19.4	19.7	18.5	15.5	28.4	39.8	29.4
Silt	41.1	45.7	39.7	36.3	38.7	35.9	28.4	30.4	28.9
Clay	37.3	29.9	34.6	36.7	37.8	43.3	38.0	20.1	34.0
Moisture	2.8	2.5	2.4	2.6	2.5	2.9	2.6	1.9	2.8
L. on acid treatment	1.7	1.2	1.1	1.2	0.6	0.6	1.6	0.9	3.7
Chlorides (as Cl)								0.002	0.002
Reaction pH	5.7	5.7	5.6	5.7	5.6	6.1	8.6	6.0	6.6