Department of Agriculture, Victoria, Australia

SOILS AND LAND USE

IN THE

ROCHESTER AND ECHUCA DISTRICTS, VICTORIA

Including the Rochester Irrigation Area, Campaspe Irrigation District, and Echuca East Irrigation Settlement

By

J K M Skene and L B Harford

TECHNICAL BULLETIN NO. 17
MELBOURNE 1964

ACKNOWLEDGEMENT

The soil survey described in this bulletin was made by the Department of Agriculture. The State Rivers and Water Supply Commission assisted by providing vehicles, field assistants, aerial photographs, plans and district office facilities. The Commission also contributed half of the cost of this publication.

The whole of the category for the soil maps was carried out by the Department of Crown Lands and Survey, as was the preparation of the plates for colour printing.

Numerous people in the three organizations have contributed much to the soil survey.

Special mention is made of the many officers of the State Rivers and Water Supply Commission; Mr W P Dunk, Chief Irrigation Officer, for organizing the assistance provided, and the officers at the Rochester district office for, either directly or indirectly, providing assistance with the soil auger, maintaining the survey vehicle and providing office facilities and local information.

Officers of the Regional Mapping Section of the Department of Crown Lands and Survey who warrant special mention are Mr S P Hurrey who supervised the preparation of the soil maps, and Mr V K M Daniell who did the cartography.

Mr K H Northcote, Division of Soils, Commonwealth Scientific and Industrial Research Organization, made a special visit to advise on the classification of the soils.

Among present and past colleagues in the Department of Agriculture who have assisted, first mention must be made to the soil surveyors listed at the beginning of the report. Mr T J Poutsma, former Soil Officers, was responsible for the supervision of the soil survey in its initial stages. Mr B Cockroft, Senior Irrigation Officer as the Tatura Horticultural Research Station, provided information about horticulture in the Bamawm area. Others who have helped materially are the chemists and laboratory assistants responsible for the analyses. Last, but not least, mention must be made to the landholders who, without exception, freely allowed the soil surveyors access to their properties.

To all of these people the authors extend their sincere thanks.

CONTENTS

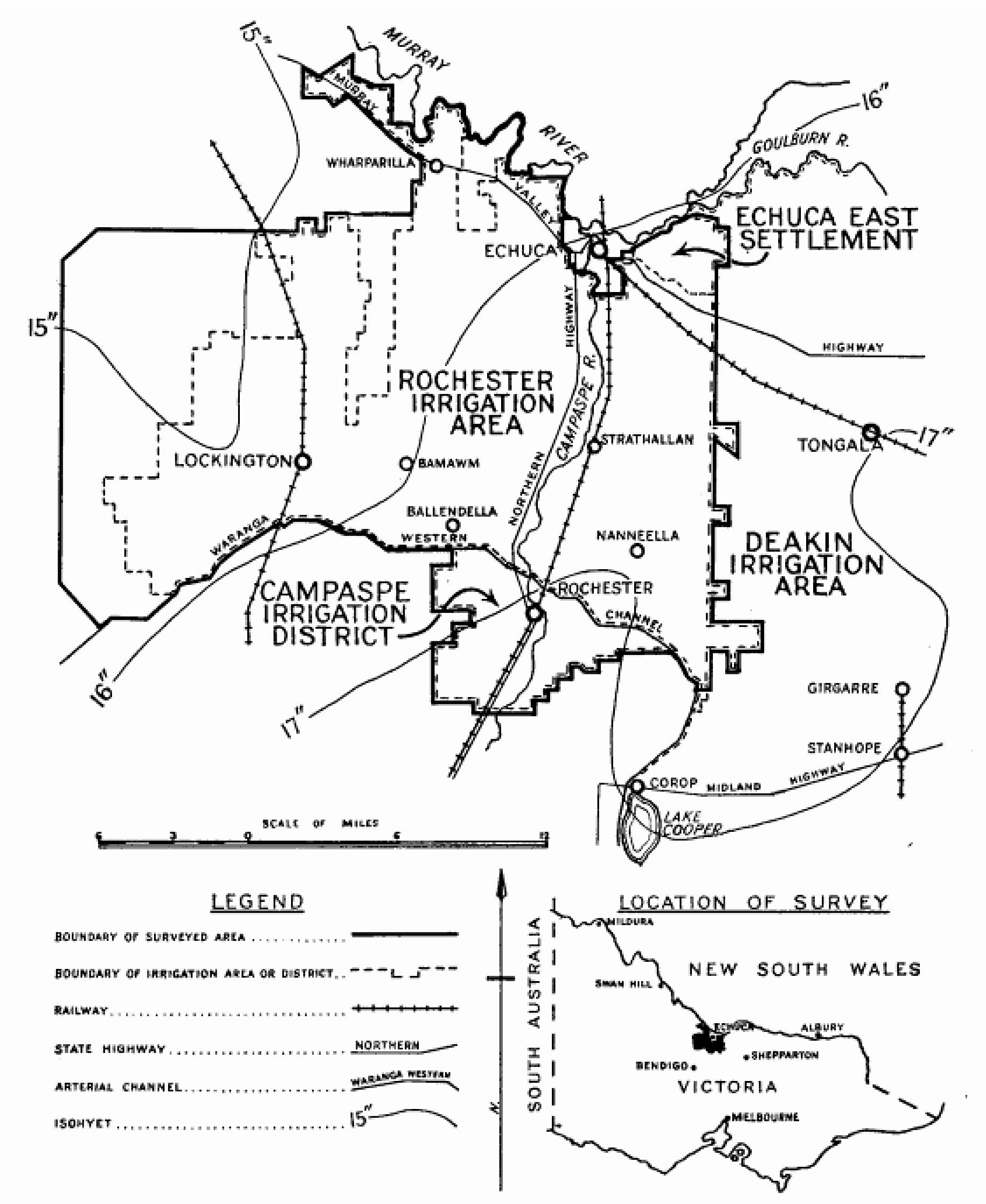

Fig 1. – Locality plan, Rochester and Echuca districts.

Soils and Land Use in the Rochester and Echuca Districts, Victoria
Including the Rochester Irrigation Area, Campaspe Irrigation District, and Echuca East Irrigation Settlement

By J K M Skene* and L B Harford[!]
Soils surveyed by J H Bird, L B Harford, I R J Morris, J C Nieuwenhuis, I J Sargeant and H H M Sarolea.

This report, "Soils and Land Use in the Rochester and Echuca Districts, Victoria", concerns the detailed soil survey of about 264,000 acres of farm land in the counties of Rodney, Bendigo and Gunbower (Fig 1). About 186,000 acres are served by irrigation water, although only a little less than half of this is irrigated. The irrigated land is mainly given to dairying and fat lamb production on perennial and annual pastures and on lucerne. Relatively small area are under orchards and market gardens. Dry-farming pursuits are wheat-farming and the grazing of sheep for wool production on native and volunteer pastures. Further information concerning the location and settlement are given in the section, "General information about the Area".

SUITABILITY OF THE SOILS FOR VARIOUS IRRIGATED CROPS

The soils have been classified into soil types and other mapping units. Most of the soil types have been given names but some are designated by letters and numbers. Full description can be found in a following section. "Description of Soil Types and Miscellaneous Units".

In the present section, all of the soil types with similar capabilities in regard to *irrigated* crops are grouped together. There are six different groups. The common crops that normally could be grown satisfactorily at present are listed at the head of each group, followed by the summarized features of the main soil types and the names of the soil types in the group. In the case of Groups I, IV and V the soil types are placed in sub-groups on the basis of soil differences.

Table 1 is provided to enable the crop suitability grouping of any soil type or other mapping unit to be found readily. All the soil types are listed alphabetically in the table.

Table 1 – Crop Suitability Grouping of the Soil Types and other Units

Soil Type	Crop Suitability Group	Soil Type or Mapping Units	Crop Suitability Group
Binabbin clay	IVA	Wanalta loam	IVB
Carag clay	VI	Wanurp sandy loam	III
Colbinabbin clay loam	IVA	Yambuna clay	VA
Colbinabbin clay loam, shallow phase	IVA	Yuga clay	VB
Colbinabbin clay	IVA	Type A	IVD
Cornella clay	VA	Type B	IVD
Corop clay	VI	Type C	IVB
Kanyapella clay loam	VA	Type D	III
Kanyapella clay	VA	Type E	IVB
Koga clay loam	IVC	Type F	IVB
Koyuga clay loam	IVC	Soils of the Campaspe Suite	
Lockington sand	IA	Type 1	VA
Lockington sand, shallow phase	IB	Type 2	VA
Nanneella loamy fine sand	IB	Type 3	VA
Nanneella fine sandy loam	IB	Soils of Prior Stream Beds	
Restdown clay	VB	Type 1	IVE
Rochester clay	VB	Type 1h	IVE
Rochester clay, heavily gilgaied variant	VI	Type 2	VI
Timmering loam	II	Variable Soils in Drainage Ways	VI
Wallenjoe clay	VI	Intermittent Watercourses and Waterholes	VI
Wana loam	IVB	River Frontage	VI
Wana clay loam	IVB		

* Senior Soils Officer
[!] Formerly Soils Officer, Department of Agriculture, Victoria

Crops that could be grown under dry-land farming have not been included in the crops listed. All the soils can be cultivated except some of the mapping units in Group IV.

Readers are asked to be cautious about accepting the crop suitability groups as a rating of the soil types in order of agricultural merit, although it does suggest a general order, since high return crops can be grown less successfully in descending order from Group I to Group VI. However, if the factors restricting certain soil types to a limited range of irrigation crops are removed or ameliorated, such soil types may prove equal to or better than others with natural superiority. For example, the recommended use of the soil types in Group V for annual pastures is because of their poor surface drainage. But, if drainage can be made adequate, some of these soil types such as Cornella clay and Kanyapella clay loam should be capable of supporting very satisfactory perennial pastures.

The area is not free from salinity hazards: reference is made to these in this and later sections of the bulletin, and they are dealt with particularly in the section, "Soil Features and Irrigation". Landholders should give consideration to salinity aspects when planning the land use of specific areas, particularly if salt-sensitive crops are contemplated.

GROUP I

Very good soils, if given careful irrigation, for all horticultural crops, vegetables, tomatoes and, in the case of sub-group (a) soils, tobacco. Summer fodder crops, cereals, lucerne, and perennial and annual pastures also can be grown successfully.

(a) Highly permeable, deep, sandy, brown soils without clay subsoils

LOCKINGTON SAND

Lockington sand has a low storage capacity for moisture and a high permeability, consequently water should be applied as light, frequent irrigations to annual crops and pasture species. However, deep-rooting plants, such as fruit trees, do not necessarily require frequent irrigation. Spray irrigation gives the best control of water on this soil type. If the soils are not irrigated carefully, there is a danger of causing waterlogging and salting on the lower land.

Tobacco should only be grown on Lockington sand if the salt content of the soil has been checked and found satisfactory.

(b) Brown soils mostly 9 to 18 inches thick, overlaying permeable, red-brown clay subsoils which are underlain by sandy layers.

LOCKINGTON SAND, SHALLOW PAHSE
NANNELLA LOAMY FINE SAND
NANNELLA FINE SANDY LOAM

The soils can be watered by furrow and flood irrigation, but care is necessary to prevent over-watering as the soils are liable to watertables. These watertables are not normally harmful to pastures and cultivated crops, but can be dangerous to fruit trees if salt is present, as occasionally happens. Although the soil types in this Group generally are suitable for fruit trees, it is advisable wherever citrus or stone fruits are contemplated on Group I soils, to have the proposed site checked for salinity before planting.*

The tendency for the surface to crust makes Nanneella fine sandy loam unsuitable for the small seeded vegetable crops, such as carrots and lettuce, sown directly in drill rows.

GROUP II

Good soils for all horticultural crops (except citrus), pumpkins, peas, beans, tomatoes, summer fodder crops, cereals, lucerne, and perennial and annual pastures.

Brown soils mostly 6 to 10 inches thick, overlying moderately permeable, red-brown clay subsoils with lighter and more permeable layers below 2 feet.

TIMMERING LOAM

Whilst Timmering loam is generally suitable for fruit trees, including stone fruits, there is danger from waterlogging and salinity in some situations. In consequence, all sites should be checked*.

There are no problems for irrigated pastures on Timmering loam. Adequate penetration of irrigation water is readily achieved and, although excessive irrigation may build up a watertable in the deep subsoil, there is little danger to pastures from salinity in this soil type.

GROUP III

Good soils for apricots, apples, pears, plums, summer fodder crops, cereals and perennial and annual pastures. Fair soils for peaches, tomatoes, pumpkins, peas, beans and lucerne.

Brown sandy soils 6 to 16 inches thick, overlying red-brown or weakly mottled clay, with variable clay and sometimes lighter layers below 2 feet:

WANURP SANDY LOAM
TYPE D

Wanurp sandy loam and Type D, although classified as suitable for horticultural crops, are not likely to be considered seriously for fruit trees, since they occur in small areas associated with less suitable soils.

GROUP IV

Good soils for summer fodder crops, cereals and perennial and annual pastures, except that sub-group (c) soils may be only fair for perennial pastures. Fair soils for pears and plums.

* Specialist officers from the Horticultural Research Station Tatura, will check the soil and advise on horticultural plantings on request to the Manager. This service is provided free by the Department of Agriculture.

(a) Moderately well-structured, brown, clay soils on Cambrian hill slopes:

BINABBIN CLAY
COLBINABBIN CLAY LOAM
COLBINABBIN CLAY LOAM, SHALLOW PHASE
COLBINABBIN CLAY

Experience with a limited amount of irrigation on these soil types shows that they can support perennial pastures satisfactorily. Salt levels in the subsoils are low and there is danger from salinity in the lower situations only if watertables should develop.

(b) Mainly brown and grey-brown loams 3 to 6 inches thick, overlying moderately permeable, red-brown or dull-coloured clay subsoils.

WANA LOAM
WANA CLAY LOAM
WANALTA LOAM
TYPE C
TYPE E
TYPE F

Although perennial pastures can generally be grown satisfactorily on the soils of this sub-group, the surface soil is rather shallow and permeability is low in some situations. Such situations are more suited to annual than to perennial pastures. In general the salt content of the subsoils is low.

(c) Shallow, brown, and grey-brown clay loams over dense, dull red-brown, or yellowish-brown clay subsoils:

KOGA CLAY LOAM
KOYUGA CLAY LOAM

Perennial pastures are unlikely to do well on these soil types because of their shallow surface, low subsoil permeability, and slow surface drainage. These influences are slightly less pronounced in Koyuga clay loam than in Koga clay loam, while there are some situations in both soil types where the surface is sufficiently deep for perennial pastures. Generally, however, the soils in this group are best suited under irrigation for annual pastures.

Many situations contain moderate amounts of salt at a depth of about 3 feet; this serves to emphasize the need for the efficient use of water in the irrigation of these soils.

(d) Dull-coloured, sandy soils 7 to 18 inches thick, overlying mottled clay subsoils:

TYPE A
TYPE B

These soils are liable to surface waterlogging, but perennial pastures can be sown with careful irrigation.

(e) Brown soils with permeable subsoils in depressions:

SOIL OF PRIOR STREAM BEDS: TYPES 1 AND 1H

Watertables are likely to occur in the permeable subsoils and may persist close to the surface. Therefore, provided salt is not present, these soils should be used for shallow rooting crops, or for those fruit trees which can withstand appreciable waterlogging of the rootzone.

GROUP V

Summer fodder crops, cereals and annual pasture can be grown; if adequately drained sub-group (a) soils are satisfactory for perennial pastures.

(a) Well-structured, moderately permeable, heavy-textured, grey soils:

CORNELLA CLAY
KANYPAPELLA CLAY LOAM
KANYAPELLA CLAY
YAMBUNA CLAY
CAMPASPE SUITE:
TYPE 1
TYPE 2
TYPE 3

These are soils with good physical characteristics, but they suffer from restricted surface drainage. However, if this limitation is removed, the soils are capable of growing good perennial pastures under irrigation. The sub-soils have low salt contents.

(b) Shallow grey and brown, gilgaied clays, overlying variable permeable, and sometimes dense, clay sub-soils:

ROCHESTER CLAY
RESTDOWN CLAY
YUGA CLAY

Moderate levels of salt are present in many of the subsoils and, in Restdown clay, high levels are fairly frequent.

Attention to grading, drainage, and efficient watering are prerequisites to the satisfactory utilization of these soils for irrigated pastures. Rochester clay, in particular, may be difficult to grade properly because of its Gilgai surface. On the other hand, the Gilgai “puffs” confer a better structure and permeability on Rochester clay than is found in Restdown clay and Yuga clay. Generally, these soil types appear best suited to annual pastures under irrigation.

GROUP VI

Soils not recommended for irrigation because of swampiness, liability to intermittent flooding, salinity, and surface features making layout for irrigation impracticable.

Mainly low-lying, heavy-textured, grey soils:

CARAG CLAY
COROP CLAY
ROCHESTER CLAY, heavily gilgaied variant
WALLENJOE CLAY
SOILS OF PRIOR STREAM BEDS: TYPE 2
VARIABLE SOILS IN DRAINAGE WAYS
INTERMITTENT WATER COURSES AND WATER HOLES
RIVER FRONTAGE

Whilst the soil types and mapping units in this group are, in general, not recommended for irrigation, individual situations might support irrigated pastures where the disabilities be alleviated. However, landholders should seek advice from the District Agricultural Officer* before attempting to irrigate soils in Group VI.

* District Agricultural Centre, Moore-street, Rochester. Phone: Rochester 12

SOIL FEATURES AND IRRIGATION

In this section, some of the broad considerations concerned in the successful irrigation of the soil types found in the Rochester and Echuca districts are discussed. This necessarily involves references to soil aspects dealt with in the following sections and readers should refer, when necessary, to these sections for detailed information about the characteristics of the soil types.

SOIL PERMEABILITY

The behaviour of the soil types to water intake determines to a large degree the crops than can be grown successfully under irrigation. High intake rates lead to watertables and consequent danger of waterlogging and salinity, whilst low infiltration rates lead to shallow-rooting plants, moisture stress, and under some circumstances, to surface waterlogging.

Watertables –
The area of highly permeable soils, i.e., soils in which it is virtually impossible to prevent watertables from developing using gravity methods of waters, is very small. The soil types concerned are Lockington sand and Nanneella loamy fine sand.

Nanneella fine sandy loam, a slightly less permeable, but more widespread soil type, is also a major source of entry of irrigation water to the district watertable. This is particularly so in the Nanneella district where the soils are largely under perennial pastures irrigated by flooding methods. However, watertables in Nanneella fine sandy loam also developed in the horticultural as well as the pastoral parts of the Bamawm and Ballendella, and have been responsible for the very marked decline of citrus in these districts (Penman 1936).

The only other soil type in which watertables are common is Timmering loam. This soil type has a permeable surface and permeable deep subsoil interposed by a much less permeable subsoil. As a consequence of the slowly permeable subsoil, it is possible to minimize entry of water into the deep subsoil by careful watering practices. A low watertable is an important consideration in the utilization of Timmering loam for horticulture, since there is a degree of salt risk not present in similar soil used successfully for horticulture in the Goulburn Valley.

Watertables, once developed in the abovementioned soil types, fall slowly after irrigation ceases, since all are underlain by very slowly permeable layers. The depth to these layers has not been investigated thoroughly – most of them probably occur between 6 and 10 feet, but some are as close as 4½ feet to the surface.

The relatively permeable soil types described are to be found almost entirely within areas totally 42,300 acres and defined by the Nanneella and Timmering soil associations shown on the folder map in the envelope at the back of this bulletin, and described in the section, "Soil Associations". Although these permeable soils comprise only 16 per cent of the total surveyed area, they represent a most important component, since they are the soils with the most diverse land use capabilities (Groups I and II). Further they comprise the major part of the Campaspe Irrigation District which is shortly to be brought under irrigation.

Slow Water Intake –
The great majority of the soils do not develop watertables readily. This is a consequence of slow water intake arising from high clay contents. All the clay soils tend to crack when dry. These cracks are points of water entry into the subsoils, but in most of the soil types swelling of the clay quickly closes the cracks and soil pores, and infiltration of water than becomes very slow. Nevertheless, not all of the heavily-textured soil types have slow infiltration rates. Several of them notably Kanyapella clay loam, Kanyapella clay, Yambuna clay, Cornella clay, Colbinabbin clay loam, Binabbin clay and Types 1 and 3 of the Campaspe Suite have sufficiently good aggregation of their clay particles to allow irrigation water to penetrate deeply enough for deep-rooting pasture species. In fact, extravagant use of water might lead to watertables in these soil types.

Problems arising from shallow penetration of irrigation water are most likely to occur on the soil types which have only a few inches of surface soil overlying a much heavier and intractable clay subsoil. These soils are mainly the commonly occurring types, Koyuga clay loam and Koga clay loam which are delineated by the Koyuga and Koga soil associations constituting 87,500 acres, or 33 per cent of the surveyed area. Much of these soil associations is either not irrigated at present, or is irrigated to only a limited extent. It is difficult to obtain sufficient stored moisture in Koyuga clay loam and Koga clay loam to meet the water requirements of summer-grown crops, consequently these soil types are more suited to spring and autumn-irrigated annual pastures than to perennial pastures.

Less frequently, shallow penetration of irrigation water occurs on Wanalta loam, Wanalta clay loam and Wana loam, soil types which also have contrasting surface soils and subsoils. Generally, however, these soil types have sufficient moisture storage capacity for summer-grown pastures.

Some 71,000 acres, mainly Restdown clay and Rochester clay, consist of more or less gilgaied areas only sparsely irrigated, or un-irrigated at present. These gilgai clay soils are variable permeable since the "puff" situations of the gilgaies are highly structure and absorb water fairly quickly, whereas the intervening situations and non-gilgaied areas tend to hold water on their surfaces. The proportion of slowly permeable situations is likely to be greater in Restdown clay than in Rochester clay owing to fewer gilgai manifestations in the former soil type.

Measures aimed at increasing the depth of soil wetting have not been very successful where they have been attempted on slowly permeable soils in nearby districts. These include deep ripping of pastures and surface application of gypsum. The former is a temporary expedient and beneficial for only or two years. Gypsum probably does not penetrate to the subsoil when applied to the surface of pasture land. Incorporation of gypsum when cultivating the land in preparation for sowing-down might have some effect, but has not been tried on soils in the Rochester and Echuca districts.

SOIL SALINITY

Within the context of the broad salinity pattern in northern Victoria, the Rochester-Echuca district lies between the appreciably saline soils of the Loddon River Valley to the north-west and the practically non-saline soils of the Goulburn Valley to the east and the south-east. Consequently, situations with salinity hazards can be expected to occur within the district and, in fact, irrigated pastures and fruit trees have been injured by salt in some parts. Salting has played some part in the decline of citrus through waterlogging referred to previous at Bamawm and Ballendella. Also, tobacco-growing has ceased in the district due to the detrimental effect in even a small amount of salt on the quality of the cured leaf.

Salt Survey –
The salt status* of the soils has been investigated in some detail. Soil samples taken at 3 to 4 feet depth were analysed from approximately 10,800 sites scattered over the whole area. The salt content at this depth provides a suitable guide in unirrigated soils to the risk of salting should the soils be irrigated, since the salt level in the subsoil tends to increase to a maximum a little before 3 feet, the depth depending on the soil type. The danger lies in redistribution of salt from these lower depth into the rootzone above, and the likelihood of salt rising is increased in the soil types which are liable to develop watertables.

Salt Map –
The pattern of salt distribution in the subsoils of the district, as disclosed by the survey referred to, is shown on the Salt Map in the envelope at the back of this bulletin. Comparison of this map with Figure 2 in the section, "Landscape Units and Guide to Soil Types" shows that the broad pattern of salinity is related to the landscape units described. Thus the soil types of the *treeless plain* and *swamp landscape units* are inherently saline to a moderate, and occasionally to a high degree, while those in *the prior stream, riverine woodland* and *Cambrian upland landscape units* are only slightly, and occasionally moderately saline, but are never highly saline.

Many of the moderately saline situations on the treeless plains have never been irrigated, or have been irrigated only lightly. Should intensification of irrigation occur on these areas – principally the Koyuga clay loam, Koga clay loam, Restdown clay and Rochester clay soil types – the risk of salting should be kept in mind, but if efficient irrigation practices in regard to grading, watering and drainage are employed, it should be possible to grown annual pasture successfully.

Irrigation is concentrated at Nanneella, Ballendella, Bamawm and Lockington on soil types of inherently low salt status, principally Nanneella loamy fine sand, Nanneella fine sandy loam, Timmering loam, Wanalta loam and Wana loam. Nevertheless, as shown the Salt Map, appreciable areas of soils with moderately saline subsoils also occur in these localities. It is not known to what extent these more saline situations may have arisen from irrigation, but their presence is a warning that sound watering and drainage practices should not be overlooked either in the established irrigation areas, or in the newly formed Campaspe Irrigation District when irrigation comes to it. The above soil types are widespread in this District, although their present salt status is almost universally low.

Value of Salt Map to Landholders and Advisory Officers –
The map does not necessarily indicate areas where actual salt injury to crops has occurred, it shows areas of different degrees of *potential salt hazard* to irrigation crops. It is useful, therefore, to indicate the *localities* where the crops recommended in the section, "Suitability of the Soils for Various Irrigated Crops" might be grown with a minimum risk of salt injury. It also indicates localities where special precautionary drainage measures might be necessary or where the situation should be investigated by further soil analyses for salt content before irrigation development takes place. The map is not detailed enough to show the salt status of individual holdings, consequently landholders should seek advice from an advisory officer of the Department of Agriculture when planning new plantings, particularly if these involve crops sensitive to salt, such as stone fruits.

Campaspe Irrigation District –
The salinity situation prior to irrigation in the Campaspe Irrigation District is promising for its future. Practically all the subsoils have low salt contents of less than 0.10 per cent. And even the very few, small, moderately saline areas shown on the Salt Map have less than 0.15 per cent; there are no significant areas with more salt than this. Some of the soil types (Lockington, Nanneella and Timmering series) are prone to watertables but, provided steps are taken to minimize these, the low salt hazard should enable stone fruits and other fruit trees, if necessary, to be grown on

* In this report the salt (sodium chloride) status of the soil is described arbitrarily as follows: Low – under 0.10 per cent; moderate – between 0.10 and 0.3 percent; high – between 0.3 and 0.5 per cent; very high – over 0.5 per cent. The degree of risk at any one of these salt levels varies with the soil type and with the salt tolerance of the crop grown.

these soil types. There should be no salinity problems with irrigated, perennial pastures and lucerne, both of which could be grown very extensively in the district.

THE SURFACE SOILS

The soil types are considered here in regard to properties of their surface soils which are important to plant growth and irrigation, namely, depth, structure, texture, consistence and permeability. Unevenness of surface is also concerned.

Root distribution and consequent vigour of pasture, crop, and horticultural plants are flavoured by a deep surface soil, although the minimum satisfactory depth will depend on the rooting habits of the plants grown and on cultural practices. A reasonable depth of surface soil is also necessary for satisfactory grading when laying out land for irrigation. Lockington sand, Nanneella loamy fine sand, Nanneella fine sandy loam and Timmering loam are always satisfactory in that the depth is more than 6 inches, a depth which may be regarded as an arbitrary minimum satisfactory for nearly all crops. Wanalta loam and Wana loam generally have about 5 inches of surface which makes these soil types less satisfactory for fruit trees, since the effective surface depth is further reduced through destruction of the uppermost feeding roots of trees by cultivation practices. However, these two soil types, as well as Kanyapella clay loam, has a sufficient surface depth for perennial pastures, while grading presents no problems.

On the other hand, Koyuga clay loam and Koga clay loam are extensive soil types with only 3 to 4 inches of surface, while a further type, Restdown clay, has less than 2 inches. These depths do not allow pasture plants to develop rooting systems sufficiently deep to withstand moisture stress in summer. This introduces watering difficulties with permanent pastures on these soil types. Also, care is required when grading to avoid exposure of the clay subsoil. This is likely to be particularly difficult in some situations of Restdown clay.

The structure and consistence of the surface soils determine the ability of pasture plants to develop adequate root systems in the clay surface soil types. Thus the surface soils of Cornella clay, Yambuna clay and Binabbin clay are all well-structured, and crumble when dry. As water penetrates readily, these soil types can support perennial pasture plants, if drainage is satisfactory. Colbinabbin clay loam, a soil type with a shallow surface, is in this category also.

Rochester clay is a variable soil type which includes both well-aggregated and poorly structured soils. The former occupy the sites of Gilgai “puffs”. Gilgaies tend to return after first grading, and it usually takes some years to produce a satisfactory surface for irrigation in strongly gilgaied situations. Gilgaies also occur in Restdown clay and Cornella clay, and to a lesser extent in the other clay soils.

The surface soils of Yuga clay, Carag clay and Wallenjoe clay are very hard and cloddy when dry, and are very unfavourable for water and subsequent root entry. The soils are also difficult to break down by cultivation which leads to unsatisfactory grading. These aspects, together with surface drainage difficulties, make the last two soil types generally unsuitable for irrigation.

The fine sandy loam and loam soils (Nanneella, Timmering and Wanalta soil types) tend to set hard when dry. This is a consequence of their high amounts of fine sand and silt. Hard setting may be accentuated where the soils have been cultivated for a long period and their naturally weak aggregation in destroyed. Infiltration of water is slowed down under these circumstances, but it is not known to what extent this effect may be important in the management of these soil types in the present area. It is a matter of concern in some orchards in the Goulburn Valley.

CHEMICAL ASPECTS

The soils are known to be deficient in phosphorus and nitrogen. Superphosphate is a necessary fertilizer in all forms of agriculture in the area, where nitrogenous fertilizers are required for intensive agriculture such as horticulture and vegetation growing.

The analytical data show the soils to have good potassium reserves and it is difficult to see potash being of benefit on pastures, orchards or cultivated crops.

Calcium and magnesium are normally at good levels, and the pH is satisfactory. Under these circumstances. No benefit can be expected from using lime. Dolomite, or magnesium-containing materials. However, should sulphate of ammonia be used consistently, as in horticulture and vegetable growing, some soils may become sufficiently acid to warrant the use of lime to counter the soil acidity produced. Soil tests are useful to indicate whether liming is warranted in such cases. Dolomitic limestone which supplies both calcium and magnesium can be used, but it is doubtful whether additional benefits would accrue from its magnesium content on the majority of the soils.

No investigations have been made into the trace element status of the soils, but it is known from field trials in northern Victoria that, generally, trace elements are not necessary for the satisfactory growth of any crops. However, zinc deficiency does occur to a small extent in fruit trees on similar soil in the Goulburn Valley, and it would seem that this would be the only trace elements deficiency likely in the Rochester and Echuca districts.

In southern Victoria, copper is sometimes required for the maintenance of stock health above the amount needed to maintain satisfactory clover growth in pastures. There is no evidence whatsoever that copper needs to be applied to pastures for this purpose in the present area.

High amounts of exchangeable sodium occur in some of the subsoils, notably in Koyuga clay loam, Koga clay loam, Yuga clay and sometimes Restdown clay. This may lead to lowered permeability, resulting in difficulty in obtaining sufficiently deep penetration of irrigation water fro pasture plants on some of the treeless plain situations. It is not known to what extent this is a present, or may be a future, problem on irrigated soils in the area. Corrective treatment would involve the use of gypsum should slow permeability from exchangeable sodium arise.

Landholders with problems suspected of arising from any of the above mentioned aspects should seek advice from their district agricultural adviser.

RELATION TO HORTICULTURE

Rochester Irrigation Area –

The Rochester Irrigation Area is not a horticulturally important district, since in 1963 only 554 acres were under fruit trees. About 400 acres in the Bamawm and Ballendella localities mainly comprise pears, peaches, apricots and citrus in that order. The situation was not always so. Departmental statistics give 67,285 trees as the citrus planting in 1933, but earlier it was probably much greater, since at that time trees were dying and others were un-thrifty. Thirty-one years later the numbers have dropped to 5,236 trees.

Penman (1936), in a comprehensive investigation, suggested that free water, salt, low level of nutrition, disease and root stocks all played some part in the unthriftiness of the trees, but he emphasized the importance of soil type in regard to the incidence of watertables and salting. He also stated that salt was a secondary problem in view of the moderate salinity of the soils. The physical character and salinity of the Nanneella, Timmering and Wanalta series have been referred to earlier in this section in connection with the decline of citrus on these soil types. The question is whether the soil conditions have contributed to the poor condition and death of citrus are also a danger to less sensitive horticultural crops, and whether the conditions can be improved. There has been some replanting of citrus area with pears, stone fruits, and other varieties, as present tree plantings, other than citrus, total 42,697. But clearly, there has been no pronounced swing to alternative forms of horticulture, and much of the original horticultural land is now under irrigated perennial pastures. The intermingling of dairying with fruit-growing is possibly a reason, although probably not the only one, why horticultural actives have not developed more. The intensive watering which dairy pastures demand leads to high district watertables; these increase the hazard of tree losses from seasonal waterlogging which inevitably occurs in the district every decade or so. Attempts to control the height of the watertable by open intercepting drains have not been particularly successful, while tile drains are not considered economic to combat waterlogging in the absence of salt. Nevertheless most of the soils subject to watertables would respond to tile drainage, should the watertable be saline and near the rootzone, this would be the only method of protecting fruit trees from salt injury.

Campaspe Irrigation District –

It is important to know where the soils stand in relation to fruit-growing in view of the future development of irrigation in the Campaspe Irrigation District. In this regard a large part of the areas consists of Nanneella loamy fine sand, Nanneella fine sandy loam and Timmering loam, soil types which superficially at any rate have desirable qualities for the growth of fruit trees. Wanalta loam is another, but less attractive soil type which might be used fro the growing of less exacting varieties. The desirable qualities in the first three soil types include light to moderate textures within the rootzone, adequate surface depth, and low salt contents.

Watertables are absent at present, but it must be accepted that they will appear in lighter soils with the advent of widespread irrigation. Relatively impermeable layers are thought to be common within 10 feet of the surface and these will operate towards the formation of watertables. Fortunately, subsoil salt levels are low almost everywhere, and the risks to fruit trees from salt injury would be slight. There is not *direct* risk to fruit trees from *stationary*, *non-saline* watertables where these remain below 3 or 4 feet. The hazard lies in the possibility that levels should build up to an extent that the whole, or major part of the rootzone is saturated periodically for unduly long periods. It is only sensible, therefore, that practices which will keep watertables to the lowest possible depth should be strongly advocated from the inception of irrigation, whatever the irrigated crops. Further, watertables will be more readily controlled if dairying and fruit-growing are not closely intermingled.

The risks to stone fruits from waterlogging in excessively wet years appear to be the same as in the main northern orchard areas. Actually, losses of these fruit trees in the Bamawm area in the wet years of 1956 and 1963 were proportionately the same as in the Goulburn Valley.

DESCRIPTION OF SOIL TYPES AND MISCELLANEOUS UNITS

In this section, all of the soil types and other mapping units shown on the eighteen soil maps with this bulletin are described in regard to their profiles, occurrence and land use.

The profile features given in each case are the average for the particular soil type. The profiles of individual situations will usually depart in some respects from these averages.

Five landscape patterns, each with its own distinctive topography and vegetation, can be recognized in the area. These have been designated landscape units and are indicated by italics in the ensuing parts of this section. Each soil type occupies a definite place in the landscape pattern, consequently positional relationships occur between the soil types in each landscape unit. These aspects are dealt with fully in the section, "Landscape Units and Guide to Soil Types" which is also a help to the identification of the soil types in the field.

In the first section of this bulletin, the soil types are grouped in regard to suitability for particular irrigation crops. In this section, the information is elaborated for the soil types individually. In addition, reference is made to present as well as to potential land use.

The 23 names soil types found in the surveyed area (Table 1) are dealt with in alphabetical order. These are followed by nine unnamed soil types, three types of prior stream bed, a drainage unit of variable soils, and miscellaneous mapping units. Fourteen of the soil types have been recorded previously in the adjoining Deakin Irrigation Area (Skene 1963).

A number of areas totally 920 acres in the Bamawm and Ballendella localities was covered by soil survey in 1935 and nine soil types were named and described (Penman 1936). These areas are included in the present survey, and the relationship between the earlier soil types and the present ones is dealt with in the last part of this section.

The overall-pattern and approximate extent of the main soil series can be pictured from the Soil Association Map; this is discussed in the section "Soil Associations."

BINABBIN CLAY

Surface soil -

A	0 to 3 inches; dark grey-brown (7.5 to 10YR 3/3)* cracking clay; crumbles to fine subangular blocky peds; friable moist; plastic and slightly sticky when wet; slight calcium carbonate may be present; grade into:

Subsoil –

B	3 to 16 inches; dark greyish brown (7.5YR 3/3) heavy clay; moderate medium subangular blocky structure; friable moist, plastic wet; slight calcium carbonate usually present; grades into:

C	16 to 30 inches; dark brown (5YR3/4) heavy clay; light calcium carbonate; gypsum irregularly present; grades into:

30 to 72 inches; brown, passing to reddish brown (2.5YR 4/5), heavy clay; light calcium carbonate; at variable depths below 6 feet grades into clay containing fragments of weathered rock.

Occurrence – Binabbin clay has been recorded previously in the adjoining Deakin Irrigation Area (Skene 1963). It is found on the slopes of the Cambrian hills and on immediately adjoining plain in the south-eastern part of the surveyed area. Binabbin clay is closely associated with Cornella clay and often occurs with that type as a soil complex. It is a component of the *Cambrian upland landscape unit*.

Land Use – Binabbin clay is used mainly for wheat growing and high yields are obtained. The soil profile appears to have good physical properties for water penetration and should support irrigated perennial pastures well, although seasonal cracking, and sometimes a gilgaied surface, are detracting properties which may render some situations more suitable for annual pastures. Salinity risks appear to be low.

CARAG CLAY

Surface soil –

A	0 to 3 inches; grey (2.5Y 6/1) to brown grey (10YR 5/2) cracking clay; with rusty mottling along root channels; fine subangular to medium angular blocky structure; hard dry, plastic and slightly sticky when wet; at 1 to 5 inches sharply separate from:

Subsoil –

B	3 to 20 inches; yellow-grey (2.5Y 5/3) heavy clay with black staining on ped faces in top few inches; moderate, passing to weak angular blocky structure; hard dry, tough and intractable moist; grades into:

B_2C	20 to 36 inches; similar to above with slight soft calcium carbonate and concretions; gypsum infrequently present; grades into:

36 to 72 inches; brownish or mottled, yellow-grey medium clay; slight calcium carbonate.

Variants – These are indicated by inscriptions on the soil maps, *gravelly deep subsoil* denoting appreciable gravel, *light deep subsoil* the present of light clay or lighter textures, and *brownish profile* a browner than usual colour in the subsoil.

Occurrence – Carag clay resembles Congupna clay, a depression soil described by Skene and Poutsma (1962) in the Goulburn Valley. It has been recorded previously by Skene (1963) in the Deakin Irrigation Area where it is widespread. Carag clay occupies low-lying areas and drainage lines in both the *prior stream* and the *treeless plain landscape units.* Some depressions classified as Carag clay in the largely treeless plain landscape found in the western part of the surveyed area are probably prior stream beds.

---

* Munsell colour notation of moist soil. Only the main colour is given for mottled soils. Also see Appendix III.

Land Use – Carag clay is not recommended for irrigation generally, because of drainage difficulties arising from its low position in the landscape. It is also unattractive because of its heavy-textured, impermeable profile. It might be used for the irrigation of annual pastures in some situations where drainage can be improved sufficiently, although there may be a moderate salinity risk.

COLBINABBIN CLAY LOAM

Surface soil –

A 0 to 6 inches; dark reddish brown (2.5YR 3/4) clay loam, slightly hard dry or crumbling to fine subangular blocky peds; very friable moist, sharply separated from:

Subsoil –

B_1 6 to 21 inches; dark reddish brown (2.5YR 3/4) heavy clay; moderate to strong medium subangular blocky structure, hard, dry, friable moist; grades into:

B_2C 21 to 33 inches; reddish brown (2.5YR 3/6) heavy clay; structure as above; slight to light calcium carbonate; grades into:

33 to 48 inches; red-brown heavy clay; decreasing calcium carbonate; gypsum sometimes present; grades into:

48 to 84 inches; as above or with inclusions of weathered rock.

Occurrence - This soil type occurs on the slopes of the Cambrian hills and on parts of the adjoining plain which form the *Cambrian upland landscape unit*. Skene (1963) has recorded Colbinabbin clay loam and Colbinabbin clay in the Deakin Irrigation Area, but describes the surface soils as crumbly rather than hard setting. There is evidence that the soils on the steeper slopes tend to be crumbly and those on the gentler slopes hard setting.

Land Use – Colbinabbin clay loam is farmed extensively for wheat and yields well. The fine subangular blocky structure in the surface soil confers good properties for cultivation, but, in the marginal down-slope occurrences this characteristic is not pronounced, or is absent. The last soils tend to be hard setting when dry.

Colbinabbin clay loam is irrigated to only a very small extent, but is capable of supporting good perennial pastures. The subsoils have low salt contents and the risk of salinity developing is slight.

Shallow phase
In this phase, weathered rock occurs at less than 2½ feet from the surface.

COLBINABBIN CLAY

Surface soil –

A 0 to 3 inches; dark brown 5 to 7.5YR 3/4) light clay; moderately hard dry, friable moist; sharply separated from:

Subsoil –

B 3 to 15 inches; dark brown (5YR 3/4) or dark reddish brown (2.5YR 3/4) heavy clay; moderate subangular blocky structure; hard dry, friable moist; grades into:

15+ inches; similar to Colbinabbin clay loam.

Occurrence and Land Use – Colbinabbin clay occurs almost entirely as a subdominant soil type intermingled with Binabbin clay and Cornella clay. These areas are given to wheat-farming and grazing. They are suitable for perennial pastures provided the surface, which is often gilgaied, can be graded satisfactorily.

CORNELLA CLAY

Surface soil –

A 0 to 5 inches; dark grey (10YR to 2.5Y 3/1) medium clay; strong medium or fine subangular blocky structure; “self-mulching” when slightly moist; often with slight fine calcium carbonate concretions; at 3 to 6 inches grades into:

Subsoil –

B 5 to 20 inches; dark grey (10YR to 2.5Y 3/1) heavy clay; strong coarse prismatic structure showing deep vertical cracking, very friable moist; light soft calcium carbonate and a few concretions; grades into:

20 to 36 inches; dark grey heavy clay with pockets of yellowish brown (10YR 5/4) clay increasing with depth; light soft calcium carbonate and concretions; grades into:

36 to 84 inches; weakly mottled yellowish brown (10YR 5/4) clay with yellow-grey colours increasing and calcium carbonate decreasing gradually with depth; black inclusions often prominent with depth.

Occurrence – Cornella clay has been recorded previously by Skene (1963) on a treeless plain landscape in the Deakin Irrigation Area. In the present area, it is a component of the *Cambrian upland landscape unit* since it occurs on the Cambrian hill slopes and nearby plain a co-dominant type in a soil complex with Binabbin clay. The surface has a gilgai microrelief.

Land Use – Dry-farming pursuits on this soil type are wheat-growing and the grazing of volunteer pastures. Little of the complex referred to is irrigated, but, given adequate drainage and grading, it should grow perennial pastures well, since the soil profile has a favourable structure for root and water penetration. The likelihood of salt injury is slight since the subsoils generally have low salt contents.

COROP CLAY

Surface soil –

A 0 to 3 inches; grey (5Y 5/1) medium clay; weak angular blocky structure; hard dry, sticky wet; sharply separated from:

Subsoil –

B_1 3 to 18 inches; grey (5Y 4/1) heavy clay; moderate medium subangular blocky structure; very friable moist, sticky wet; grades into:

B_2C 18 to 42 inches; yellowish grey (5Y 5/2) heavy clay; structure as above; very friable moist; slight soft calcium carbonate and concretions; slight gypsum; grades into:

42 to 72 inches; weakly mottled yellowish grey heavy clay; slight calcium carbonate.

Occurrence and Land Use – Corop clay is of practically no agricultural importance in the surveyed area, although it is widespread beyond the south-eastern part towards Corop (Skene 1963). It is unattractive for irrigation because of its liability to inundation, heavy-textured and shallow surface soils, and saline deep sub-soils.

KANYAPELLA CLAY LOAM

Surface soil –

A 0 to 4 inches; grey (2.5Y 5/1) or brownish grey clay loam; moderate medium subangular blocky structure; vesicular peds; slight buckshot; at 3 to 7 inches; grades into:

Subsoil -

B_1 4 to 18 inches; yellowish grey (2.5Y 5/2) with slight rusty mottling, light or medium clay; moderate angular blocky structure, vesicular peds, sometimes slight buckshot; grades into:

B_2 18 to 33 inches; weakly mottled yellow-grey and yellow-brown medium clay; slight soft black inclusions; slight soft calcium carbonate and concretions;

C 33 to 48 inches; mottled yellow-brown and grey micaceous slight clay; soft black inclusions; calcium carbonate irregularly present; grades into:

48 to 72 inches; variable, as above, or silty clay or micaceous fine sandy clay passing to fine sandy clay loam; calcium carbonate concretions sometimes present.

Variant – Sometimes micaceous fine sandy clay occurs in the deep subsoil at less than 48 inches from the surface.

Occurrence – Kanyapella clay loam occurs only in the Echuca East Settlement and is contiguous with an extensive occurrence recorded by Skene (1963) in the Deakin Irrigation Area. The area is one of riverine black box woodland which has been cleared and protected from flooding from the Murray River by a levee bank.

Land Use – The soils support good irrigated perennial pastures which are used for dairying. There is no evidence of a salinity hazard in these soils.

KANYAPELLA CLAY

This soil type commonly has grey light clay surface 2 to 4 inches deep, otherwise it is identical with Kanyapella clay loam.

Occurrence and Land Use – The remarks about Kanyapella clay loam apply also to Kanyapella clay.

KOGA CLAY LOAM

Surface soil –

A 0 to 4 inches; diffusely mottled grey-brown (7.5YR 4/4 to 10YR 5/3) clay loam; hard dry, plastic and slightly sticky moist; A_2 very thin, sporadically bleached; at 2 to 6 inches sharply separated from;

Subsoil -

B_1 4 to 21 inches; dull brown (7.5YR 4/3) to yellowish grey-brown (10YR 4/3) heavy clay often darker with diffuse rusty mottling in the upper part; moderate angular blocky structure; peds 3 to 6 inches; hard dry, tough and intractable moist; grades into:

B_2C 21 to 30 inches; dull yellowish brown (10YR 5/4) heavy clay; moderate medium subangular blocky structure; hard, dry, friable moist; slight soft calcium carbonate and fine concretions; grades into:

30 to 48 inches; dull yellowish brown or diffusely mottled yellowish grey-brown medium clay; friable moist; variable calcium carbonate; gypsum irregularly present; grades into:

48 to 84 inches; moderately mottled brownish yellow-grey and brown medium clay, black flecks on ped faces; slight calcium carbonate irregularly present.

Variants – The inscriptions on the soil maps of deep surface and *bright deep subsoil* denote, respectively, a surface thicker than 6 inches, and uniformly reddish or yellowish brown colours in the deep subsoil below 30 inches.

Occurrence – Koga clay loam is widespread and is probably the most extensive soil type. It is the commonest member of the Koyuga-Koga-Yuga toposequence in the eastern part, but largely gives way to Koyuga clay loam in the western part of the surveyed area. This toposequence together with Rochester clay and Restdown clay from the *treeless plain landscape unit*.

Koga clay loam also occurs extensively in the adjacent Deakin Irrigation Area (Skene 1963), and extends slightly into the Tongala-Stanhope Irrigation Area (Skene and Poutsma 1962).

Land Use – The dry-land agriculture practised on Koga clay loam is cereal-farming and the grazing of sheep for wool production, mostly on native and volunteer pastures. Where it is irrigated, it mainly supports annual pastures. Perennial pastures are likely to be less successful, except possibly on the deep surface variant, since the soils are usually shallow and slowly permeable, while surface drainage is only fair or indifferent. The soil type is unattractive for horticulture and at the most the better situations could be used for pears and plums. The subsoils are frequently moderately, and sometimes highly, saline, and in such situations there is risk of salt troubles developing under irrigation, if drainage is unsatisfactory.

KOYUGA CLAY LOAM

Surface soil –

A 0 to 5 inches; dull brown (7.5YR 5/4) clay loam, occasionally loam, structureless or weak angular blocky structure; hard dry; A_2 very thin, sporadically bleached; at 3 to 7 inches sharply separated from:

Subsoil –

B_1 5 to 21 inches; dark reddish brown (2.5YR 3/4) passing to brown heavy clay; moderate intractable moist; grades into:

B_2C 21 to 30 inches; yellowish brown, sometimes diffusely mottled, heavy clay; friably moist slight to light soft calcium carbonate and concretions; grades into:

30 to 48 inches; diffusely mottled yellowish brown medium clay; friable moist; slight calcium carbonate; gypsum irregularly present; grades into:

48 to 72 inches; moderately mottled brownish yellow-grey and brown medium clay; black flecks on ped faces; slight calcium carbonate irregularly present.

Variants – A *deep surface inscription* on the soil maps denotes a surface depth greater than 7 inches. *Light surface* refers to a loam texture and gritty surface to the presence of appreciable fine gravel. A *bright deep subsoil* variant is similar to that in Koga clay loam.

Occurrence – This soil type occupies the slightly higher, better drained positions on the *treeless plain landscape unit*. Whilst it occurs extensively throughout the surveyed area, it is particularly prevalent in the north-western parts. Koyuga clay loam is recorded as not being particularly widespread in the treeless plain parts of the Deakin Irrigation Area (Skene 1963), while only minor occurrences are found further eastward (Skene and Poutsma 1962).

Land Use – Agricultural pursuits on Koyuga clay loam are similar to those on Koga clay loam, although much more of the soils are outside the irrigation area and given to dryland farming. Like Koga clay loam, the soil type is considered best suited for annual pastures under irrigation, although it has a slightly greater potential for perennial pastures because of its slightly deeper and lighter-textured surface and somewhat better drainage situation. Low permeability of the subsoils is the main drawback to utilization for permanent pastures. Koyuga clay loam generally, like Koga clay loam, is unattractive for horticulture.

Although moderate salt contents occur in most of the subsoil, the salinity hazards are rather less than in the associated Koga clay loam because of slightly better drainage possibilities.

LOCKINGTON SAND

Surface soil -

A_1 0 to 7 inches; greyish brown (7.5YR 4/4) sand or loamy sand; structureless; friable dry and moist; at 6 to 11 inches separated sharply from:

A_2 7 to 40 inches; brown (5YR 5/4) sand or loamy sand; gradual transition to:

Subsoil –

B_1 40 to 60 inches; reddish brown, sometimes diffusely mottled greyish brown, micaceous fine sandy loam or fine sandy clay loam; friable dry and moist; grades into:

60 to 72 inches; yellowish brown, micaceous fine sand or heavier textures (clay loam passing to light clay).

Occurrence – Locking sand is a minor component of the *prior stream landscape unit* in situations where the prior streams are more strongly developed. Most occurrences are individually too small to show on the soil maps, and these are shown either in complex with Nanneella fine sandy loam or are denoted by an inscription. The few individual occurrences that are shown below to a *shallow phase*. Penman (1936) has described Lockington sand previously at Bamawm.

Similar Soil Type – Lockington sand has the same light-textured profile as Sandmount sand (Butler et al, 1942, Skene and Poutsma 1962), but occupies less obvious rises.

Land Use – Since Lockington sand is intermingled with Nanneella fine sandy loam, its land use is usually the same as for that soil type. Lockington sand, but not its shallow phase, is considered suitable for citrus and tobacco provided it can be watered and drained efficiently, and salt concentrations are sufficiently low. Only very small, undefined areas are likely to be in this category, and prospects for either citrus or tobacco-growing are slight.

Shallow Phase –
In this phase, the B_1 horizon occurs at depths between 24 and 36 inches from the surface.

Land Use - This is the same as for Nanneella fine sandy loam.

NANNEELA LOAMY FINE SAND

Surface soil –

A_1 0 to 6 inches; greyish brown (7.5YR 4/4) to grey-brown loamy fine sand; structureless; diffuse boundary with:

A_2 6 to 11 inches; lighter brown (7.5YR 5/4) to loamy fine sand; structureless; grades into:

20 to 32 inches; diffusely mottled reddish and yellowish brown, micaceous, fine sandy clay loam; grades into:

32 to 48 inches; light yellowish brown, micaceous, fine sandy loam; slight calcium carbonate irregularly present:

48 to 72 inches; variable textures ranging from sand to light clay; slight soft calcium carbonate and concretions.

Variant – The presence of a cemented layer in the deep subsoil is indicated on the soil maps by the inscription *hardpan in deep subsoil*.

Occurrence – This soil type is found on the levees of the stronger prior streams. It occurs extensively in the Campaspe Irrigation District; elsewhere it is of minor extent.

Land Use – Nanneella loamy fine sand has not been irrigated to any extent, and has been utilized for cereal-growing and the grazing of sheep on volunteer pastures, clover ley and dry-lucerne in the Campaspe Irrigation District. Under careful irrigation, it should be very suitable for all horticultural crops, most vegetables, tomatoes, lucerne and annual and perennial pastures. However, the presence of a restricting clay layer at variable depths below 4½ feet suggests that Nanneella loamy fine sand will develop watertables readily under careless irrigation practices. Fortunately, the salt status of the subsoils is low.

NANNEELLA FINE SANDY LOAM

Surface soil -

A 0 to 10 inches; greyish brown (7.5YR 4/4) passing to brown sandy loam; moderately hard dry, friable moist; sometimes differentiated into an A_1 and a lighter coloured A_2 horizon; at 7 to 12 inches sharply separated from:

Subsoil –

B_1 10 to 18 inches; red-brown (2.5YR 3/6) to reddish brown (5YR 3/6) light or medium clay; medium angular blocky structure; grades into:

B_2C 18 to 24 inches; brown, or diffusely mottled reddish and yellowish brown, light clay or clay loam; calcium carbonate sometimes present; grades into:

24 to 32 inches; yellowish brown, micaceous, fine sandy clay loam; slight soft calcium carbonate and concretions.

32 to 58 inches; moderately mottled yellowish brown and grey-brown fine sandy loam or fine sandy clay loam; calcium carbonate decreasing; grades into:

58 to 72 inches; continuing light textures, or moderately mottled grey and brown light clay.

Variants – *Loam surface* denotes areas with heavier than normal surface textures, whilst the presence of appreciable grit in various parts of the soil profile is indicated by the inscription *gritty profile*.

Occurrence – Nanneella fine sandy loam is widely distributed and is a prominent soil type in the *prior stream* landscape unit where it occurs on the levees of the stronger prior streams.

Similar Soil Type – East Shepparton fine sandy loam is a similar soil type which occurs on the levees of prior streams in the Goulburn Valley (Skene and Poutsma 1962). It differs from Nanneella fine sandy loam mainly in its deep subsoil which seldom includes a slowly permeable layer within 7 feet of the surface, whereas such a layer frequently occurs in Nanneella fine sandy loam at depths between 4½ and 7 feet.

Land Use – Whilst Nanneella fine sandy loam has the same dry-farming use as Nanneella loamy fine sand, it is much more extensive and has been used successfully for dairying and fat lamb production on irrigated, perennial pastures. Citrus are grown on Nanneella fine sandy loam in the Bamawm and Ballendella localities, but the area has diminished greatly through waterlogging, and the type is not recommended for future citrus plantings in situations where there is likelihood of high watertables. However, it should be a good soil for most other horticultural crops, vegetables, tomatoes and lucerne.

Although salt levels in the subsoils are usually low, watertables are liable to develop and there is some risk to stone fruits unless the watertable is kept in check by efficient watering and drainage methods.

RESTDOWN CLAY

This soil type occurs on more or less gilgaied situations which, in the undisturbed state, are marked by areas of crumbly clay (puff) slightly raised above intervening less friable, flat land (shelf). Restdown clay includes profiles ranging between these two situations. The two extremes are described below, but the proportion of each in any one area depends on the degree of Gilgai manifestation.

"PUFF" PROFILE

Surface soil –

0 to 5 inches; greyish brown (7.5YR 4/4) to dark grey-brown medium clay; strong, medium for fine subangular blocky structure; crumbles to hard peds when dry; slight calcium carbonate concretions; at 3 to 7 inches grades into:

Subsoil –

5 to 30 inches; dark-brown (5YR ¾) to yellowish brown heavy clay; strong, passing to moderate, coarse angular blocky structure; light soft calcium carbonate, slight concretions; grades into:

38 to 48 inches; yellowish brown heavy clay; uniformly coloured or diffusely mottled; calcium carbonate as above.

"SHELF" PROFILE

Surface soil –

A 0 to 2 inches; greyish brown (7.5YR 4/4) to grey-brown light clay or clay loam; weak subangular blocky structure; hard dry; sharply separated from:

Subsoil –

B_1 2 to 18 inches; dark-brown (5YR 3/4) to dark grey-brown (7.5YR 3/4) heavy clay; moderate coarse angular blocky structure; hard dry, tough and intractable moist; grades into:

B_2C 18 to 28 inches; brown to yellowish brown, uniformly coloured or diffusely mottled, heavy clay; friable; slight to light calcium carbonate; gypsum irregularly present; grades into:

18 to 48 inches; diffusely mottled brown and greyish yellow-brown heavy clay; moderately friable; slight calcium carbonate

Occurrence – Restdown clay is one of a pair of gilgaied soils found on the *treeless plain landscape unit* west of Echuca South fault line. It groups brown soils in this landscape unit which have a widespread gilgai microrelief. It is commonly intermingled with Rochester clay to such an extent that the two soil types cannot be shown separately on the soil map.

Land Use – Wheat-growing and the grazing of sheep on unimproved pastures as the principal agricultural pursuits on Restdown clay. A little is irrigated and carries annual pastures.

Restdown clay has heavy clay textured almost from the surface; these operate against a favourable infiltration rate under irrigation, but intake of water and root penetration may be assisted by fairly extensive cracking. The shallow and often heavy-textured surface is not amenable to easy grading, while the subsoils have moderate, and in some cases, high salt contents. For all these reasons, Restdown clay is unlikely to be satisfactory for perennial pastures, but it should support reasonable annual pastures, summer fodder crops and cereals, providing proper grading and surface drainage can be accomplished.

ROCHESTER CLAY

Like Restdown clay this soil type occurs on gilgaied situations which, in the undisturbed state, are marked by areas of crumbly clay (puff) slightly raised above intervening, less friable, flat land (shelf) or depressions. Rochester clay includes profiles ranging between the two extreme situations. Profiles for "*puff*" and "*shelf*" are described in below, but the proportion of each in any one area depends on the degree of gilgai manifestation.

"PUFF" PROFILE

Surface soil –

0 to 6 inches; dark grey (10YR 3/1) heavy clay; strong, medium or fine subangular blocky structures; crumbles to hard peds when dry; slight calcium carbonate; grades into:

6 to 28 inches; dark yellowish grey (2.5YR 3/1) heavy clay; strong passing to moderate, coarse angular blocky structure; slight soft calcium carbonate and fine concretions; grades into:

28 to 48 inches; yellowish grey heavy clay; slight or light calcium carbonate.

"SHELF" PROFILE

Surface soil –

A 0 to 5 inches; dark grey (10YR3/1), diffusely mottled with rusty colours, medium clay; moderate medium subangular blocky structure; hard and cracks when dry; sharply separated from:

Subsoil –

B 5 to 20 inches; dark brownish grey (10YR 3/2) heavy clay; moderate angular blocky structure; hard dry, tough and intractable moist; grades into:

B_2C 20 to 48 inches; brownish grey or yellowish grey-brown heavy clay; slight soft calcium carbonate and fine concretions.

Variant.—The inscription *bright deep subsoil* refers to uniform yellowish brown, reddish brown, or brown colours in the subsoil below 2 feet. A more than normal gilgai manifestation is indicated by the inscription "*very heavily gilgaied ".*

Occurrence.—Except for soils in depressions and drainage lines, Rochester clay groups the grey gilgai soils found in the *treeless plain landscape unit* west of the Echuca South fault line. It frequently occurs intermingled with Restdown clay, and sometimes these two soil types cannot be shown separately on the soil map.

Land Use.—The remarks given about Restdown clay apply to Rochester clay, except that the latter soil type is often more strongly gilgaied and grading and surface drainage measures may be more difficult. Subsoil salt levels are either low or moderate. The area marked "very heavily gilgaied" is considered unsuitable for irrigation layout.

TIMMERING LOAM.

Surface soil—

A 0 to 7 inches; dull brown (7.5YR 4/4) loam; occasionally fine sandy loam, usually differentiated into an A, and a thin, lighter-coloured A2 horizon sometimes sporadically bleached; moderately hard dry, friable moist; at 6 to 10 inches sharply separated from:

Subsoil-

B_2 7 to 19 inches; red-brown (2.5YR 3/6) medium clay; moderate medium subangular blocky structure; hard dry, plastic wet; grades into:

B_2C 19 to 27 inches; brown or yellowish brown light clay becoming diffusely mottled with depth; strong medium subangular structure; calcium carbonate irregularly present; grades into:

27 to 38 inches; diffusely mottled yellowish grey-brown and brown light clay, passing to fine sandy clay, fine sandy clay loam or clay loam; trace to light amounts of calcium carbonate concretions; grades into:

38 to 48 inches; moderately or diffusely mottled (colours yellower and greyer than above), fine sandy clay or fine sandy clay loam; traces of calcium carbonate concretions diminishing with depth; grades into:

48 to 72 inches; textures as above or lighter; usually resting on a heavier-textured, moderately mottled layer before 8 feet.

Variants—Shallow surface refers to a surface depth of less than 6 inches, *deep surface* to more than 10 inches. Various *gritty* designations indicate that there is appreciable grit in the specified parts of the soil profile. *Sandy profile* refers to the presence of distinct amounts of coarse sand accompanied by a deeper than usual surface horizon. Other variants are *grey surface* and *hard pan in the* deep *subsoil,* the latter indicating the presence of a cemented layer.

Occurrence—Timmering loam occurs on the levee and near-flood plain parts of the prior *stream landscape unit.*

*Similar Soil Type—*Brown soils with red-brown clay subsoils and lighter textures beneath, such as occur in Timmering loam, are common on the well-drained positions in the prior stream landscapes of Northern Victoria. Timmering fine sandy loam is such a soil type recorded in the Deakin Irrigation Area (Skene 1963); others similar to Timmering are Shepparton fine sandy loam in the Goulburn Valley (Skene and Poutsma 1962) and Cobram loam in the area between Numurkah and Cobram (Butler *et al.,* 1942).

*Land Use—*Apart from the Campaspe Irrigation District where Timmering loam at present is cropped and grazed by sheep, most areas are under irrigation given to dairying and fat lamb production on perennial pastures. Citrus were once grown fairly widely in the Bamawm locality and a little is still under fruit trees.

Timmering loam has physical characteristics favourable for irrigation. The surface soils are sufficiently deep and workable to allow efficient grading, while the clay subsoils are moderately permeable and allow enough intake of water for deep-rooting crops. In fact, rather than inadequate penetration, there is danger of watertables forming in the deep subsoils. These may present some risk to stone fruits from waterlogging, but, as salt levels are low in the subsoils, the risk of injury from salt is slight provided sound irrigation practices are employed. Experience has shown that citrus should not be grown, but there should be no problems with vegetables, lucerne and perennial and annual pastures.

WALLENJOE CLAY.

Surface soil—

A 0 to 4 inches; dark bluish grey (N 4/0) to dark grey (10YR 4/1) heavy clay; rusty mottling along root channels; moderate coarse angular blocky structure; very hard dry, sticky wet; at 3 to 6 inches grades into:

Subsoil—

B 4 to 22 inches; dark bluish grey (N 4/0) heavy clay; moderate large angular blocky structure; very hard dry, very sticky moist; grades into:

22 to 48 inches; as above; slight calcium carbonate concretions.

Occurrence—Wallenjoe clay is found in swamps and drainage ways which remain inundated for long periods, and is usually marked by lignum bushes and a gilgai microrelief. It has been recorded previously in the Deakin Irrigation Area where it is very extensive (Skene 1963).

Land Use—Prolonged inundation prevents Wallenjoe clay from being used for other than sparse grazing during its drier periods. Some drainage ways represent natural drainage outlets and are utilized as such.

WANA LOAM

Surface soil—

A 0 to 5 inches; grey-brown (7.5 to 10YR 5/3) loam; hard dry; sporadically bleached at junction with B1; at 4 to 7 inches sharply separated from:

Subsoil—

B_1 5 to 19 inches; yellowish brown (7.5 to 10YR 3/4) heavy clay; moderate prismatic passing to weak blocky structure; hard dry, plastic and sticky wet; grades into:

B_2C 19 to 30 inches; duller-coloured heavy or medium clay; slight soft calcium carbonate and concretions; grades into:

30 to 48 inches; diffusely mottled yellowish grey-brown medium clay; trace of calcium carbonate concretions; gypsum irregularly present.

Variants—Deep surface refers to a surface depth of more than 7 inches, *light deep surface* to a fine sandy loam surface from 9 to 13 inches deep, and *gritty profile* to the presence of appreciable fine gravel in both surface and subsoil or deep subsoil.

Occurrence—Skene (1963) has previously recorded Wana loam in the Deakin Irrigation Area. It is found on nearly level situations in mid-flood plain positions of the *prior stream landscape unit.*

Similar Soil Type—Goulburn loam which occurs extensively on mid-flood plain positions in the prior stream landscape in the Goulburn Valley (Skene and Freedman 1944, Skene and Poutsma 1962) shows only minor variations from Wana loam.

Land Use—The present land use of Wana loam is similar to that given for Wanalta loam. It is regarded as a good soil for irrigated perennial and annual pastures, summer fodder crops and cereals, but is a poor soil for horticultural crops other than pears and plums. The salt contents of the subsoils are generally low, but sometimes reach moderate levels.

WANA CLAY LOAM.

The profile of Wana clay loam is similar to that of Wana loam except that the surface is clay loam varying from 3 to 6 inches thick.

Variant—Heavy surface refers to surface textures heavier than clay loam. The surface of this variant is greyer, and an angular blocky structure is more strongly developed than in the surface horizon of Wana clay loam. *Gritty surface* identifies soils with appreciable amounts of grit.

Occurrence—Wana clay loam occurs at slightly lower positions than Wana loam on the mid-flood plain of the *prior stream landscape unit.*

Land Use—Wana clay loam can be considered with Wana loam in this regard.

WANALTA LOAM.

Surface soil—

A 0 to 5 inches; brown or greyish brown (5 to 7.5YR 4/4) loam, occasionally clay loam; hard dry, friable moist; usually sporadically bleached at junction with B_1; at 4 to 8 inches sharply separated from:

Subsoil—

B_1 6 to 20 inches; red-brown to reddish brown (2.5 to 5YR 3/4 to 6) heavy clay; moderate prismatic passing to weak blocky structure; hard dry, plastic and slightly sticky wet; grades into:

B_2 20 to 28 inches; brown or yellowish brown medium clay; slight soft calcium carbonate and concretions; grades into:

C 28 to 48 inches; weakly mottled greyish brown and yellowish grey-brown light clay or medium clay; calcium carbonate diminishing with depth:

48 to 72 inches; moderately mottled grey and grey-brown medium clay.

Variants—Shallow surface refers to a surface depth of less than 5 inches, *deep surface* to more than 9 inches. A *light deep surface* variant has 6 to 11 inches of fine sandy loam. Other variants are *grey surface*, and various *gritty* designations indicating appreciable grit in the specified parts of the soil profile.

Occurrence—Wanalta loam was first identified on near-flood plain positions in the prior stream landscape in the adjoining Deakin Irrigation Area (Skene 1963). It occupies similar positions in the *prior stream landscape unit* of the present area, but also occurs on a few of the low levees adjoining the drainage ways found on the treeless plains.

Similar Soil Type—Lemnos loam is a very similar soil type associated with the prior streams in the Goulburn Valley (Skene and Freedman 1944, Skene and Poutsma 1962) and Moira loam in the Murray Valley Irrigation Area (Butler *et al.*, 1942).

Land Use—Besides being used extensively for cereal-farming and the grazing of sheep, mostly on volunteer and native pastures, Wanalta loam is irrigated extensively and supports good perennial and annual pastures. It has not been used much for fruit-growing.

Experience with horticultural crops in the Goulburn Valley on the similar Lemnos loam suggests that apples, pears and plums could be grown successfully. However, prospects for stone fruits are only fair, or even poor due to shallow surface depths, and rather slow permeability of the clay subsoils. The deep and light surface variants should be satisfactory, but the grey surface variants are definitely unsuitable for these varieties. The salt status of the subsoils is low and occasionally moderate. Generally, proposed sites on Wanalta loam should be checked for suitability before planting to horticultural crops.

WANURP SANDY LOAM.

Surface soil—

A1 0 to 6 inches; greyish brown sandy loam or loamy sand; structureless; sharply separated from:

A2 6 to 11 inches; light grey-brown sandy loam or loamy sand; conspicuously bleached; cemented when dry; at 6 to 16 inches sharply separated from:

Subsoil—

B_1 11 to 22 inches; reddish brown medium or heavy clay; traces of sand irregularly present; occasional black staining on the ped faces; grades into:

C 22 to 48 inches; variably coloured, textures ranging from medium clay to coarse sandy clay loam; occasionally cemented when dry.

Variants—Shallow surface refers to a surface depth of less than 6 inches and *mottled subsoil to* diffuse mottling in the B, horizon.

Occurrence—Wanurp sandy loam is a soil type of small extent found on low rises flanking some of the depressions shown as Variable Soils in Drainage Ways in the western part of the surveyed area. Together these soils comprise a weakly developed *prior stream landscape unit*. The subsoils have moderate salt contents.

Land Use—Wheat-growing and the grazing of sheep on volunteer pastures is carried out on Wanurp sandy loam a little of which is irrigated and carries perennial pastures. As far as can be judged all situations would be capable of supporting Group III. crops under irrigation, while some might be suitable for Group II. crops.

YAMBUNA CLAY

Surface soil—

A 0 to 4 inches; diffusely mottled grey (2.5Y to 10YR 4/1) light or medium clay; at 3 to 6 inches grades into:

Subsoil-

B_1 4 to 24 inches; dark yellowish grey (2.5Y to 10 YR 3/1) passing to yellow—grey heavy clay; moderate coarse angular blocky structure with deep vertical cracking; grades into:

B_2C 24 to 33 inches; yellow-grey medium clay; black inclusions; variable soft calcium carbonate and concretions; grades into:

33 to 43 inches; moderately mottled yellow-grey and brownish grey, micaceous, light clay; grades into:

43 to 72 inches; diffusely mottled brownish grey and yellowish grey light clay, silty clay, or micaceous, fine sandy clay; slight calcium carbonate concretions.

Occurrence—Yambuna clay is a component of the *riverine woodland landscape unit* and occupies the lowest positions in this generally low-lying area. It is found only in the Echuca East locality in the present area, but has been recorded previously in the adjoining part of the Deakin Irrigation Area (Skene 1963).

Land Use—Yambuna clay supports good irrigated pastures in the Echuca East Settlement where it has been protected from flooding from the Murray River and has installations to deal with surface drainage. Salt levels in the subsoils are low, while the physical nature of the profile is such that infiltration of irrigation water is satisfactory for pastures.

YUGA CLAY

Surface soil—

A 0 to 3 inches; brownish grey to grey (2.5Y to 10YR 4/2), diffusely mottled with rusty colours, light clay, hard and cloddy dry; often with slight ferruginous concretions; at 2 to 4 inches sharply separated from:

Subsoil-

B_1 3 to 15 inches; dark brownish grey (10YR 3/2) or dark yellowish grey (2.5Y 3/2) heavy clay; moderate coarse angular blocky structure; hard dry, tough and intractable moist; grades into:

B_2 15 to 25 inches; brownish yellow-grey heavy clay; weak coarse angular blocky structure; trace calcium carbonate; grades into:

25 to 48 inches; yellow-grey heavy clay; slight calcium carbonate; gypsum irregularly present.

Variant—Bright deep subsoil refers to soils which have a yellowish or reddish brown instead of a yellow-grey deep subsoil.

Occurrence—Yuga clay has been recorded previously in the Goulburn Valley (Skene and Poutsma 1962) and in the Deakin Irrigation Area (Skene 1963). It occurs on low plain and in shallow depressions in the *treeless plain landscape unit.*

Land Use—Dry-farming areas are used mainly for grazing unimproved pastures. The few irrigated situations are given to annual pasture.

The low situation of Yuga clay requires that provision for surface drainage should be adequate. The salt status of the subsoils is usually moderately high, but if drainage is satisfactory, annual pastures, summer fodder crops and cereals can be grown under irrigation. Yuga clay should be avoided for horticulture and is very doubtful for satisfactory perennial pastures.

UNNAMED SOIL TYPES.

The following soil types are all of small extent and are agriculturally unimportant. In some cases the descriptions given below are based on only a few observations. The unnamed types do not correspond in any way to unnamed types with the same distinguishing letters in other surveyed areas.

Type A

A_1 0 to 8 inches; dark grey sandy loam; diffuse boundary with:

A_2 8 to 13 inches; diffusely mottled grey-brown sandy loam; sharply separated from:

BC 13 to 48 inches; moderately mottled yellowish grey-brown and brown medium clay.

Occurrence and Land Use —Only one situation of Type A in the Parish of Pannoobamawm has been recorded where it occurs on the lower parts of the levees of the *prior stream landscape unit.* Although the type supports a predominantly stone fruit orchard at present, it is not recommended for apricots and peaches due to its liability to waterlogging.

Type B

A 0 to 12 inches; greyish brown loamy sand differentiated into an A_1 and slightly lighter coloured A_2 horizon; at 7 to 18 inches sharply separated from:

B 12 to 48 inches; moderately mottled yellowish brown and grey medium clay.

Variant—A *deep surface* variant refers to surface depths in excess of 18 inches.

Occurrence and Land Use—This type is found in the Parish of Wharparilla associated with a prior stream system as a sandsheet of variable thickness on the finer deposits of the plain. Type B is subject to the development of perched watertables at the junction of the sandy surface and heavy clay subsoil. Most areas occupied by this type carry irrigated perennial pastures.

Type C

A 0 to 7 inches; diffusely mottled brownish grey clay loam; sharply separated from:

B_1 7 to 23 inches; diffusely mottled brown heavy clay; grades into:

B_2 23 to 30 inches; diffusely mottled yellowish grey-brown medium clay passing to light clay; light calcium carbonate; grades into:

C 30 to 48 inches; diffusely mottled yellowish grey-brown clay loam.

Occurrence and Land Use—Type C occurs only over a small area in the Nanneella district where it occupies an outlying part of the *prior stream landscape unit.* At present, the type supports irrigated annual pastures.

Type D

A_1 0 to 13 inches; grey-brown coarse sandy loam; sharply separated from:

A_2 13 to 24 inches; light grey-brown to very light brownish grey coarse sandy loam; moderately cemented when dry; sharply separated from:

BC 24 to 48 inches; moderately mottled brown coarse sandy clay loam or coarse sandy clay, sometimes becoming lighter with depth; usually moderately cemented when dry; black staining on the ped faces.

Occurrence and Land Use—Type D occurs in association with Wanurp sandy loam on the levees of the *prior stream landscape unit* found in the extreme western part of the surveyed area. In view of its small extent and close association with Wanurp sandy loam, Type D can be considered with that soil type in regard to any form of land use.

Type E

A 0 to 5 inches; greyish brown to brownish grey clay loam; sharply separated from:

B 5 to 24 inches; greyish brown grading into yellowish brown medium clay; grades into:

C 24 to 30 inches; diffusely mottled yellow and grey light clay or micaceous sandy clay; grades into:

30 to 48 inches; moderately mottled yellow and grey sandy clay or sandy clay loam.

Variant—Light deep surface indicates a sandy loam surface over 7 inches deep.

Occurrence and Land Use—Type E is a minor occurrence found on the highest parts of the *riverine woodland landscape unit* in the Echuca East locality. Like the associated soil types, Kanyapella clay loam and Yambuna clay, it is used successfully for irrigated perennial pastures.

Type F

A_1 0 to 5 inches; greyish brown loam; diffuse boundary with:

A_2 5 to 8 inches; diffusely mottled grey-brown clay loam, weakly bleached; grades into:

B_1 8 to 14 inches; yellow-grey, diffusely mottled with reddish brown, light clay passing to medium clay; friable; sharply separated from:

B_2 14 to 38 inches; yellowish brown, moderately mottled with brown, heavy clay; black inclusions; strong angular blocky structure; tough and intractable; grades into:

38 to 48 inches; moderately mottled brownish yellow and brown medium clay; more crumbly than above; slight calcium carbonate.

Occurrence and Land Use—This soil type is usually found in association with Koyuga clay loam and Koga clay loam and is one of the more widespread of the unnamed soil types. A few areas of Type F have been irrigated and it is considered to be a good soil for irrigated annual pastures.

Soils of the Campaspe Suite

The Campaspe Suite comprises a group of three unnamed soil types found in the parts of the *riverine woodland landscape unit* which fringe the Campaspe River along' its course through the surveyed area.

Type 1

0 to 10 inches; grey-brown (7.5YR 4/2) loam; often differentiated into an A_1 and a lighter-coloured A2 horizon; at 8 to 16 inches sharply separated from:

10 to 17 inches; dark greyish brown (7.5YR 3/2) medium clay; grades into:

17 to 30 inches; greyish brown medium clay; grades into:

30 to 48 inches; diffusely mottled yellowish and greyish brown medium clay; textures may decrease to light clay or clay loam with depth.

Variants—Light deep surface refers to a fine sandy loam surface exceeding 16 inches in depth, and *shallow surface* to less than 8 inches of surface depth.

Type 2

0 to 6 inches; brownish grey light clay; at 5 to 12 inches sharply separated from:

6 to 20 inches; dark brownish grey heavy clay; sharply separated from:

20 to 30 inches; grey-brown heavy clay; grades into:

30 to 48 inches; brown, yellowish brown or reddish brown medium clay, sometimes passing to light clay.

Type 3

0 to 14 inches; dark brownish grey (10YR 4/2) light clay; sharply separated from:

14 to 36 inches; very dark-grey (10YR 3/1) heavy clay, becoming slightly lighter in colour with depth; grades into:

36 to 48 inches; diffusely mottled grey and greyish brown medium clay; slight calcium carbonate irregularly present.

Occurrence—All of the soil types of the Campaspe Suite are subject to periodic flooding from the Campaspe River. In the uncultivated state, most of these soils probably carried dense stands of river red gum. Yellow box has been noted on Type 1.

Land Use—Types 1 and 3 should produce good irrigated annual and perennial pastures if given adequate drainage, but Type 2 is rated as only a fair soil for irrigated pastures. The non-irrigated uses for all types are wheat-growing and the grazing of unimproved pastures.

SOILS OF THE PRIOR STREAM BEDS

The soils in this group are found in the beds of the more or less continuous depressions running through the higher parts of the depositional plains in northern Victoria. These are old, non-functional streams.

The soils vary considerably, not only along and across the stream beds, but also with depth. The changes are too frequent to show on the soil maps, consequently the prior stream depressions are separated only into three broad types, based mainly on differences in the permeability of their soils. These depression types are the same as those recorded in the Goulburn Valley (Skene and Poutsma 1962) and Deakin (Skene 1963) areas.

Type 1

This is a well-drained depression and water normally moves away rapidly through and over the soil. Surface textures are usually sandy loam or sand, while subsoil textures are never heavier than sandy clay. These light textures frequently persist beyond 6 feet, but their full extent has not been investigated in this or in the other depression types.

Land Use—Where these depressions are capable of being laid out to irrigation, they can be used for Group IV. crops, but should be avoided for stone fruits. Watertables are present where the soils are under irrigation.

Type 1h

This also is a well-drained depression of dominantly brown and grey-brown soils, but textures are a degree heavier than in Type 1 depressions. The surface is sandy loam or loam and the subsoil light or medium clay. The clay may occur either within the first foot or at greater depths; it overlies lighter-textured materials in the deep subsoil as in Type 1 depressions.

Land Use—Type 1h depressions are less permeable than Type 1 and therefore they drain more slowly. Situations capable of being laid out to irrigation are suitable for Group IV. crops. The deep subsoils are usually highly permeable and watertables are present where irrigation is practised.

Type 2

These depressions have impeded downward drainage and water may lie on the surface for extended periods. The surface soil is from 2 to 12 inches thick and ranges from grey to grey-brown in colour, and from loam, or even sandy loam, to light clay in texture. The subsurface is commonly bleached to light grey in the deeper soils and is separated sharply from the clay subsoil beneath. This is usually medium or heavy clay, with colours varying from mottled brownish grey to yellow-grey. The clay may extend downward for more than 6 feet, but eventually it grades into the sandy channel deposits.

Land Use—Since Type 2 depressions are liable to hold water for prolonged periods they are not recommended for irrigation. They can sometimes be used for sites of constructed drains.

VARIABLE SOILS IN DRAINAGE WAYS

This unit groups together those soils found in drainage ways which cannot be classified as Carag clay, Wallenjoe clay or Types 1, lh and 2 of the prior stream beds. The drainage ways vary from narrow, deeply incised, continuous depressions carrying black box or red gum to broad, shallow, treeless, discontinuous depressions.

The unit is extensive, particularly in the *treeless plain landscape unit* in the western part of the area. Most of the soils here are heavy textured, but some contain quite high proportions of coarse material in the deep subsoil and these probably are prior stream channels.

The Variable Soils in Drainage Ways, due to their position in the landscape, have little or no positive agricultural importance, and generally are not recommended for irrigation. Some of the less pronounced depressions could be used for irrigated annual pastures, if drainage measures were made adequate, although moderate and possibly high salt contents in the subsoils present some risk.

MISCELLANEOUS UNITS

Several features in which the soils have not been identified or have been examined only cursorily are shown on the soil maps. These are described below.

Intermittent Watercourses and Waterholes

This small unit comprises watercourses and small lagoons in the vicinities of the Campaspe and Murray rivers. They are well incised in most places with their beds sometimes more than 5 feet below the general land surface. Their lower position in the landscape and their association with the present courses of the Campaspe and Murray rivers make the soils in this unit more often flooded for longer periods than other adjoining soils.

River red gum may be present along the watercourses. In many places the surface is bare and cracked when dry.

River Frontage

This unit comprises the low recent river terraces of the Campaspe and Murray rivers, which are subject to seasonal flooding and for the most part carry a cover of river red gum.

The soils have been given only a cursory examination as the unit has little or no agricultural value. However, north-west of Echuca appreciable areas of river frontage have been mapped. Brief observations here indicate that the area is composed mainly of weakly-organized silty or fine sandy surface soils. In the north-west corner of the Parish of Wharparilla, there are a few sand hills on the lower river terraces. These are at present used for citrus and tobacco-growing, but elsewhere the soils are of little agricultural importance except for sparse grazing.

Sandy Rises and Sand Sheets

This category includes small areas of unclassified soils, mostly above gravitational supply level. They vary from sand sheets over clay to deep sands and have no uniform land use rating. In most cases each individual occurrence has been given the rating of the adjoining soil type.

SOIL TYPES AT BAMAWM AND BALLENDELLA

Special mention is made of the soils at Bamawm and Ballendella because a soil survey was made in these localities nearly 30 years ago (Penman 1936). Penman described and named nine soil types and published a soil map showing their distribution. Those who compare this map with the latest one will see little or no outward resemblance between the two maps. Further, only one of the original soil types, Lockington sand, has been retained in the present survey. These apparent anomalies are explained here for the benefit of landholders in the resurveyed areas.

At the time of the earlier survey the role of prior streams in determining the soil pattern in the district was unknown. Consequently, the scattered nature of the soil survey—soils were examined only in the 93 individual citrus groves in the district—made it impossible to recognize the textural gradation in the soil pattern which is now known to exist, and which is the basis of an orderly distinction between the soil types of the present soil survey. The earlier soil types were derived by arbitrarily grouping profiles with similar textural characteristics, and, as this was done on a rather narrow basis resulting in a large number of soil types for a comparatively small area, it is not to be expected that the earlier soil types will correspond texturally with the later types. Comparison of the descriptions given by Penman (1936) with those in this bulletin, and allowing for changes in textural standards, suggests the approximate relationships given below between the two sets of soil types.

1936	1964
Lockington sand	Lockington sand
Bamawm sand	Nanneella loamy fine sand
Bamawm extension sandy loam	Nanneella fine sandy loam
Bamawm loam	Nanneella fine sandy loam
Ballendella sandy loam	Nanneella fine sandy loam
Bamawm fine sandy loam	Nanneella fine sandy loam
Bamawm sandy loam	Nanneella fine sandy loam
Ballendella loam	Timmering loam
Lockington loam	Timmering loam

Examination of the remapped areas shows that the above relationships do not always hold. All the 1936 types overlap with two or more of the 1964 types to some degree, but the principal deviations evident from the soil maps are: Bamawm extension sandy loam, Ballendella sandy loam, Bamawm fine sandy loam and Bamawm loam all are mapped in places as Timmering loam. Ballendella loam is shown as Nanneella fine sandy loam as frequently as it is shown as Timmering loam; and Lockington loam is recorded occasionally as Wanalta loam.

The overlapping which is evident may be due to two factors, viz., (i) the application of different standards for the recognition of the field texture classes as between the two surveys, and (ii) a lesser amount of detail placed in the field mapping in the later survey.

LANDSCAPE UNITS AND GUIDE TO SOIL TYPES

Five broad landscape units are recognizable; they are uplands of Cambrian rocks south-east of Rochester, woodland plains associated with prior stream courses, treeless plains, riverine woodland adjoining the Murray and Campaspe rivers, and swamps. The distribution of the landscape units is shown in Figure 2.

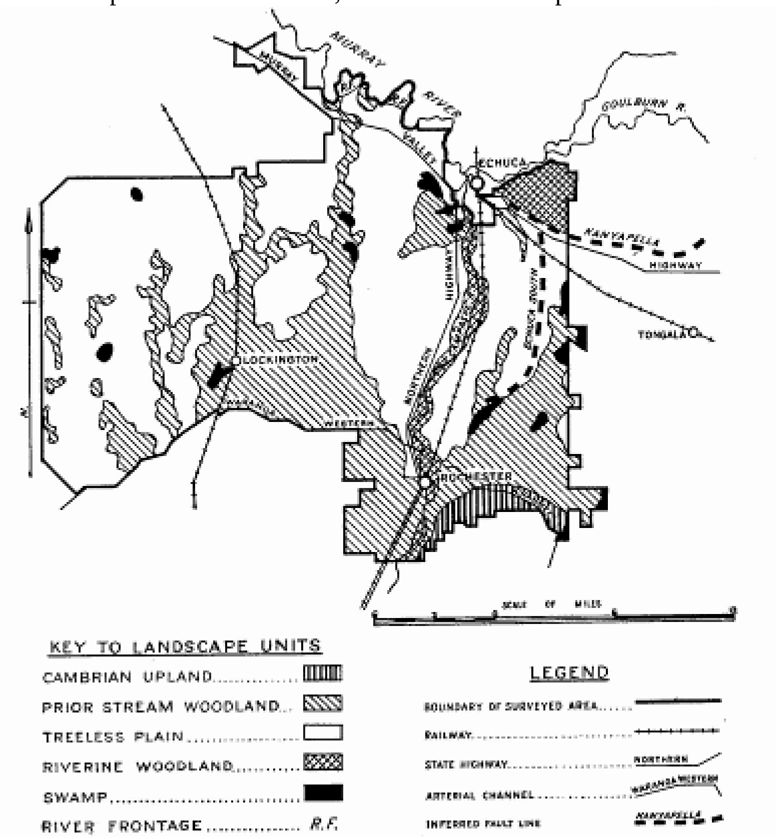

Figure 2 – Landscape units in the Rochester and Echuca districts

Each of the landscape units has its own array of soil types. Whilst in all of the units the soil types occupy definite positions in the landscape, in the prior stream and treeless plain units certain of the soil types are related to each other through their positions in slope sequences (toposequences). Two such toposequences are described later. The illustrative diagrams presented show idealized arrangements; each member of the toposequence is not necessarily present, and a soil type as found in the field may not occur next to the soil types shown adjoining it in the diagram.

Recurring soil patterns are evident in each of the landscape units. These are the *soil associations* described in the following section and shown on the Soil Association Map in the envelope at the back of this bulletin. The relationships between the landscape units and the soil associations are given in Table 2.

TABLE 2. Relation between Landscape Units and Soil Associations.

Landscape Unit	Soil Association	Area Acres	
Cambrian Upland -			5,100
	Binabbin	5,100	
Prior Stream Woodland -			84,500
	Nanneella	13,000	
	Timmering	29,300	
	Wanalta	37,700	
	Wanurp	4,500	
Riverine Woodland -			11,700
	Kanyapella	5,300	
	Campaspe	6,400	
Treeless Plain -			157,500
	Koga	68,800	
	Koyuga	17,700	
	Restdown	33,400	
	Rochester	37,600	
Swamp -			5,500
	Carag	5,100	
	Corop	400	
	Total	**264,300**	**264,300**

In the descriptions that follow, the component soil types of each landscape unit are shown in italics, the main distinguishing features of the soil types in the unit are given, while, in some cases, reference is made to differences between equivalent soil types in other landscape units.

CAMBRIAN UPLAND

This landscape unit which corresponds to the *Binabbin soil association* occurs only to the south-east of Rochester where the Colbinabbin Range of Cambrian rocks falls away to the Riverine Plain (see "Physiography and Geology"). It includes both the lower, flat areas and the slowly rising slopes.

Colbinabbin clay loam occupies the higher positions. This soil type is characterized by strong reddish colours in both the surface and subsoil. The colour, moreover, changes only gradually down the soil profile. In *Colbinabbin clay*, the surface is heavier and shallower, and the profile colours tend more towards brown.

Binabbin clay occupies lower and, perhaps, less well-drained sites than Colbinabbin clay loam. It is distinguished from Colbinabbin clay by the drab colour of its profile, and the occasional presence of calcium carbonate in the surface soil. Colours are grey-brown in the surface and subsoil, although the profile gradually becomes brown, or even red-brown in the deep subsoil. Binabbin clay mainly occurs intermingled with *Cornella clay* on the lower, flat areas adjoining the Riverine Plain. This soil type is a calcareous, grey, self-mulching clay and is readily distinguished from Binabbin clay by its colour, and greater calcareousness. In the complexes, Binabbin clay occurs as very low rises, while Cornella clay is gilgaied.

Cornella clay does not occur on the main slopes and, in fact, is regarded as a soil of the treeless plains, since it occurs fairly extensively as a single soil type in such a landscape where it adjoins the Colbinabbin Range in the Deakin Irrigation Area. There are no mappable single occurrences of Cornella clay in the present area.

PRIOR STREAM WOODLAND

Although much of the timber has been cleared from this unit, sufficient remains to identify its original woodland character. Grey box is easily the dominant species with buloke a minor component. The lighter-textured soils also carry yellow box, while some Murray pine was present as well before clearing. Black box still occupies the more pronounced depressions.

The soil types in this landscape unit are directly controlled by the prior streams and their deposits. They comprise a toposequence with the prior stream the focal point of the sequence. Skene and Poutsma (1962) illustrate one such sequence of soil types in the Goulburn Valley, and Skene (1963) illustrates a similar sequence of different soil types on a more weakly developed prior stream landscape in the Deakin Irrigation Area.

The prior stream landscape is fairly strongly developed and, as is shown by Figure 2, is extensive in the Rochester and Echuca districts.

In all but the extreme western occurrence, the soil types are the same as those that occur in the Deakin Irrigation Area, except that additional light profile soil types have been recorded. An idealized arrangement with all members present is illustrated in Figure 3. The sequence of soils on the weakly developed occurrence in the western part of the area is not illustrated diagrammatically, but will be described later.

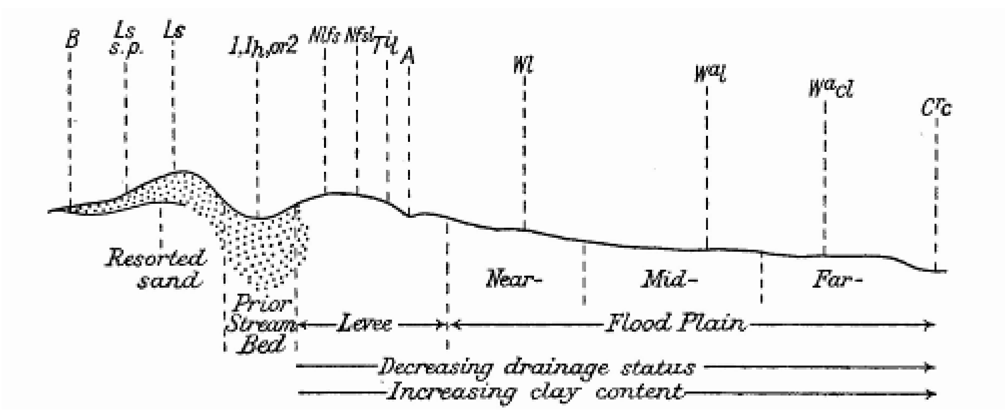

Figure 3 —Toposequence of soil types on the prior stream landscape.

C^rc = Carag clay; Ls = Lockington sand; Nlfs = Nanneella loamy fine sand; Nfsl = Nanneella fine sandy loam; T^il = Timmering loam; W^al = Wana loam; W^acl = Wana clay loam; Wl = Wanalta loam; Types A, B; 1, 1h, 2 = prior stream depression; s.p. = shallow phase.

The soils in the beds of the prior stream channels range from well-drained brown soils with light *(Type 1*) and medium *(Type lh*) textured profiles to poorly drained grey soils with clayey profiles *(Type 2*). The Type 1 and Type lh depressions are readily identified as prior stream channels by their brown colour and the fact that they occur as winding, high level depressions flanked by levees. The grey Type 2 depressions are not so readily identified, as some act as present day drainage ways and superficially the channel bed soils may be similar to *Carag clay.* However, sandy channel deposits occur below the clay horizons and usually, but not always, there is some evidence of these between 4 and 6 feet. In addition, prior stream channels are flanked by one or more of the soil types of the prior stream toposequence illustrated in Figure 3.

Lockington sand and *Type B* are developed on sand blown up by prevailing wind action from the prior stream bed. In Lockington sand, the sand is always deeper than 6 feet with a weak B horizon of red-brown clay accumulation below 3 feet from the surface. In *Lockington sand shallow phase,* this horizon occurs between 2 and 3 feet, then reverts to lighter textures in the deep subsoil. In Type B the sand is spread as a sheet about 1 foot thick over clay.

Nanneella loamy fine sand adjoins or may be intermingled with Lockington sand. It differs from the shallow phase in having more fine sand in the surface soil and the B horizon of red-brown clay accumulation *before* 2 feet.

Nanneella fine sandy loam, Timmering loam and *Wanalta loam* are three brown soils with red-brown clay subsoils. These soil types grade into each other texturally. The surface becomes slightly heavier and shallower passing from Nanneella fine sandy loam to Wanalta loam, while the parent material becomes finer. Thus Nanneella fine sandy loam and Timmering loam differ from Wanalta loam by having fine sandy clay or lighter textures in the deep subsoil; Wanalta loam has light or medium clay to a depth of at least 4 feet. The surface texture does not always distinguish Nanneella fine sandy loam from Timmering loam, but the textures in the deep subsoil do. In Nanneella fine sandy loam the red-brown clayey B horizon passes to fine sandy clay and fine sandy clay loam *before* 27 inches, whereas fine sandy clay never occurs until *after* 27 inches in Timmering loam.

Some soils classified as Wanalta loam have a clay loam surface. These soils are indistinguishable in profile features from Koyuga clay loam, and the distinction in such cases has been based on landscape and the associated soil types.

Wanalta loam, *Wana loam* and *Carag clay* form a colour sequence, surface colours down-slope passing from brown through grey-brown to grey, and subsoil colours from red-brown through yellowish brown to yellow-grey. Texturally, Wanalta loam and Wana loam are almost similar, the distinguishing feature being the absence of any reddishness in the B horizon of Wana loam. *Wana clay loam* is distinguished from Wana loam on the basis of surface texture.

Carag clay, a heavy-textured grey soil, is the lowest member in the prior stream landscape unit and occupies clearly defined depressions and superimposed drainage ways. It is intermittently inundated and usually carries black box. By virtue of its outlying situation in the unit, Carag clay tends to intermingle with the soils of the treeless plain landscape unit and in places becomes a component of that unit. It is also a component of the swamp landscape unit.

Type A and *Type C* are isolated occurrences which have no clear place in the prior stream pattern of soil types.

In the western part of the area, the depositional pattern associated with prior stream activity is less apparent than that mentioned above. Appreciable areas of soils with light-textured deep subsoils are absent, while the prior stream beds are often present as discontinuous, black box depressions. These, as well as the continuous depressions, are not readily recognizable as prior stream sites, since sandy channel deposits cannot always be found within 6 feet of the surface. The soils in the depressions are occasionally Carag clay, but more often are grey soils having lighter-textured and deeper surface layers. The latter soils have been included with the Variable Soils in Drainage Ways, although this group also covers depressions which are not related to prior streams.

Wanurp sandy loam and *Type D* occupy the levees and near-flood plain positions which are usually covered with bulokes. These soil types, like Nanneella fine sandy loam, Timmering loam and Wanalta loam, are brown surface soils with red-brown colours in the B horizon, but differ in having much more coarse sand in the profile. Type D is distinguished from Wanurp sandy loam by having an A horizon deeper than 18 inches, and sandy clay instead of medium or heavy clay in the B horizon.

There are no far-flood plain soil types in this prior stream landscape; in fact in many places, the levees are so subdued that treeless plain soil types, either Koyuga clay loam or Koga clay loam, adjoin the depressions.

TREELESS PLAIN

This is easily the most extensive landscape unit and is marked by an almost level plain having but little topographical relief and practically devoid of trees. However, some of the drainage lines carry fairly dense stands of black box or red gum.

A toposequence of soil on treeless plain situations has been described previously by Skene and Poutsma (1962) and by Skene (1963). This sequence in widespread in the Rochester and Echuca districts and is illustrated in Figure 4. The soil types are *Koyuga clay loam* on the fractionally highest situations, *Koga clay* *loam* on intermediate levels, and *Yuga clay* on low plain. This catena of soils is equivalent to the Wanalta—Wana—Carag catena of the prior stream landscape unit in that colours grade down-slope from brown to grey. Differences between Koyuga clay loam and Wanalta loam, and between Koga clay loam and Wana loam, lie in the slightly heavier and shallower surface horizons, the somewhat duller-coloured and more intractable subsoil clays, and the more common presence of gypsum in the deep subsoils of the Koyuga and Koga soil types. Yuga clay is a dominantly grey clay soil and, apart from the presence of gypsum, is similar in profile characteristics to Carag clay. However, their landscape positions are different as Carag clay occupies depression lines whilst Yuga clay in confined to low plain.

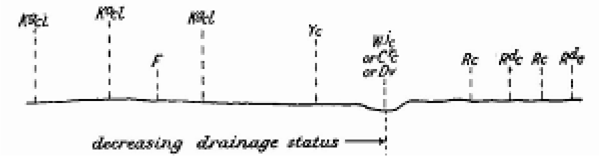

Figure 4 – Toposequence of soil types on the treeless plain landscape

C'c = Carag clay; Dv = Variable Soils in Drainage Ways; K°cl = Koyuga clay loam; K^kcl = Koga clay loam; Rc = Rochester clay; R^dc = Restdown clay; W^jc = Wallenjoe clay; Yc = Yuga clay; Type F.

Type F is a minor soil type which occurs with Koyuga clay loam and Koga clay loam. It differs from these soil types in having textures which increase gradually from loam to medium clay over the upper 14 inches of the profile.

Whilst the above soil types are not gilgaied to any marked extent, a second group of soils in this unit is characterized by a gilgai micro-relief of dominantly clay textures at the surface.

The soil types are *Restdown clay* and *Rochester clay*. The former is a brown soil and appears to have a slightly higher position in the landscape than Rochester clay, but, as they frequently occur together as a soil complex, landscape position is not a critical condition. Rochester clay is a grey soil and is often calcareous at the surface. However, both soil types include a range of profiles as is usual with gilgaied soils. The "shelf" profile of Rest-down clay is similar in general profile character to Koyuga clay loam, and its duller occurrences to Koga clay loam, but the distinguishing feature separating the two types is the depth of the surface horizon; this is 2 *inches or less* in Restdown clay and more than 2 *inches* in Koyuga clay loam.

Rochester clay, particularly its "puff" profile, resembles Cornella clay, but is not so conspicuously calcareous in the subsoil. It differs from Yuga clay in its general self-mulching character, although "shelf" situations are not readily distinguishable.

The soil types in the more pronounced depressions on the treeless plains are *Carag clay* and *Wallenjoe clay*. Both are heavy-textured grey soils, but Wallenjoe clay has a definitely steel-grey profile, whereas Carag clay tends to be dominantly brownish or yellowish grey. Soils dissimilar to these two soil types occur in some depressions; these have been placed in the unit of *Variable Soils in Drainage Ways* described under "Prior Stream Woodland".

RIVERINE WOODLAND

This landscape unit delineates the *Kanyapella* and the *Campaspe soil associations*. The former occupies a rather uniformly low area adjoining the Murray River east of Echuca, and some 8 feet below the general level of the surrounding plains. Although only remnants of trees exist, these indicate that the area was originally densely wooded with black box. The unit was once subject to frequent flooding from the Murray River. It extends into the adjoining Deakin Irrigation Area (Skene, 1963).

Kanyapella clay loam occurs on fractionally higher levels in the lowland than Kanyapella clay and Yambuna clay. These are well-structured, grey soils with micaceous, fine sandy or silty textures occurring at about 4 feet depth. Yambuna clay is almost identical with Kanyapella clay, but has greyer colours and more rusty mottling arising from its low situation. It differs from the low-lying Carag clay in having superior physical qualities due to the lower clay contents and better aggregation in its subsoils. Also, the micaceous and silty textures present in the deep subsoils of Yambuna clay are not present in Carag clay.

Type E is a minor soil type found on low rises. It appears to represent the remnants of prior stream levees and has textural similarities with Timmering loam, but a duller profile. Nevertheless, the profile is brownish compared with the dominantly grey colours of the associated Kanyapella clay loam.

The riverine woodland adjoining the Campaspe River is largely red gum and is subject to periodic flooding. Three minor soil types, collectively referred to as the *Campaspe Suite*, are present. The types are distinguished on the basis of their profile colours, although they show no consistent differences in their topographic situations. *Type 1* is a grey-brown soil with a brown clay subsoil while *Type* 2 has a brownish grey and *Type 3* a very dark-grey profile. Types 1 and 3 are characterized by well-structured surface horizons deeper than 8 inches, but Type 2 has a shallower surface depth and less attractive structure. Yellow box is present sometimes on Type 1.

Other features in this part of the riverine woodland landscape unit are small areas of river frontage and watercourses in which the soils have not been identified.

SWAMPS

Whilst there is a considerable area in the Rochester and Echuca districts of low-lying land which is flooded periodically, situations which may be regarded as intermittent or permanent swamps are numerous rather than individually large. Carag clay, Wallenjoe clay, Type 2 of the Prior Stream Bed Soils and the Variable Soils in Drainage Ways may all occupy more or less swampy situations in the treeless plain and the prior stream landscape units. However, only Carag clay and *Wallenjoe clay* are found in occurrences sufficiently large to be regarded as comprising a swamp landscape entity. The area of this unit is less than 2 per cent. of the surveyed area and Carag clay is much more extensive then Wallenjoe clay.

Wallenjoe clay differs from Carag clay in the extent to which inundation has modified the colour and structure of their profiles and their vegetation. The former soil in its extreme development is a steel-grey clay, very sticky when wet and extremely hard and cloddy when dry. It is either treeless and carries lignum or supports red gum. Carag clay on the other hand has brownish-grey and yellow-grey colours in its profile and supports black box.

SOIL ASSOCIATIONS

The soil types have been combined into larger units called soil associations; these are shown on the Soil Association Map contained in the envelope at the back of this publication. This map enables the over-all soil pattern of the area to be seen readily. It also indicates in a broad way the potential land use in different parts of the area.

A soil association is a grouping of adjoining soil types which occurs in a pattern that may be repeated in different parts of the area. The pattern is dominated by one and sometimes by two of the component soil types. The soils grouped in this way occupy a particular and usually distinctive part of the landscape.

Thirteen soil associations have been recognized in the present area. Seven of these have been recorded previously by Skene (1963) in the adjoining Deakin Irrigation Area. These are the Carag, Corop, Kanyapella, Koga, Koyuga, Timmering, and Wanalta associations. The relationship of the soil associations to landscape features is given in the section, "Landscape Units and Guide to Soil Types" and is set out in Table 2. The areas of the individual soil associations are also given in the table.

The soil associations, in alphabetical order, are described below in terms of their dominant, subdominant, and minor soil types, and general agricultural use. Any one soil type may occur in two or more different soil associations, assuming a different degree of importance in each. Each soil association has been given the name of its dominant soil type.

BINABBIN ASSOCIATION

The Binabbin association covers the soils found on the *Cambrian upland landscape unit* in the south-eastern part of the surveyed area.

Dominant soil type:-
Binabbin clay.
Subdominant soil types:-
Colbinabbin clay loam.
Cornella clay.
A minor soil type is Colbinabbin clay.

The soils of the Binabbin association are regarded highly for wheat-growing. The greater part of the association is in the recently constituted Campaspe Irrigation District and has not yet been subjected to intensive irrigation. However, where irrigation has been practised, pastures grow well, and the soils generally should be suitable for perennial pastures where satisfactory grading can be accomplished. The soils have low salt contents. There is no experience with fruit trees on these soils.

CAMPASPE ASSOCIATION

This association comprises part of the *riverine woodland landscape unit.* It occupies land immediately adjoining the Campaspe River and is subject to periodic flooding.

Dominant soil type: -
Campaspe Suite—Type 1.

Subdominant soil types:-
Campaspe Suite—Types 2 and 3.

Type 3 occurs as a co-dominant soil type with Type 1 south of Strathallan, whilst Type 2 is co-dominant with Type 1 to the north. Intermittent watercourses and river frontage are included in the association.

Dry-farming pursuits are wheat-growing and grazing. The soils are productive, but the risk of flooding from the Campaspe River limits their utilization for most irrigation purposes.

CARAG ASSOCIATION

This association delineates the relatively few, larger occurrences of swampland found on the *treeless plain* and the *prior stream landscape units.* The soils are mainly grey clays of low permeability.

Dominant soil type:-
Carag clay.
Subdominant soil type:-
Wallenjoe clay.

Carag clay dominates all but a few occurrences in which Wallenjoe clay is the main soil type. Only small areas of other soil types usually are present. These are Yuga clay and Koga clay loam in the treeless plain landscape, and Wana loam and Wana clay loam in the prior stream landscape.

The Carag association defines areas generally unsuitable for irrigation because of *drainage* difficulties, poor permeability, and moderate salinity risk. The soils are used mainly for grazing purposes at present.

COROP ASSOCIATION

The Corop association is quite unimportant in the present area, where it covers only a very small acreage in the extreme south-western part of the Rochester Irrigation Area. It is widely distributed in the Deakin Irrigation Area (Skene 1963), where it is regarded as unsuitable for irrigation. The principal soil types are Corop clay and Wallenjoe clay. Unclassified soils on lunettes are also an important part of the association where it is more extensively developed.

KANYAPELLA ASSOCIATION

The Kanyapella association represents part of the *riverine woodland landscape unit.*

Dominant soil type:-
Kanyapella clay.
Subdominant soil types:-
Kanyapella clay loam. Yambuna clay.

Type E occurs as a subdominant soil type in the southern and western parts of this association; elsewhere, it is of minor importance. A few drainage ways with variable soils are present.

This association formerly carried rather dense black box forest. It is now mostly cleared and supports good irrigated perennial pastures. Fortunately the salinity of the subsoils is low. Nevertheless, adequate drainage is of prime importance for the successful irrigation of the soils in this association.

KOGA ASSOCIATION

This is an association of grey-brown and grey, shallow surface, heavy soils found on the *treeless plain landscape* unit.

Dominant soil type:-
Koga clay loam.
Subdominant soil types:-
Koyuga clay loam.
Yuga clay.

Koyuga clay loam varies markedly in occurrence. It is a minor component of the association eastward of the Campaspe River, but becomes increasingly prevalent towards the western part of the surveyed area. On the other hand, Yuga clay is reduced to a minor component in the western parts. Minor soils in the association are Rochester clay, Restdown clay, Carag clay, Type F, and the Variable Soils in Drainage Ways.

Most of the Koga association is used for wheat-growing and the grazing of unimproved pastures, but a small portion is given to the irrigation of annual pastures. Heavy, slowly permeable soils, and slow surface drainage, are drawbacks to the establishment of perennial pastures except in favoured situations. A further hazard is a moderate, and sometimes a high, salinity level in the deep subsoils. For these reasons, the Koga association can be regarded as delineating areas, if irrigated, best suited to annual pastures.

KOYUGA ASSOCIATION

This is an association of dominantly brown, shallow surface, heavy soils found on the *treeless plain landscape unit* in the western section of the area.

Dominant soil type:-
Koyuga clay loam.
Subdominant soil types:-
Koga clay loam.

The Koyuga differs from the Koga association in that Koyuga clay loam replaces Koga clay loam as the dominant soil type, Yuga clay is almost absent, and complexes of Rest-down clay and Rochester clay occur more frequently, although these soil types are minor components of the association. Variable soils and Carag clay occupy the drainage ways.

Wheat-growing and grazing for wool production are the agricultural pursuits on this association. None is irrigated as it lies outside the Rochester Irrigation Area. Subsoil salinity, in general, is moderate, although some situations show either high or low levels. The association defines areas with the same potential for irrigation as the Koga association, viz., annual pastures.

NANNEELLA ASSOCIATION

The soils in the Nanneella association occur on the levee and near-flood plain positions of the *prior stream landscape unit.* These are the slightly higher and better drained parts of the depositional land surface. The topography is very gently undulating to nearly level plain.

Dominant soil type: —
Nanneella fine sandy loam.
Subdominant soil types:-
Nanneella loamy fine sand.
Timmering loam.

Nanneella loamy fine sand is absent in some areas, but occurs as a co-dominant soil type west of Rochester township. The minor occurrences present are Lockington sand, Wanalta loam, and Soils of the Prior Stream Beds.

The soils are used widely for the irrigation of annual and perennial pastures and fruit trees; vegetables are grown to a lesser extent. Salt levels are naturally low, but even so citrus have declined on some of these soils in the Bamawm and Ballendella districts.

The Nanneella association is important in the recently constituted Campaspe Irrigation District as it defines areas which could be considered for fruit-growing and intensive forms of agriculture, in addition to irrigated pastures. It also defines areas where water-tables are to be expected under irrigation. Present dry-farming pursuits are wheat-growing and the grazing of sheep on native and volunteer pastures.

RESTDOWN ASSOCIATION

The soils in this association are predominantly brown, heavy soils, frequently gilgaied, situated in the *treeless plain landscape unit.*

Dominant soil types-
Restdown soil type:—
Subdominant soil types:—
Koyuga clay loam.
Koga clay loam. Rochester clay.

In some localities, Koyuga clay loam is co-dominant with Restdown clay. Rochester clay is usually present in a complex pattern with Restdown clay. Minor soils are Carag clay and the Variable Soils in Drainage Ways.

The Restdown association is used for grazing sheep, mostly on native pastures, with some cereal-cropping. The subsoils have the highest inherent salinity levels of any in the area and present risks of salinity developing if the soils are irrigated. Nevertheless, the association defines areas which might be utilized for irrigated annual pastures provided careful attention is given to irrigation methods.

ROCHESTER ASSOCIATION

The Rochester association covers the predominantly grey, gilgaied, clay soils of the *treeless plain landscape unit.*

Dominant soil type:—
Rochester clay.
Subdominant soil type: —
Restdown clay.

Restdown clay usually occurs as a complex with Rochester clay. Minor soils are Koga clay loam, Koyuga clay loam, Carag clay, Type F and the Variable Soils in Drainage Ways. Sometimes, Koga clay loam replaces Restdown clay as a subdominant soil type.

This association is used in the same way as the Restdown association and has much the same potential use under irrigation. However, it defines areas which may have surface drainage and grading problems should the soils be irrigated. The soils are rather less saline in the deep subsoils, levels being either low or moderate.

TIMMERING ASSOCIATION

The Timmering association occurs on the levees and near-flood plain parts of the *prior stream landscape* unit and occupies the higher and better drained parts of the depositional land surface. The landscape varies from gently undulating to nearly level plain.

Dominant soil type: —
Timmering loam.
Subdominant soil types:-
Nanneella fine sandy loam.
Wanalta loam.

In places, Nanneella fine sandy loam approaches co-dominance with Timmering loam. Minor soil types are Wana loam, Wana clay loam, Carag clay, and Soils of the Prior Stream Beds.

The Timmering association in the Rochester Irrigation Area is utilized for dairying and fat lamb production on irrigated pastures, fruit-growing and some vegetable-growing. It occurs extensively in the Campaspe Irrigation District where it is under dry-farming agriculture at present. With the Nanneella association, it defines the areas with the widest land use possibilities, but it also defines areas liable to watertables. However, subsoil salt levels are almost always low and, provided careful attention is given to irrigation, most of the Timmering association can be considered for horticulture.

WANALTA ASSOCIATION

This association occupies the nearly level near and mid-flood plain parts of the *prior stream landscape unit.*

Dominant soil type:-
Wanalta loam.
Subdominant soil types:—
Timmering loam.
Wana loam.
Wana clay loam.

Minor soils are Carag clay, Variable Soils in Drainage Ways, and the Soils of the Prior Stream Beds. Wana loam and Wana clay loam vary markedly in prominence and may occur as minor soil types in some areas.

The soils in this association are largely irrigated and are used mainly for dairying and fat lamb production on perennial and annual pastures. Wheat-growing and the grazing of sheep, mostly on native and volunteer pastures, are the main activities where the soils are not irrigated. The association defines areas which are suitable mainly for irrigated annual and perennial pastures. Prospects for horticulture are limited principally to pears and plums. Watertables are present to only a small extent while the salinity of the subsoils is low, or occasionally moderate.

WANURP ASSOCIATION

The Wanurp is a minor association comprising soils adjoining and in the channels of weak prior streams in the western part of the surveyed area.

Dominant soil type: —
Wanurp sandy loam.
Subdominant soil types:-
Wanalta loam.
Variable Soils in Drainage Ways.

Minor soils are Carag clay, Koyuga Clay loam, Type D, and the Variable Soils in Drainage Ways.

The Wanurp association, which is almost entirely west of the Rochester Irrigation Area, is given to cereal cropping and grazing. Should the soils be irrigated, the association indicates areas which might be considered for perennial as well as for annual pastures. The more highly situated parts should be suitable for horticulture, but are probably too small in area to warrant consideration. The salinity of the subsoils often rises to moderate levels.

CHEMICAL AND PHYSICAL PROPERTIES

Thirty-eight profiles taken from the principal soil types have been examined in the laboratory. The locations of these are shown by numbers on the soil maps while their analyses are presented in Appendix I. This appendix, therefore, provides a reference to the more important measurable characteristics of the principal soil types. The analytical methods employed are given in Appendix II.

PARTICLE SIZE DISTRIBUTION

The analyses in Appendix I relate particle size distribution to field texture assessments and their main purpose is to enable a better understanding of the textures given in the morphological descriptions of the soil types. But it should not be overlooked that the analyses is some cases represent only single profiles, whereas the soil types each cover a range of textures. However, some idea of the range in the mechanical composition of the more common soil types may be gained, since several profiles are illustrated in these cases. The following comments arise from consideration of this data.

The mechanical composition of Timmering loam overlaps that of Wanalta loam in the surface, B_1 horizon, and between the B_1 and 48 inches depth. Since the distinction between Timmering loam and Wanalta loam—other characteristics being equal—rests on the recognition in the zone between the B_1 and 48 inches depth of fine sandy clay in Timmering loam against light clay in Wanalta loam, it is clear that separation on this distinction has not been reliable in all cases.

Wanalta loam overlaps Koyuga clay loam in mechanical composition, although the average clay contents of the A and B_1 horizons and the zone below the B_1 are slightly higher in Koyuga clay loam. However, the clay contents are not sufficiently different for field texture to be particularly useful in field mapping, and, since other morphological characteristics also are very similar, a great deal of dependence has been placed on landscape relationships to separate these two soil types.

Koyuga clay loam and Koga clay loam have approximately the same mechanical composition, although the latter has a slightly higher average clay content throughout the profile.

Coarse sand is an unimportant component of the non-clay fraction and rarely exceeds 3 per cent, in the subsoil horizons. Exceptions with a little more than this are the three profiles from the Cambrian uplands and one or two others. On the other hand, fine sand is nearly always dominant, in the non-clay fraction, ratios of fine sand to silt in the B horizons mostly ranging from 1.1 to 2.3. An exception is the light-textured Nanneella loamy fine sand with a ratio of 5.1. A few subsoils are dominated by silt in the non-clay fraction. The most notable of these are in the riverine woodland soils, Kanyapella clay loam and Yambuna clay in which the ratio of fine sand to silt is only 0.2.

The particle size data in Appendix I illustrate the claypan nature of some of the soil types, and the uniformly high clay level throughout the profiles of others. These characteristics, as well as the over-all texture profiles of the principal soil types, can be envisaged more readily from the clay contents of a selection of profiles presented in Table 3.

TABLE 3. Clay Content of Principal Soil Types

Landscape Unit and Soil Type	Profile No.	Surface		Subsoil			
		A Horizon		B Horizon		C Horizon	
		Depth	Clay	Depth	Clay	Depth	Clay
		in	%	in	%	in	%
Prior Stream -							
Nanneella loamy fine sand	32	0-14	10	14-36	27	36-52	15
Nanneella fine sandy loam	31	0-7	16	8-24	38	24-34	25
Timmering loam	14	0-7	16	8-18	50	18-36	41
Wanalta loam	40	0-8	22	8-24	52	24-33	45
Wana loam	36	-6	27	6-28	54	28-43	46
Carag clay	16	0-3	58	3-11	75	11-26	67
Treeless Plain -							
Koyuga clay loam	4	0-4	23	4-13	60	13-23	54
Koga clay loam	27	0-3	33	3-15	64	15-25	59
Yuga clay	7	0-3	35	3-14	72	14-25	71
Wallenjoe clay	24	0-6	66	6-22	60	22-32	62
Restdown clay							
"puff"*	11	0-6	65	6-13	65	13-25	65
"shelf"	21	0-2	57	2-7	61	7-27	64
Rochester clay							
"puff"*	28	0-2	57	2-7	61	7-27	64
Riverine Woodland-							
Kanyapella clay loam	2	0-5	30	5-15	46	15-25	39
Yambuna clay	1	0-1	37	1-11	64	11-24	61
Campaspe Suite							
Type 1	18	0-8	25	8-18	49	18-25	35
Type 3	23	0-8	28	8-26	52	26-41	49
Cambrian Upland -							
Colbinabbin clay loam	33	0-3	23	3-27	67	27-35	66
Binabbin clay	34	0-2	54	2-17	59	17-37	56
Cornella clay							
"puff"*	39	0-3	60	3-21	67	21-36	62

* The horizon nomenclature in the table is not applicable to these soils.

The data in Table 2 demonstrate the increasing clay content, representing increasing fineness, in the parent materials of the prior stream soil types, passing from the levee through near-to far-flood plain positions.

CALCIUM CARBONATE

The soils of the Cambrian uplands and the "puff profiles of Restdown clay and Rochester clay appear to contain more calcium carbonate than the rest of the soil types, otherwise there is no apparent relationship between lime content and soil type.

In general, the profiles of the more calcareous soils, Binabbin clay, Colbinabbin clay, Cornella clay, and the "puff" profiles mentioned are moderately calcareous from the surface, or a few inches below it, to depths of 5 feet or more. Usually, about 1 per cent of finely divided calcium carbonate is present in the upper 20 inches of the profile, but this increases to 3 or 4 per cent and occasionally to as much as 7 per cent, below this depth. Usually small amounts of concretionary calcium carbonate are present in most of these profiles.

In all of the other soil types (except Wallenjoe clay) , and in the "shelf" profiles of Rest-down clay and Rochester clay, the amounts of finely divided lime are small, although variable amounts of concretionary calcium carbonate may accompany the soft lime. Commonly, the lime first appears between 15 and 24 inches. In this part of the profile, the soft lime varies from 0.1 to about 1 per cent and the concretionary lime from traces to 7 per cent. The lime either increases or decreases in the horizons below the zone of first appearance, but no consistency in this is evident from the profiles analysed.

No lime is present in the one profile of Wallenjoe clay illustrated, while only very small amounts below 36 inches occur in the light-textured Nanneella loamy fine sand profile.

pH

The profile data show that the soils fall into two groups, viz., those that are non-calcareous close to the surface and are slightly acid in their A horizons, and those that are calcareous and slightly to moderately alkaline in the surface few inches. The surface pH values are mainly within the limits 6 0 to 6 9 in the first group and 7.4 to 8.5 in the second. The B horizons are, respectively, slightly or moderately alkaline (pH range 7.3 to 8.5), and moderately or strongly alkaline (pH range 8 1 to 8.9). Deeper horizons, representing the C horizons and unrelated layers, are variably alkaline in both groups (pH range 8.1 to 9.8). A few horizons have pH values outside these limits, but the only notable instance is in the Cornella clay profile. In this, the surface 3 inches is slightly acid whereas it is normally slightly or moderately alkaline in this soil type.

The first group of soils includes all the soil types in the prior stream landscape unit, the non-gilgai situations and "shelf" profiles on the treeless plains, and the soils in the riverine woodland unit. The second group covers the soil types in the Cambrian upland unit, and the "puff" profiles of gilgai areas on the treeless plains.

The pH data indicate that liming practices are unnecessary on the soils in the Rochester and Echuca areas unless acid-forming fertilizers such as sulphate of ammonia have been used liberally.

EXCHANGEABLE CATIONS

The exchangeable calcium, magnesium, potassium, sodium, and hydrogen, and the sum of these cations representing the exchange capacity, are given in Appendix I. for selected horizons in sixteen profiles.

The cation exchangeable capacity of the clay fraction is a broad guide to its mineralogy and may be calculated for the subsoil horizons which do not contain organic matter. Such values, representing mainly B and C horizons, show that the soils fall into two groups, but it is unlikely that there are differences between the soil types individually in either group. In a group of three profiles from the Cambrian upland landscape unit, the values are high, four out of six exceeding 70 m.e. per 100 g of clay. In the other thirteen profiles drawn from soil types in the prior stream, treeless plain, and riverine woodland landscape units, the range is from 42 to 58 m.e. per 100 g of clay. The latter values are comparable with those found in soils of the Goulburn Valley (Skene and Freedman 1944, Skene and Poutsma 1962) and Deakin (Skene 1963) areas, and are of the usual order for mixed, but dominantly illite type, clay minerals.

Calcium and magnesium are the principal metal ions in all of the surface soils, and the amount of calcium is usually two or three times the magnesium. But the calcium to magnesium ratio is quite different in five profiles from soil types in the treeless plain landscape unit; in these magnesium is dominant and may be nearly twice the calcium. The types concerned are Koyuga clay loam, Koga loam, Yuga clay loam and a "shelf" situation of Restdown clay.

As has been found repeatedly in similar soils elsewhere in Australia, the proportion of magnesium increases with depth in the soil profile. It is only in the more calcareous profiles, viz., Binabbin clay, Colbinabbin clay loam, Cornella clay and the “puff” profiles of Restdown clay and Rochester clay that calcium dominance is clearly maintained in the 13, horizons. However, in the lower horizons of these profiles magnesium nearly always exceeds the calcium, while in the treeless plain profiles referred to it amounts to three or four times the calcium.

The main agricultural interest is in the exchangeable sodium percentage, as values above 15 per cent are considered to materially impair the physical properties of the soil when such soils are irrigated, since dispersion of the clay tends to occur, and infiltration becomes difficult. Fortunately, all of the surface soils have low sodium percentages, but sodium increases with depth in the profile, and some of the B_1 horizons have from 12 to 22 per cent. Such sodium levels may lead to low subsoil permeability. The soils concerned are Koyuga clay loam, Koga clay loam, Yuga clay, and the "shelf" situations of Restdown clay. These are the soils referred to previously in which magnesium markedly dominates calcium.

A further increase in sodium is evident in the C horizons of all the soil types, eleven out of thirteen horizons examined having sodium percentages between 13 and 31.

Exchangeable potassium contents are high in all of the surface and subsoil horizons indicating that potash is not needed in fertilizer programmes.

ORGANIC MATTER

The general level of organic matter in the soils can be appreciated from the total nitrogen and organic carbon values reported in Appendix I.

Total nitrogen varies from 0.05 to 0.37 per cent in 37 surface soils and averages 0.14 per cent. In the same soils, organic carbon ranges from 0.67 to 4.29 and averages 1.55 per cent. The average carbon-nitrogen ratio is 11.

In 30 13, horizons, total nitrogen varies from 0.03 to 0.14 per cent (average 0.08 per cent.) and organic carbon from 0.28 to 1.10 per cent (average 0.62 per cent.). The average carbon-nitrogen value is 8.

The range of nitrogen contents in the surface soils is wide since the soils analysed were drawn from irrigated as well as from dry-land areas, and include textures ranging from loamy sand to clay.

SOLUBLE SALTS

Total Soluble Salts.
Low amounts of soluble salts, usually less than 0.07 per cent are present in all of the surface soils. Slightly higher levels occur in the B_1 horizons, but levels in most cases are less than 0.10 per cent. However, there are some exceptions and eleven profiles have contents ranging from 0.10 to 0.30 per cent in their B_1 horizons.

The deeper horizons almost always contain more salts, and in most of the profiles the amounts present below 3 feet range from 0.1 to 0.2 per cent. But an almost equal number of profiles have more than this with contents of up to approximately 0.5 per cent. The higher amounts occur in profiles from the Koyuga clay loam, Koga clay loam, Restdown clay, Wanalta loam, Wana loam and Wana clay loam soil types. These are soils which may contain gypsum in their subsoils and the high levels, in some cases, are due in part to the presence of this salt. In some profiles gypsum is visibly present, and in such cases total salts have not been estimated in the horizons concerned.

The constituent cations and anions (except chloride) of the soluble salts have not been determined.

Sodium chloride.
Chlorides have been estimated in all of the profiles shown in Appendix I and are reported as sodium chloride. Levels in general parallel the total salt values. In most horizons, sodium chloride comprises from one-third to two-thirds of the total salts, the lower proportions being common where the total salt levels are low.

The salt data mentioned do no more than indicate that salt is present in significant quantities in may of the subsoils which occur below 2 or 3 feet depth. This confirms that soil samples analyzed from the 3 to 4 feet depth, as has been done in general salt survey of the whole area, are appropriate to evaluate potential salinity hazards. These hazards, and details of salt levels and distribution found from the salt survey are dealt with in the section, "Soil Features and Irrigation".

CLASSIFICATION AND FORMATION

CLASSIFICATION

The area lies in the red-brown earth zone originally defined by Prescott (1944) and later modified by Stephens (1961).

The soils on the well-drained positions fit reasonably well into the general description of the red-brown earths given by Stephens (1962). These are the Lockington, Nanneella, Timmering, Wanalta, Wanurp, Koyuga and Colbinabbin soil series. Down-slope the soils lose their red-brown colouring and commonly are considered to be hydromorphic variants; the soil series concerned are Wana and Koga.

The low-lying grey soils comprising the Rochester, Yuga, Kanyapella, Yambuna, Carag and Wallenjoe soil series are all regarded as grey soils of heavy texture (Stephens 1962), although the Kanyapella and Yambuna soils show greater differentiation between the A and B horizons than is usual in this great soil group.

Cornella clay has a calcareous profile and perhaps could best be regarded as a calcimorphic grey soil of heavy texture.

Restdown clay is a brown soil of heavy texture although it includes profiles with shallow A horizons which are red-brown earths.

Northcote (1962) includes the Rochester-Echuca area in a landscape unit of dominantly, *hard setting* loamy *soils* with *red clayey subsoils, an alkaline trend through the profile, and with sporadically bleached A_2 horizons.* He records a complex soil pattern and classifies the component soils into categories based on new concepts (Northcote 1960). He has not named his classificational units, but identifies them by a notation system. The place of each of the principal soil types in Northcote's system of classification is as follows: —

Gr2-13	Nanneella loamy fine sand.
Dr2.13	Nanneella fine sandy loam, Colbinabbin clay loam Nanneella fine sandy loam also includes soils with an A_2 horizon (Dr2-23), and the Colbinabbin series soils which are not hard setting (Dr4-13).
Dr2.33	Timmering loam, Wanalta loam, Koyuga clay loam, Restdown clay "shelf" profile. Soils with a very weak A, horizon and not sporadically bleached

(Dr2.23) occur infrequently in all of these soil types.

Dr2.43 Wanurp sandy loam.
Db1.33 Wana series, Koga clay loam.
Dy3.33 Kanyapella clay loam (probably).
Ug5.24 Cornella clay, Rochester claw "puff" profile.
Ug5.3 Binabbin clay.
Ug5.39 Restdown clay "puff" profile.
Ug5.5 Rochester clay "shelf" profile, Yuga clay, Carag clay, Wallenjoe clay.

Some soils with a sporadic bleached A, horizon (Ug3.2) are included in those soil types. Small areas of Yuga clay with a clay loam surface are Dy3.33 or Dy4.33 soils.

FORMATION

The principal soil types are formed from dominantly fine-textured parent materials. Practically all of the material is less than 50 microns* and most of it is less than 2 microns. Some of the parent material is known to be riverine, and some of it may be parna from distant sources. But irrespective of whether the deposits are riverine, aeolian, or both, most of them contain much clay. Coarser wind-blown materials from local prior stream beds contribute in a small way to the parent materials of soils on parts of the prior stream levees.

The soils formed on the interbedded basic lavas of the Cambrian upland are also derived from materials with a high clay fraction. However, the high iron oxide and high calcium status have produced strong red colours, well-developed structure, and friable peds in the Colbinabbin series on the higher slopes.

Cornelia clay has appreciable calcium carbonate throughout its profile. It has developed from calcareous, clayey materials, and through the influence of the lime has a uniform texture profile, dark coloured and self-mulching surface, and a generally well-structured profile. The origin of the calcium carbonate is explained by the situation and drainage status of the Cornella clay landscape. Cornella clay is found on flat areas where the Cambrian hills grade into the alluvial plain. Some restriction of drainage has led to enrichment of the clayey materials with calcium carbonate, derived probably from the basic materials of the adjacent hills.

It is suggested that the texture profiles of the red-brown earths can be explained from the particle size data by eluviation of the parent clay. The presence of appreciable sodium in the subsoils suggests that the clay may have moved from the surface downward under the colonizing influence of sodium ions. But the columnar solonetzic morphology of the II horizon commonly attributed to sodium has not been found in these soils.

* Unpublished data

GENERAL INFORMATION ABOUT THE AREA

LOCATION

While the location and outline of the surveyed area can be found from the locality plan (Fig. 1), and the "Index to Soil Maps", additional information about locality references is given below.

Rochester is 112 miles by road to the north of Melbourne, while Echuca is 18 miles further on. Lockington is a township 17 miles to the north-west of Rochester but other locality references are mainly districts identified by country post offices, schools, etc.

The parishes covered by the soil maps, either wholly or in part, are: Ballendella, Bamawm, Bonn, Diggora, Echuca North, Echuca South, Millewa, Milloo, Nanneella, Pannoobamawm, Pannoomilloo, Rochester, Rochester West, Terrick Terrick East, Timmering, Turrumberry, Turrumberry North, Wanurp and Wharparilla in the Counties of Bendigo, Gunbower and Rodney.

The soil maps accord with the standard mapping areas of the Military Map Series. However, for convenience, parts of more than one standard mapping area have been placed on some of the map sheets. The standard mapping areas are shown on the Soil Association Map of the district and this map may be used to locate the military sheet reference for any of the soil maps.

The Rochester Irrigation Area, and the Echuca East Settlement which is part of the Tongala-Stanhope Irrigation Area, are both part of the Goulburn—Murray Irrigation District. Irrigation areas in this district which have been soil-surveyed previously are Shepparton (Skene and Freedman 1944), North Shepparton, South Shepparton, Rodney and Tongala—Stanhope (Skene and Poutsma 1962) and Deakin (Skene 1963). These irrigation areas are all administrative divisions set up by the State Rivers and Water Supply Commission for the control and distribution of water in particular, defined locations.

The total area covered by soil surveys in the Goulburn—Murray Irrigation District and the newly constituted Campaspe Irrigation District is 990,000 acres. This includes some adjoining land outside the statutory irrigation districts.

SETTLEMENT, WATER SUPPLY AND GOVERNMENT CENTRES

In 1846, Dr. John Rowe took control of Restdown Station consisting of approximately 100,000 acres along the Campaspe River. The homestead of this grazing area was situated a little north of the present township of Rochester which took its name from a settlement about a hotel built by Dr. Rowe in 1854. The settlement was known as Rowes' Camp, later Rowechester and later still was gazetted as Rochester. After the decline of the 1853 gold boom, settlement was intensified and wheat growing expanded with the subdivision of the larger holdings. Settlers early looked to the river waters for irrigation and stock and domestic water. The Rochester Irrigation and Water Supply Trust was formed in 1889 and a timber weir was built over the Campaspe River to enable water to be diverted for irrigation and other purposes. However, general irrigation was not to reach the district until some time later. The Goulburn Weir near Nagambie, built in 1892 to utilize the waters of the Goulburn River, soon proved inadequate to supply the early irrigation settlements of Ardmona and Lancaster. In consequence the Waranga Reservoir was constructed in 1908 and this provided a storage which enabled irrigation to be extended into the Rochester area.

Expansion of agricultural activities requiring water from the Goulburn River for irrigation has continued over the years and storages have progressively increased. Waranga Reservoir was enlarged in 1924 while Eildon Reservoir on the Upper Goulburn was completed in 1926 and considerably enlarged in recent years. To-day these structures have a total capacity of 3,104,100 acre-feet of water.[*]

Water from the Waranga Reservoir reaches the Rochester Irrigation Area via the Waranga Western Main Channel. The Echuca East Settlement also draws its water from Waranga Reservoir, but is served from supplies to the Tongala-Stanhope Irrigation Area. Water to the new Campaspe Irrigation District will come from the Eppalock Reservoir on the Campaspe River. This reservoir which was completed in 1963 and has a storage capacity of 252,860 acre feet is located upstream from the township of Axedale.

The State Rivers and Water Supply Commission administers the Rochester Irrigation Area and the Campaspe Irrigation District from its district office at Rochester, and the water supplies for the Echuca East Settlement from its Tongala office.

Recent reclassification of lands in the Rochester Irrigation Area (181,782 acres) has raised the area of land classified as irrigable from 57,014 acres in 1959-60 to 131,118 acres in 1962-63. But apportioned water rights were still relatively low at 67,973 acre feet, and it would appear that there is considerable room for extension of irrigation in the area. However, this has already taken place to some extent through sales of water, since total deliveries to users in the district were 111,173 acre feet of water. The area actually irrigated in 1962-63 is given as 81,752 acres, comprising the following crops:

[*] Statistics given in this section are taken from the 1962-3 Annual Report of the State Rivers and Water Supply Commission

		Acres
Pastures -	Annual	37,965
	Perennial	37,391
	Native	1,704
Lucerne		2,348
Cereals		70
Summer fodder crops		1,186
Orchards		554
Market gardens		129
Miscellaneous		405

Most of the irrigated lands are used for dairying and fat lamb production. Fruit-growing has declined and is now a rather small part of the irrigation culture in the area. The market gardens are almost entirely given to tomato-growing.

The Echuca East Settlement of approximately 4,600 acres is principally under perennial pastures supporting dairy cows.

About 177,000 acres within the surveyed area represents land which, in the main, is devoted to dry-farming agriculture. Mixed wheat and sheep-farming, or the grazing of sheep for meat and wool production, are the principal activities on most of this land. About 19,735 acres are in the Campaspe Irrigation District and much of this area will eventually come under irrigation.

The Department of Agriculture provides advisory services from its district offices at Rochester and Echuca. It also has two research stations, the Irrigation Research Station, Kyabram, and the Horticultural Research Station, Tatura, which offer research and advisory services to pastoralists, orchardists and vegetable growers in the region generally.

CLIMATE

Meteorological data are available for both Rochester and Echuca, but as these are both rather similar only the monthly values for Rochester are given in Table 4. The yearly average rainfall for Echuca is 16.7 inches, while yearly average maximum and minimum temperatures are, respectively, 71.6° and 49.5°. Rainfall at Lockington over a 21-year period shows a yearly average of 15.0 inches.

TABLE 4. Meteorological Data – Rochester

Month	Rainfall (51 years)	Temperature (14 years			Evaporation
		Average Max	Average Min	Average Mean	
	in	°F	°F	°F	in
January	1.12	85.9	58.5	72.2	8.9
February	1.38	83.1	58.5	70.8	7.1
March	1.32	78.2	54.5	66.3	5.5
April	1.12	67.6	48.8	59.2	3.5
May	1.71	61.7	43.7	52.7	1.8
June	1.88	55.7	39.7	47.7	1.1
July	1.76	54.4	38.6	46.5	0.9
August	1.57	57.7	39.6	48.7	1.6
September	1.52	63.5	42.6	53.1	2.4
October	1.69	68.1	46.8	57.5	4.1
November	1.20	74.7	50.9	62.8	6.1
December	1.16	82.2	55.5	68.9	8.2
Year	17.43	69.4	48.1	58.8	51.2

Winter rainfall is a little higher than summer rainfall, 9.56 inches falling on the average in the period April to September and 8.87 inches in October to March.

The rainfall varies considerably from year to year. Data are not given, but the rainfall in the summer and autumn months is markedly more erratic than the winter and spring rainfall.

Monthly mean temperatures range from 47.7° in June to 72 2° in January.

The evaporation figures given in Table 4 are calculated values from relative humidity readings at Rochester adjusted slightly on the basis of evaporimeter tank readings at Tatura about 30 miles away. Yearly evaporation exceeds the rainfall by 33.8 inches. June and July are the only months in which rainfall is higher than the evaporation.

PHYSIOGRAPHY AND GEOLOGY

The Riverine Plain of south-eastern Australia is a huge depositional plain which extends over northern Victoria and southern New South Wales. This physiographic unit is in turn a component of the Murray—Darling basin.

An elaborate, braided system of non-functional or prior streams traverses the Riverine Plain in a north-westerly direction. The prior streams have ceased to carry water and materials from the mountain catchment and their old courses are now largely filled. Usually their slightly raised levees and high level channels are recognizable features of the landscape, but in places the stream courses have been obliterated. Also, present-day water-courses and drainage lines sometimes coincide with the old prior stream channels, although usually they follow separate courses.

The present-day streams which traverse the Plain are essentially "rivers of transit", i.e. they carry mainly water from the mountain catchments to the Murray River, and the Plain itself contributes but little to their flow.

The Riverine Plain is built up of a considerable thickness of unconsolidated sediments of Tertiary and Quaternary Age. The exposed prior streams have been held responsible by Butler (1950) and others for most of the superficial deposits. However, the proposition that the uppermost layer over part, but not all of the Plain is aeolian clay or parna has been put forward more recently by Butler (1956). This, and other aspects of depositional theories as they apply to the Goulburn Valley have been mentioned by Skene and Poutsma (1962). Their remarks apply also to the Rochester—Echuca district and will not be repeated here.

The surveyed area represents a small segment of the vast Riverine Plain and lies between the Colbinabbin Range and the Murray River.

The Range falls away gradually in a northerly direction, and its lower slopes merge with the alluvium of the Plain only about 1 mile to the south-east of Rochester; a small part is within the Rochester Irrigation Area.

The rocks of the Colbinabbin Range are principally Cambrian basic lavas interbedded with cherts and shales of Silurian and Lower Devonian Age.

The Campaspe River is a well-defined stream with its channel deeply cut into the alluvium of the Plain. However, it has an extremely variable flow and barely flows at all for the greater part of the year, but periodically it floods its banks and causes serious inundation from Rochester to Echuca. There are no other waterways of note in the area. Shallow drainage ways traverse the plains and slowly take flood waters in a northerly direction to the Murray River. The fall from Rochester (373-ft. elevation) to Echuca (315 feet) is about 3 feet to 1 mile.

Prior streams occur on both sides of the Campaspe River. The principal occurrences have been traced to a common prior stream course (see Soil Association Map) which enters the area about 2 miles south-west of Rochester. This former stream, which possibly had the same watershed as the present Campaspe River, shows the deltaic pattern often seen at the terminal parts of prior stream courses. The distributory branches fade into the plains north-ward of Nanneella on the east side of the Campaspe River and into the plains north of Bamawm on the west side of the river. Remnants of a weaker prior stream are evident in the extreme western part of the area.

Bedrock movements are known to have influenced the drainage pattern in the Echuca region. A fault line referred to here as the Echuca South fault is evident as a scarp of 7 to 10 feet which runs parallel to the Campaspe River. This is shown in Figure 2. North of the Murray Valley Highway a large area of low land which includes the Echuca East Settlement lies about 10 feet below the general level of the depositional plain. Bowler and Harford (1963) recognize this as having its origin in faulting and suggest a sequence of events in regard to geomorphic features in that area.

The principal recognizable landscape features are prior streams, treeless plain, riverine woodland, swamps, and Cambrian upland. These are discussed in relation to the soils on them in the section, "Landscape Units and Guide to Soil Types", and they are illustrated in Figure 2.

VEGETATION

The above physiographic features originally carried their own distinctive tree communities. However, the landscape has been greatly modified by clearing for agricultural purposes and, in places, only remnants of the original timber remain.

Grey box *(Eucalyptus hemiphloia)*, buloke *(Casuarina Leuhmannii)*, yellow box (*E. melliodora*), Murray pine *(Callitris columellaris)* and black box (*E. largiflorens)* were the tree components of the savannah woodlands which originally covered the prior stream landscape unit. Grey box was generally dominant on Timmering loam, Wanalta loam and the Wana series. Murray pine and yellow box occurred as well as grey box on the lighter-textured Nanneella series situated on the prior stream levees. Buloke occurred irregularly and at times was found on all but poorly drained situations. Black box still remains in many of the continuous drainage lines which outline the prior stream channels and the soil type is Carag clay.

The few trees standing on the Cambrian upland landscape unit indicate that this originally supported on the upper slopes a grey box buloke woodland, with grey box the dominant species. However, it is probable that the Binabbin-Cornelia soil complex on the lower flat areas was sparsely timbered or treeless.

Black box is conspicuous as the tree component of the riverine woodland landscape unit where the soil types are Kanyapella clay loam, Kanyapella clay, and Yambuna clay. But in this unit where it occurs along the Campaspe River, river red gum (*E. camaldulensis)* is usually the dominant tree species. Yellow box occurs on some of the higher and better drained situations in the unit.

Black box also occurs in the more pronounced swamps as well as in some of the numerous small depressions and continuous drainage ways. The soil type is usually Carag clay, but some depressions have variable soils. Red gum generally is found in the more severely inundated situations.

The ground cover, although varied, is dominantly Wallaby grass (*Danthonia* spp.), spear grass *(Stipa* spp.), barley grass *(Hordeum murinum*) and species of Poa, *Festuca* and *Bromus.* Beauty heads *(Calocephalus citreus),* common sneezeweed *(Centipedia cunninghamii),* native pennyroyal (*Mentha satureioides)* and common rush *(Juncus polyanthemus)* are peculiar to the wetter situations. Saffron thistle (*Carthamus lanatus)* grows profusely on the gilgaied areas.

On the irrigated soils, improved pastures are of the perennial and annual types. The former are based on perennial rye grass *(Lolium perenne)* and white clover *(Trifolium repens),* with cocksfoot *(Dactylis glomerata*), paspalum *(Paspalum dilatatum)* and strawberry clover *(T. fragiferum)* sometimes present. A small amount of lucerne *(Medicago sativa)* is grown also. The annual pastures are of the subterranean clover (*T. subterraneum)* —Wimmera rye grass *(L. rigidum)* type.

Cumbungi or bulrush *(Typha* spp.*)* is conspicuous as tall dense stands in many drains and some irrigation channels.

REFERENCES

Bowler, J. M. and Harford, L. B. (1963).—Geomorphic sequence of the Riverine Plain near Echuca. Aust. J. Sci. 26: 88.

Butler, B. E., Baldwin, J. G., Penman, F. and Downes, R. G. (1942).—Soil survey of part of County Moira, Victoria. C.S.I.R. Aust. Div. Soils, Bull. No. 152.

Butler, B. E. (1950).—A theory of prior streams as a casual factor of soil occurrence in the Riverine Plain of south-eastern Australia. Aust. J. Agric. Res. 1: 231-252.

Butler, B. E. (1956).—Parna, an aeolian clay. Aust. J. Sci. 18: 145-151.

Hutton, J. T. (1955).—A method of particle size analysis of soils. C.S.I.R.O. Aust. Div. Soils, Div. Rep. No. 11/55.

Peech, M., Cowan, R. L. and Baker, J. H. (1962).—A critical study of the Ba C12—triethanolamine and the ammonium acetate methods for determining exchangeable hydrogen of soils. Proc. Soil Sc. Soc. Am. 26: 37-40.

Penman, F. (1936).—Soil conditions at Bamawm and Ballendella in relation to citrus growth. J. Dept. Agric. Vic. 34: 399-432.

Piper, C. S. (1950).—"Soil and Plant Analysis" (Adelaide University).

Prescott, J. A. (1944).—A Soil Map of Australia. C.S.I.R.O. Aust. Bull. No. 177.

Northcote, K. H. (1960).—A factual key for the recognition of Australian soils. C.S.I.R.O. Aust. Div. Soils, Div. Rep. No. 4/60.

Northcote, K. H. (1962).—"Atlas of Australian Soils; Explanatory Data for Sheet 2, Melbourne–Tasmania Area" (C.S.I.R.O. and Melbourne University Press).

Skene, J. K. M. and Freedman, J. R. (1944).—Soil survey of part of Shepparton Irrigation District, Victoria. Dept. Agric. Vic. Tech. Bull. No. 3.

Skene, J. K. M. and Poutsma, T. J. (1962).—Soils and land use in part of the Goulburn Valley, Victoria. Dept. Agric. Vic. Tech. Bull. No. 14.

Skene, J. K. M. (1963).—Soils and Land Use in the Deakin Irrigation Area, Victoria. Dept. Agric. Vic. Tech. Bull. No. 16.

Stephens, C. G. (1961).—The soil landscapes of Australia. C.S.I.R.O. Aust. Div. Soils, Soil Public. No. 18.

Stephens, C. G. (1962).—"A Manual of Australian Soils", 3rd Ed. (C.S.I.R.O. Aust., Melbourne.)

Tucker, B. M. (1954).—The determination of exchangeable calcium and magnesium in carbonate soils. C.S.I.R.O. Aust. J. Agric. Res. 5: 706-715.

APPENDIX I. ANALYTICAL DATA FOR REPRESENTATIVE PROFILES

SYMBOLS USED: LFS, loamy fine sand; FSL, fine sandy loam; FSCL, fine sandy clay loam; VFSCL, very fine sandy clay loam; L, loam; CL, clay loam; SiCL, silty clay loam; SiC, silty clay; LC, light clay; MC, medium clay; HC, heavy clay; E.C., electrical conductivity; *, visible gypsum is present; a blank space indicates that the analysis has not been done. A dash indicates that only a trace or none of the constituent is present.

Analyses are based on the oven-dry weight of soil.

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_2 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations: H		Ca		Mg		K		Na		Cations Exchange Capacity	Sample No.
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
Binabbin Clay: Profile 34—Map 17																											
0–2	HC	7·6	24·7	—	6	25	10	54	3·6		0·7	0·05	0·01	0·19	2·11												13055
2–9	HC	7·9	25·5	—	6	23	11	58	3·4		0·5	0·05	0·01	0·14	1·17	2·5	5	32·4	71	8·4	19	1·3	3	0·7	2	45·3	13056
9–17	HC	8·2	28·5	—	5	23	10	59	3·4		0·9	0·07	0·02			—	0	27·8	64	12·4	28	1·0	2	2·4	6	43·6	13057
17–28	HC	8·7		—	5	21	9	56	8·4		4·9	0·11	0·04														13058
28–37	HC	8·9		—	5	20	10	55	10		7·9	0·17	0·08			—	0	14·8	36	16·7	41	1·1	3	8·1	20	40·7	13059
48–63	HC	8·5		—	3	20	11	58	9·5		7·0	0·54	0·33														13061
72–92	HC	8·2		—	3	19	10	65	2·6			0·62	0·39														13063
Campaspe Suite—Type 1: Profile 18—Map 12																											
0–4	CL	5·9		—	2	31	39	26	0·8	5·7		0·04	0·01	0·15	1·54												23324
4–8	CL	5·5		—	2	36	35	24	0·6			0·01	0·01	0·08	0·64												23325
8–18	HC	8·0		—	1	25	24	49	1·4	5·8		0·03	0·02														23326
18–25	LC	9·2		—	1	34	28	35	1·4		0·3	0·07	0·02														23327
25–40	LC	9·4		—	1	37	25	35	2·2	4·3	0·5	0·07	0·02														23328
40–60	HC	9·0		—	3	16	13	68	1·2		0·1	0·08	0·03														23329
Campaspe Suite Type 3: Profile 23—Map 12																											
0–8	SiCL	6·5		—	1	26	42	28	0·7	6·0		0·04	0·02	0·14	1·40												23318
8–26	SiC	8·3		—	1	17	28	52	1·6	6·2	—	0·13	0·08	0·09	0·57												23319
26–41	SiC	9·1		—	1	16	31	49	2·7		0·1	0·19	0·10														23320
41–54	SiC	9·1		—	1	22	34	40	1·6			0·14	0·07														23321
54–67	CL	9·5		3	1	37	27	32	1·4		0·5	0·16	0·06														23322
67–84	FSC	9·3		4	1	31	37	29	1·2			0·13	0·05														23323
Carag Clay: Profile 16—Map 18																											
0–3	HC	6·2		—	2	23	13	58	2·3	9·8		0·06	0·03	0·22	2·48												20722
3–11	HC	7·5		—	1	13	8	75	2·9			0·08	0·03	0·10	0·79												20723
11–26	HC	8·7		—	1	17	13	67	2·4	6·7	0·6	0·19	0·10														20724
26–35	HC	9·0		—	2	22	13	61	2·9		0·8	0·32	0·16														20725
35–54	HC	9·2		—	2	27	13	55	3·0			0·31	0·16														20726
Colbinabbin Clay Loam: Profile 33—Map 17																											
0–3	CL	8·1		—	14	43	18	23	1·0	6·8		0·06	0·01	0·15	1·67												17870
3–13	HC	8·5	23·6	—	5	17	9	67	2·8	9·4		0·07	0·02			—	0	28·0	65	12·3	28	1·7	4	1·4	3	43·4	17871
13–27	HC	9·1		—	4	15	7	67	7·4	10·2	3·4	0·14	0·07														17872
27–35	HC	9·0	24·8	—	3	15	8	66	8·2	9·8	6·3	0·38	0·15			—	0	9·0	24	18·4	49	1·4	4	8·7	23	37·5	17873
35–50	HC	8·8		—	2	15	11	68	4·3	7·9	1·8	0·38	0·25														17874
50–64	LC	8·0		—	2	15	17	65	1·3	11·8		0·54	0·33														17875
64–80	SiC	6·3		—	3	21	22	54	1·4			0·47	0·31														17876
Cornella Clay: Profile 39—Map 17																											
0–3	MC	6·6	31·5	—	5	19	12	60	2·4	12·7		0·07	0·02	0·37	4·29	11·4	21	26·2	48	10·5	19	5·3	10	0·9	2	54·3	17877
3–21	HC	8·1	31·2	—	4	17	10	67	2·3	7·9	0·1	0·05	0·02	0·11	1·10	—	0	30·6	63	12·8	27	2·8	6	2·1	4	48·3	17878
21–36	HC	9·3		—	4	16	8	62	0	9·6	7·7	0·13	0·05			—	0	21·0	45	17·7	38	1·6	3	6·7	14	47·0	17879
36–66	HC	9·5		—	2	14	9	65	9·2	9·1	7·7	0·28	0·12														17880
66–83	MC	9·3		—	2	12	7	73	6·2			0·42	0·22														17881
83–92	MC	9·1		—	2	13	7	74	5·9			0·49	0·24														17882

Exchangeable Cations: m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_3 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations H		Ca		Mg		K		Na		Cations Exchange Capacity	Sample No.
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
Kanyapella Clay Loam: Profile 2—Map 3																											
0–5	SiCL	6·3	15·6	—	2	15	49	30	1·3	7·6		0·05	0·01	0·24	2·72	8·0	36	8·0	36	4·5	21	1·1	5	0·4	2	22·0	23335
5–15	MC	7·3	15·8	—	1	9	43	46	1·1	4·6		0·03	0·01	0·07	0·44	4·3	21	6·9	34	6·9	34	1·9	9	0·5	2	20·5	23336
15–25	SiC	7·9		—	1	8	50	39	1·0			0·04	0·02														23337
25–33	SiCL	8·2		—	1	8	56	33	1·0		—	0·06	0·03			—	0	5·6	37	7·9	51	0·8	5	1·0	7	15·3	23338
33–48	SiCL	8·6		—	1	9	61	27	1·0		0·1	0·07	0·05														23339
Koga Clay Loam: Profile 22—Map 12																											
0–5	CL	6·7	10·9	—	6	33	30	28	1·5	5·1		0·02	0·01	0·10	1·06	5·6	35	3·3	21	5·6	35	0·6	4	0·8	5	15·9	8248
5–13	HC	7·6	19·9	—	3	21	23	51	2·0	6·5		0·03	0·02	0·09	0·58	5·9	21	5·5	19	12·9	46	0·6	2	3·4	12	28·3	8249
13–20	HC	8·3		—	2	15	25	57	1·8	6·5		0·09	0·06														8250
20–29	MC	8·6		—	2	14	23	59	3·0	6·2	0·2	0·30	0·13			—	0	4·1	15	16·6	60	0·8	3	6·3	23	27·8	8251
29–42	MC	8·3		—	4	20	18	56	2·9	5·8	0·3	0·38	0·16														8252
42–76	MC	8·5		3	3	21	18	54	4·9	6·4	3·5	0·34	0·17														8253
76–103	MC	8·9		1	2	21	16	51	9·9			0·28	0·16														8254
Koga Clay Loam: Profile 27—Map 14																											
0–3	CL	7·1	10·9	—	6	41	18	33	0·8	5·1		0·02	0·01	0·10	1·03	6·7	39	2·7	16	5·2	30	1·1	7	1·4	8	17·1	20662
3–15	HC	8·2	19·9	—	3	20	12	64	1·5	6·9		0·09	0·06	0·09	0·62	—	0	8·3	31	12·6	47	1·0	4	5·0	18	26·9	20663
15–25	HC	8·7		—	3	20	15	59	2·9	5·8	1·0	0·47	0·15														20664
25–42	MC	8·2		—	3	20	16	59	2·8	5·7		*	0·19			—	0	4·9	17	13·9	48	1·1	4	9·1	31	29·0	20665
42–54	MC	9·0		—	2	19	18	59	2·2	5·9	0·7	0·47	0·21														20666
60–76	LC	8·7		—	5	25	20	49	1·5	4·9		0·37	0·18														20667
Koga Clay Loam: Profile 38—Map 17																											
0–6	CL	6·3		—	1	26	47	25	0·6	4·7		0·01	0·01	0·10	1·10												22920
6–16	HC	7·4		—	—	8	25	65	1·3	7·4		0·06	0·03	0·10	0·70												22921
16–25	HC	8·2		—	—	6	30	63	1·5	6·7	—	0·16	0·06														22922
25–29	MC	8·4		—	—	7	35	55	2·1		—	0·23	0·08														22923
29–60	LC	8·5		—	3	23	29	44	1·2	4·7	—	0·25	0·10														22924
60–87	CL	8·5		—	2	43	20	34	1·0	3·7		0·23	0·13														22925
Koyuga Clay Loam: Profile 3—Map 3																											
0–3	CL	6·6		—	3	45	29	21	0·4	4·2		0·02	0·01	0·10	1·21												17895
3–18	HC	7·9		—	1	20	20	57	1·5	6·0		0·30	0·18														17896
18–24	HC	8·1		—	1	17	22	53	5·0	5·0	0·1	*	0·24														17897
24–34	MC	8·9		—	1	17	27	53	1·5	4·8	0·1	0·60	0·30														17898
34–48	MC	9·1		—	1	12	36	48	2·6	5·0	1·0	0·56	0·33														17899
48–62	LC	9·1		—	1	21	29	46	2·3	4·4		0·56	0·34														17900
Koyuga Clay Loam: Profile 4—Map 4																											
0–4	L–CL	6·5	6·8	—	2	50	23	23	0·8	3·9		0·01	0·01	0·09	0·82	5·5	46	2·3	19	2·8	24	0·8	7	0·5	4	11·9	23353
4–13	HC	7·0	20·3	—	1	24	14	60	1·4			0·08	0·05	0·11	0·86	7·7	27	5·8	21	10·1	36	1·0	4	3·5	12	28·1	23354
13–23	HC	8·1		—	1	26	16	54	1·7	7·1		0·34	0·17														23355
23–30	HC	8·0		—	1	28	17	46	6·0		0·4	*	0·19														23356
30–38	HC	8·6		—	1	32	20	45	1·7	5·2	—	0·40	0·20			—	0	3·3	15	11·3	51	1·0	5	6·5	29	22·1	23357
28–48	LC	8·5		—	3	34	23	38	1·4			0·32	0·17														23358
48–57	HC	8·5		—	2	21	18	57	2·0	5·4		0·40	0·21														23359
66–84	HC	8·8		—	2	21	25	49	1·6			0·37	0·18														23361
Koyuga Clay Loam: Profile 8—Map 5																											
0–2	CL	6·3		—	6	41	25	26	0·7	5·0		0·02	0·01	0·12	1·33												20687
2–21	HC	8·0		—	2	19	18	59	1·7			0·15	0·08	0·08	0·52												20688
21–29	MC	8·0		—	1	13	25	52	7·0	5·5	—	*	0·18														20689
29–42	MC	8·6		—	2	19	22	55	1·7	5·2	—	*	0·17														20690
42–66	MC	9·2		—	4	34	13	45	3·8		1·5	0·33	0·15														20691

Exchangeable Cations: m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_2 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations (m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity): H		Ca		Mg		K		Na		Cations Exchange Capacity	Sample No.
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
KOYUGA CLAY LOAM: PROFILE 26—MAP 14																											
0–4	CL	6·9		—	11	50	15	22	0·4	3·9		0·02	0·01	0·08	0·84												20674
4–15	HC	8·2		—	6	31	12	50	1·2	5·9		0·17	0·12	0·09	0·72												20675
15–22	HC	8·9		—	4	29	13	52	2·1	5·6	0·4	0·44	0·23														20676
22–40	MC	9·1		..	2	26	16	48	8·1	7·1	5·2	0·47	0·24														20677
40–60	LC	8·9		4	2	33	22	41	1·5		0·1	0·37	0·20														20678
60–75	MC	8·6		1	2	32	20	45	1·5			0·30	0·18														20679
NANNEELLA LOAMY FINE SAND: PROFILE 32—MAP 16																											
0–5	LFS	5·5	3·4	—	8	68	14	9	0·5	2·8		0·01	0·01	0·05	0·84	5·2	63	1·4	17	0·7	9	0·8	10	0·1	1	8·2	17815
5–11	LFS	5·5		—	7	70	14	8	0·6	1·9		0·02	0·01	0·03	0·28												17816
11–14	FSL	5·9		—	5	65	15	15	0·6	2·4		0·03	0·02														17817
14–21	FSC	5·7	10·2	—	3	56	11	29	0·8	4·0		0·05	0·03			5·7	34	2·6	15	6·7	40	0·7	4	1·2	7	16·9	17818
21–36	FSCL	6·3		—	1	61	11	26		3·4		0·07	0·04			3·4	23	2·4	16	7·3	48	0·7	4	1·4	9	15·2	17819
36–52	FSL	8·8		—	1	75	7	15	2·4	2·1	0·1	0·10	0·05														17820
52–82	FSL	9·5		—	2	71	11	15	1·2		0·5	0·14	0·05														17821
NANNEELLA FINE SANDY LOAM: PROFILE 17—MAP 11																											
0–6	FSL	6·2		—	2	60	22	14	0·8	4·2		0·06	0·03	0·11	1·25												17864
6–14	LC	8·4		—	1	41	19	38	1·3	5·0		0·16	0·09														17865
14–20	LC	9·3		—	1	44	17	36	1·9	4·3		0·29	0·15														17866
20–34	FSCL	9·5		2	1	55	16	26	1·7	3·5	0·7	0·24	0·13														17867
34–47	VFSCL	9·5		—	—	26	39	33	2·7	4·6	1·3	0·13	0·05														17868
47–68	VFSCL	9·1		—	1	39	31	28	1·5	3·7		0·02	0·02														17869
NANNEELLA FINE SANDY LOAM: PROFILE 31—MAP 16																											
0–3	FSL	6·8		—	1	51	30	15	0·9	5·3		0·03	0·02	0·15	1·70												17823
3–7	FSL	6·7		—	1	51	31	17	0·8	3·3		0·04	0·02	0·05	0·56												17824
8–17	LC	7·6		—	1	30	27	41	1·2	5·1		0·05	0·02														17825
17–24	CL	8·2		—	—	37	27	35	1·1	4·5	—	0·06	0·03														17826
24–34	FSCL	8·9		—	—	55	19	25	0·9	3·5	0·3	0·08	0·03														17827
34–45	VFSCL	8·9		—	—	31	37	29	2·2	4·5		0·10	0·04														17828
58–76	LC	9·0		—	1	16	42	40	1·1	5·3		0·07	0·04														17830
RESTDOWN CLAY "GILGAI PUFF": PROFILE 11—MAP 6																											
0–6	HC	8·7		—	1	15	13	65	6·2	8·2	3·3	0·04	0·01	0·08	0·67												20693
6–13	HC	8·8		—	1	15	13	65	6·9	8·2	4·1	0·04	0·02	0·05	0·53												20694
13–25	HC	9·2		—	—	15	14	65	6·4	7·8		0·06	0·02														20695
25–50	HC	9·2		—	—	17	16	62	5·7		3·1	0·17	0·05														20696
50–63	HC	8·1		—	—	16	19	57	5·9	5·8		*	0·13														20697
RESTDOWN CLAY "GILGAI SHELF": PROFILE 12—MAP 6																											
0–1	CL	6·6		—	3	47	23	26				0·04	0·01	0·13	1·41												20698
1–10	HC	8·1		—	1	19	12	64	2·1			0·09	0·06	0·10	0·77												20699
10–17	HC	8·7		—	1	17	15	65	2·2	6·7	0·1	0·48	0·31														20700
17–25	HC	8·1		—	1	18	15	58	6·7	6·0	0·8	*	0·43														20701
25–35	HC	8·1		—	1	18	17	57	5·9	6·0		*	0·43														20702
35–52	HC	8·3		—	—	17	21	57	4·4	5·9	1·2	*	0·42														20703
52–72	HC	8·6		—	—	15	23	58	1·9	5·8		0·61	0·41														20704
RESTDOWN CLAY: PROFILE 13—MAP 7																											
0–3	MC	7·1	19·1	—	2	25	20	52	1·6	8·6		0·02	0·01	0·21	2·43	5·6	18	16·5	53	6·6	21	2·3	7	0·3	1	31·3	20656
3–14	HC	8·6	19·2	—	1	16	17	61	5·1	8·1	3·0	0·06	0·02	0·08	0·64	—	0	20·5	66	8·8	28	1·2	4	0·7	2	31·2	20657
14–32	HC	9·2		—	1	15	14	63	6·7		4·4	0·09	0·02														20658
32–42	HC	9·1		—	1	15	19	60	4·1			0·17	0·04			—	0	10·6	35	14·2	47	0·9	3	4·6	15	30·3	20659
42–54	HC	8·1		—	—	18	25	54	3·1	5·1	0·5	*	0·05														20660
60–84	LC	8·6		—	1	21	27	50	1·3			0·27	0·06														20661

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_2 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations H		Ca		Mg		K		Na		Cations Exchange Capacity	Sample No.
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
																m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity											
Restdown Clay "Gilgai Puff": Profile 20—Map 12																											
0–3	HC	8·4		—	3	22	10	61	3·7	8·0	1·1	0·07	0·02	0·12	1·10												17837
3–11	HC	8·3		—	2	18	10	68	2·6	7·2		0·05	0·02														17838
11–25	HC	9·4		3	2	19	9	61	8·8	8·6	6·1	0·10	0·02	0·05	0·32												17839
25–44	HC	9·8		5	1	20	12	57	10·4	8·0	7·3	0·18	0·05														17840
44–60	HC	9·7		—	1	27	16	51	4·8	5·5	2·6	0·26	0·09														17841
60–78	HC	9·5		—	2	30	16	47	5·1	5·5		0·32	0·13														17842
Restdown Clay "Gilgai Shelf": Profile 21—Map 12																											
0–2	CL	7·0	10·5	—	8	44	17	29	0·7	5·2		0·03	0·01	0·12	1·30	5·9	34	4·5	26	5·0	28	1·1	6	1·1	6	17·6	17843
2–11	HC	8·3	21·4	—	3	20	10	66	1·8	7·3		0·13	0·07			—	0	7·7	28	13·3	48	1·4	5	5·4	19	27·8	17844
15–32	HC	9·0		—	2	19	12	55	12·5	10·0	9·5	0·51	0·22														17845
Rochester Clay "Gilgai Puff": Profile 9—Map 5																											
0–3	MC	7·4	18·6	—	5	25	19	47	2·1	7·8		0·04	0·02	0·20	2·10	4·6	21	17·2	56	6·3	19	2·3	10	0·5	2	30·9	20680
3–21	HC	8·9	16·5	—	4	22	17	53	3·9	6·0	1·3	0·05	0·02	0·06	0·36	—	0	17·6	64	7·9	28	0·7	3	1·3	5	27·5	20681
21–45	HC	9·3		—	3	22	17	54	3·6		1·6	0·10	0·03			—	0	12·8	42	12·5	41	0·8	3	4·1	14	30·2	20682
45–65	HC	9·2		—	2	20	19	56	4·1	5·6		0·19	0·08														20683
Rochester Clay "Gilgai Shelf": Profile 10—Map 5																											
0–6	HC	7·3	18·8	—	5	27	18	48	1·6	7·0		0·02	0·01	0·15	1·49	5·6	19	15·7	53	6·2	21	1·6	5	0·4	2	29·5	20684
6–10	HC	8·0		—	6	25	18	50	1·8	5·9	0·9	0·03	0·01	0·07	0·61												20685
10–21	HC	8·7	17·5	—	6	24	17	50	3·5		1·0	0·05	0·01			—	0	15·2	64	7·2	30	0·8	3	0·7	3	23·9	20686
Rochester Clay "Gilgai Puff": Profile 28—Map 15																											
0–2	HC	7·6		—	2	21	18	57	2·1	7·8		0·02	0·01	0·17	1·83												20668
2–7	HC	8·5		—	2	19	15	61	2·6		0·3	0·04	0·01	0·10	0·93												20669
7–27	HC	9·1		—	1	15	15	64	5·9	7·5	3·6	0·06	0·02														20670
27–40	HC	9·5		—	1	13	16	60	8·1			0·13	0·02														20671
40–60	HC	9·5		—	1	13	17	66	4·3	6·4	1·8	0·15	0·03														20672
60–84	HC	9·6		—	1	16	18	63	3·5			0·08	0·02														20673
Timmering Loam: Profile 6—Map 4																											
0–6	FSL	6·5		—	8	52	23	15	0·6	4·3		0·02	0·01	0·10	1·40												23340
6–15	MC	8·3		—	7	34	17	40	1·4	8·2		0·04	0·02	0·07	0·58												23341
15–25	LC	9·6		3	9	32	20	36	2·7		2·1	0·13	0·03														23342
25–37	VFSC	9·5		—	4	38	24	31	1·5		0·6	0·18	0·05														23343
37–54	FSCL	9·4		—	3	44	27	24	1·1			0·16	0·05														23344
54–69	FSL	9·4		—	3	53	24	18	0·8			0·06	0·02														23345
Timmering Loam: Profile 14—Map 8																											
0–7	FSL	7·0		—	5	55	21	16	1·0	6·2		0·04	0·02	0·20	2·25												20711
8–18	MC	8·8		—	2	30	16	50	2·1			0·18	0·08	0·07	0·50												20712
18–27	LC	9·6		7	1	30	21	46	2·9	5·5	1·7	0·26	0·10														20713
27–36	FSC	9·8		—	1	45	17	35	2·3		0·7	0·16	0·05														20714
36–54	FSC	9·5		5	—	46	19	34	1·8		0·3	0·08	0·02														20715
54–84	FSCL	9·0		—	2	46	20	31	1·6			0·04	0·01														20716
Timmering Loam: Profile 30—Map 16																											
0–3	L	5·6		—	1	32	45	20	0·7	5·4		0·02	0·01	0·15	1·75												17831
3–6	L	6·1		—	1	32	46	20	0·4	3·6		0·02	0·01	0·07	0·69												17832
7–20	MC	7·3		—	—	16	33	49	1·4	6·4		0·10	0·06														17833
20–26	LC	8·6		—	—	14	41	43	1·9	5·5	0·3	0·23	0·12														17834
26–42	CL	8·7		—	—	16	44	38	1·7	5·2	0·4	0·21	0·11														17835
42–61	LC	8·2		—	2	15	39	42	1·3	5·2		0·16	0·09														17836

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_2 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations: H		Ca		Mg		K		Na		Cations Exchange Capacity	Sample No.
																m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity											
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
Timmering Loam: Profile 35—Map 17																											
0–5	L	6·5	10·9	—	3	53	23	17	1·0	6·6		0·03	0·01	0·21	2·42	6·8	40	6·5	38	2·9	17	0·5	3	0·4	2	17·1	17853
5–7	FSCL	7.1		—	3	52	25	19	0·2	2·9		0·02	0·01														17854
7–18	MC	7·3	16·9	—	2	35	18	45	1·3	5·3		0·08	0·05			5·2	25	4·3	20	8·4	40	0·5	3	2·6	12	21·0	17856
18–30	LC	9·3		4	1	41	12	44	3·0	4·8	0·3	0·17	0·09			—	0	4·1	19	12·9	59	0·9	4	4·0	18	21·9	17856
30–36	CL–LC	9·4		—	1	44	9	43	3·0	4·8	1·4	0·13	0·05														17857
36–42	CL–LC	9.3		—	5	39	11	43	2·3	4·6		0·09	0·03														17858
Wallenjoe Clay: Profile 24—Map 12																											
0–6	HC	6·6		—	1	8	22	66	1·4	7·9		0·04	0·02	0·13	1·18												17891
6–22	HC	7·0		—	2	10	26	60	1·5	6·8		0·05	0·03														17892
22–32	HC	7·0		—	2	10	24	62	1·8	6·4		0·15	0·01														17893
32–48	HC	7·9		—	1	11	23	64	1·7	6·3		0·21	0·15														17894
Wana Loam: Profile 36—Map 17																											
0–3	L	6·0		—	1	22	43	28	1·4	7·1		0·18	0·07	0·22	2·25												17848
3–6	CL	6·4		—	1	24	47	26	0·8	4·3		0·04	0·02	0·09	0·84												17849
6–28	HC	7·7		—	1	13	30	54	1·5	6·5		0·16	0·07														17850
28–43	LC	8·3		2	1	30	20	46	2·5	5·0	0·2	0·57	0·13														17851
43–56	LC	8·6		2	—	33	21	44	1·7	4·6		0·45	0·14														17852
Wana Clay Loam: Profile 29—Map 16																											
0–4	CL	7·1	13·1	—	5	27	33	33	1·5	6·7		0·03	0·01														3261
4–6	CL	7·9	17·1	—	6	26	34	33	1·1	5·4		0·03	0·01														3262
6–13	MC	7·8		—	3	20	26	50	1·2	5·4		0·05	0·02														3263
13–23	HC	7·7		—	1	14	22	62	1·7	6·4	—	0·16	0·06														3264
23–34	HC	7·9		—	1	9	23	65	1·9	6·4	—	0·38	0·13														3265
34–45	HC	8·1		—	2	10	23	63	2·0	5·9	0·1	0·35	0·11														3266
45–60	HC	8·6		—	2	12	20	63	3·7	6·5		0·35	0·10														3267
Wanalta Loam: Profile 5—Map 4																											
0–5	L	5·9	6·3	—	1	52	25	21	1·0	4·2		0·01	0·01	0·11	1·14	5·8	44	4·6	35	2·1	16	0·5	4	0·2	1	13·1	23347
5–19	HC	8·0	20·4	—	—	25	18	55	1·7	6·5		0·04	0·02	0·09	0·68	3·0	11	11·4	42	10·3	38	1·0	4	1·3	5	27·0	23348
19–28	MC	8·8		—	—	31	23	42	2·1		0·4	0·13	0·06														23349
28–40	LC	8·1		—	—	31	28	38	1·5		0·1	0·30	0·15			—	0	7·2	34	10·4	48	0·7	3	3·2	15	21·5	23350
45–54	LC	7·6		—	1	21	29	46	2·0			0·70	0·48														23351
54–78	MC	7·1		—	1	27	24	46	1·9			0·63	0·41														23352
Wanalta Loam: Profile 15—Map 8																											
0–4	CL	6·1		—	7	36	30	25	0·7	5·3		0·07	0·06	0·11	1·44												20717
4–14	HC	7·5		—	3	18	22	56	1·9	6·5		*	0·21	0·07	0·67												20718
14–24	HC	8·2		—	2	14	25	56	3·2	5·5	0·8	*	0·29														20719
24–39	LC	8·1		—	3	19	19	51	7·9	6·0	4·1	*	0·12														20720
39–48	LC	8·9		—	4	23	14	52	6·8			0·33	0·09														20721
Wanalta Loam: Profile 37—Map 17																											
0–6	L	6·4		—	1	50	29	17	0·8	4·4		0·01	0·01	0·10	1·21												17859
6–15	MC	8·5		—	—	29	20	50	1·7	5·9		0·04	0·03														17860
15–29	LC	9·2		1	1	35	22	41	1·6	4·7	0·2	0·08	0·04														17861
29–41	LC	9·2		—	—	12	38	49	1·9	5·4	0·2	0·13	0·08														17862
41–63	LC	9·0		—	—	33	21	45	1·6	4·8		0·16	0·10														17863

Depth	Field Texture	pH	Moisture 15 Atmosphere	Gravel ($CaCO_3$)	Particle Size: Coarse Sand	Particle Size: Fine Sand	Particle Size: Silt	Particle Size: Clay	Loss on Acid Treatment	Loss on Ignition	Calcium Carbonate (CO_3 x 1·67)	Soluble Salts (E.C. mho/cm x 320)	Sodium Chloride (Cl x 1·64)	Nitrogen	Organic Carbon	Exchangeable Cations (m.e.%—milliequivalents per 100 g of soil; %—percentage of cation exchange capacity): H	H	Ca	Ca	Mg	Mg	K	K	Na	Na	Cations Exchange Capacity	Sample No.
in.			%	%	%	%	%	%	%	%	%	%	%	%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	%	m.e.%	
Wanalta Loam: Profile 40—Map 18																											
0–4	L	5·7	6·9		2	38	37	20		4·6		0·02	0·01	0·12	1·39	8·6	21	3·7	25	1·5	10	0·9	6	0·2	1	14·9	17883
4–8	CL	6·6		—	2	35	38	24	0·4	3·3		0·02	0·01	0·05	0·32												17884
8–17	MC	8·0	16·6	—	1	24	23	51	0·9	5·7		0·03	0·02			4·4	19	7·7	33	8·9	38	0·6	3	1·5	7	23·1	17885
17–24	MC	8·7		—	1	26	20	53	1·2	5·7	—	0·06	0·04														17886
24–33	MC	9·0		—	1	33	20	46	1·5	5·1	0·5	0·13	0·06			—	0	8·5	37	10·7	47	0·7	3	3·0	13	22·9	17887
33–45	LC	9·0		—	2	41	15	39	2·4		0·7	0·17	0·08														17888
45–58	FSC	8·8		—	4	47	15	32	1·1	3·6		0·16	0·09														17889
58–78	MC	8·7		—	3	26	26	45	1·2	4·6		0·21	0·12														17790
Yambuna Clay: Profile 1—Map 3																											
0–1	CL	7·3		—	1	21	36	37	2·0	9·5		0·09	0·05	0·24	3·44												23331
1–11	HC	7·6		—	1	6	25	64	1·9			0·10	0·07	0·11	1·00												23332
11–24	HC	8·8		—	—	6	31	61	2·1	6·4	0·5	0·17	0·08														23333
24–36	MC	8·9		4	1	9	37	49	2·0		1·0	0·19	0·09														23334
Yuga Clay: Profile 7—Map 5																											
0–3	LC	6·6	11·9	—	5	39	18	35	1·2	5·6		0·03	0·02	0·08	1·10	8·4	41	3·3	16	6·2	30	0·9	4	1·8	9	20·6	20705
3–14	HC	8·3	28·5	—	1	14	10	72	1·5			0·11	0·07	0·09	0·65	—	0	8·2	26	15·3	48	1·3	4	6·8	22	31·6	20706
14–25	HC	8·7		—	1	14	11	71	2·2		0·1	0·38	0·16														20707
25–41	HC	8·5		—	1	19	15	60	3·5	8·3	0·5	*	0·18			—	0	2·3	8	14·9	54	1·2	4	9·3	34	27·7	20708
41–62	MC	8·2		—	1	21	16	56	4·8	6·1	1·6	*	0·23														20709
62–78	MC	8·5		—	2	25	15	57	2·2	5·6		0·61	0·28														20710

APPENDIX II. ANALYTICAL METHODS

All estimations were carried out on the air-dried fine earth, i.e., material passing a 2 mm round hole sieve. For calcium carbonate, nitrogen and organic carbon analyses, the fine earth was further reduced to pass through a 0.5 mm sieve. All results except pH and gravel are reported on an oven-dry basis. Gravel is reported as a percentage of the field sample.

The methods used are given below and except where indicated otherwise are essentially as described by Piper (1950).

Particle Size Distribution.—For the majority of soils the procedure adopted followed that of the International "A" pipette method. In some cases the silt and clay were determined by a method described by Hutton (1955) using a plummet balance.

Soluble Salts.—A 1:5 soil-water suspension was shaken for one hour and the electrical conductivity (E.C.) determined at 20° C. This was converted to per cent total soluble salts (T.S.) through the relationship:

T.S. = E.C. x 320.

where E.C. is expressed in mho/cm. The factor 320 has been derived from gravimetric determinations of total soluble salts in soils from northern Victoria.

15 atmosphere percentage.—This is the moisture retained, as a percentage of the oven-dry soil, after 48 hours at 15 atmosphere pressure in the pressure membrane chamber.

pH.—After determination of electrical conductivity (soluble salts), the same suspension was used to determine pH by the glass electrode.

Chlorides.—These were determined by the electrometric titration method of Best.

Calcium Carbonate.—Carbon dioxide was determined by the vacuum method of Hutchinson and MacLennan and expressed as calcium carbonate.

Nitrogen.—The Kjeldahl method was used.

Organic Carbon.—The wet combustion method of Walkley and Black was used. Results have been multiplied by an empirical recovery factor of 1-25.

Exchangeable Cations.—The soil was first leached with 60 per cent ethanol to remove soluble salts. If no carbonates were present, it was then leached with N ammonium acetate adjusted to pH 7.0; if carbonates were present, it was leached with N ammonium chloride in 60 per cent ethanol adjusted with ammonia to pH 8.5 (Tucker, 1954).

In the leachate, calcium and magnesium were determined by EDTA titration and sodium and potassium using an EEL flame photometer. The individual cations have been expressed as milligram equivalents per 100 g of soil and as percentages of the total cation exchange capacity.

Exchangeable Hydrogen.—This was determined by Mehlich's barium chloride--triethanolamine method (reference point pH 8.0), using the modification of Peech et al. (1962).

Cation Exchange Capacity.—This is the sum of exchangeable calcium, magnesium, potassium, sodium and hydrogen.

APPENDIX III. EXPLANATION OF SOIL TERMS

Bleached: Describes a horizon which has become pale owing to leaching.

Buckshot: More or less rounded, hard ferruginous concretions varying from shot to marble size.

Catena: As used here; a sequence of different soil types derived from similar parent material, their differences arising from drainage effects due to variation in slope.

Concretions: Local concentrations of certain chemical compounds deposited in the form of hard, more or less rounded nodules of various sizes.

Consistence: This is the behaviour of the soil when manipulated. It indicates its resistance to deformation, and is a measure of the degree of cohesion of a soil or of a soil aggregate. It is affected markedly by the moisture state of the soil. The following consistence terms are used in this report: crumbly, friable, labile, plastic, tough, hard, intractable.

Ferruginous concretions: Concretions, mainly of iron oxide, deposited in the A_2 and B_1 horizons.

Gilgai: An uneven surface manifestation of puffs and depressions often referred to as crabholes.

Gypsum: Hydrated calcium sulphate.

Illuvial: Material deposited in the soil profile as the result of translocation during soil weathering processes. It is customary to refer to the A horizons as *eluvial* horizons and the B horizons as *illuvial* horizons.

Impermeable: Describes soils which are very slowly permeable to water.

Lime: Calcium carbonate either finely divided or in concretions.

Morphology: The physical constitution of the various horizons and their arrangement in the soil profile.

Munsell colour: This is the soil colour determined by matching against the Munsell colour chart and expressed in its notation of hue, value and chroma. The notations given in this report are for moist soils. These, in general, are about two intervals lower in value than for the soils in their dry states. The written descriptions of the surface soils refer to their dry state.

Parna: A fine textured calcareous deposit of aeolian origin. It is postulated to be derived from older soils and transported mostly as small clay aggregates.

Ped: An individual natural soil aggregate.

Soil association: As used here, a group of soil types regularly associated geographically in a defined proportional pattern.

Soil horizon: A layer of soil with similar characteristics throughout. The horizon may be distinguished by differences in one or more of the following characteristics: colour, texture, structure, consistence, organic matter content, and the presence of visual products of weathering such as calcium carbonate, gypsum and iron oxide concretions.

Soil profile: This is the vertical section of a soil exposing the sequence of horizons from the surface to an arbitrary depth, in this case, to at least 4 feet. The horizons in the soils described are:

A_1 The surface layer in which organic matter has accumulated and partly leached of clay and soluble material. It represents the zone of maximum biological activity and roughly corresponds to the layer affected by tillage.

A, A lighter coloured, subsurface layer, poor in organic matter. This .is the zone of maximum leaching.

B_l A subsoil layer representing the zone of accumulation of some materials, chiefly clay, from the A horizon.

B_2 A zone of accumulation of other materials, usually calcium carbonate.

C A layer representing unchanged material from which the above horizons have formed.

Soil phase: A modification of a soil type in which one feature is accentuated without altering the main profile form.

Soil series: A group of soils having horizons similar in distinguishing characteristics and arrangement in the soil profile, except for the texture of the surface soil, and formed from the same parent material. The series name is taken from the locality where it was first described

Soil type: A group of soils with the same general profile characteristics, including the texture of the surface soil. The unit of soil mapping used over most of this survey.
Solonetzic: Describes a soil having resemblances in the structure of its B_1 horizon to the columnar structure of the solonetz.

Structure: Describes the way in which the primary soil particles are arranged into soil aggregates (peds). The descriptive terms used here are: angular blocky, subangular blocky, prismatic, coherent, massive. The size or grade of the aggregates may be fine, medium or coarse while the structure may be weakly, moderately or strongly developed.

Sub plastic: This describes a soil which increases in plasticity with continued manipulation in the moist state and, in consequence, increases in field texture.

Texture: This is the grading of the soil material in respect of the size of the primary particles.

Toposequence: As used here, an orderly sequence of soil types passing from the highest to the lowest part of a particular landscape unit. The differences in soil types may be due to either parent material, or drainage, or both. Where the parent material is uniform "catena" is synonymous.

Variant: A minor modification of a soil type which is usually indicated by a suitable inscription on the soil map

APPENDIX IV. SOIL SURVEY METHODS

In making this soil survey, the soil surveyors listed at the front of this report walked over the land and bored holes at intervals varying from 4 to 20 chains apart, depending on the complexity of the soil pattern. The soil profile at each spot was exposed with a 4 inch Jarrett soil auger, usually to a depth of 4 feet, but sometimes to 7 feet, and the soil classified into its soil type. To do this the soil surveyor examined the various horizons in the soil profile and noted their texture, friability, colour, thickness, and the presence of lime, iron concretions and gypsum.

The soil type at each point examined was marked on an aerial photograph (scale 1 inch to 20 chains) and a boundary drawn to show where one soil type changed to another. Surface features such as change of slope, depressions and rises, which often show on aerial photos were helpful in determining where the change occurred. But it should be appreciated that a soil boundary line shown on a soil map represents a zone of transition. This zone may be narrow which means that the soil change covers only a few feet or yards, or it may be gradual with the transitional zone extending over one or more chains.

Preliminary soil maps at a scale of 1 inch to 20 chains were constructed by transferring the soil boundaries from the aerial photographs onto suitable base plans. These are the relevant standard mapping areas of the Military Map Series with the parishes and allotments shown.

It has been necessary to reduce the size of the soil maps for publication, consequently, the scale of the maps in this bulletin has been reduced to 1 inch to 40 chains.

The smallest area that can be shown on the soil mar at the scale used is about 11 acres, i.e., 4 chains across. This means that any area shown as a single soil type may have small areas of one or more soil types with it, *but not to a greater extent than about one sixth of the occurrence*. Where the other soil type (or types) covers more than one sixth, but not more than one third, its presence has been denoted by an *inscriptior* on the map. Should the second soil type exceed one third, the occurrence has been mapped as a *complex* of both soil types and is shown by diagonal hatchuring.

Where soil types are intermingled, it is not always practicable to make separations, even though the individual soil types occupy areas greater than 11 acres. Consequently, in some of the complexes mapped, the areas of the component soil types are much greater than this. Also, some complexes are comprised of three soil types.

A soil association may be regarded as a complex of soil types on a broad scale of mapping. The Soil Association Map shows the soils of the area grouped on this basis, but in this case the map was compiled from the detailed soil maps after they were completed, and not by mapping the soils as associations in the field.