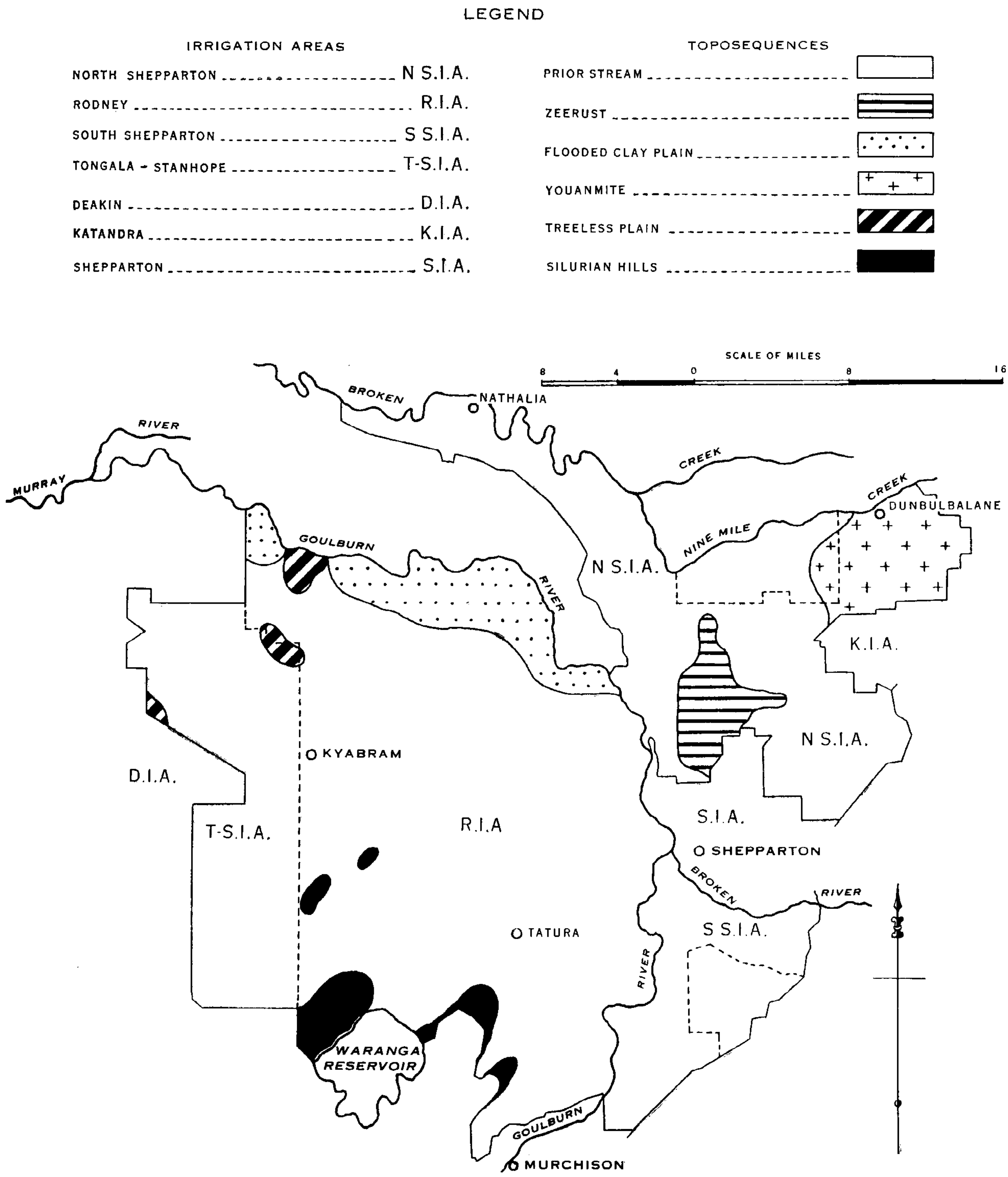


Fig. 2. Showing location of toposequences and Irrigation Areas.

## LANDSCAPE RELATIONSHIPS AND GUIDE TO SOIL TYPES

In this section, the soil types are considered in their relation to broad landscape features (see "Physiography and Geology") in order to assist in their identification in the field. Four landscape features are fairly readily recognizable; they are the hills of Silurian rocks, prior stream formations, treeless plains, and flooded clay plain. Less distinctive are the wooded plains which comprise the major part of the area, particularly as they now carry only remnants of their original tree cover. Nevertheless, in addition to the wooded flood plains of the prior streams, it is possible to recognize three other woodland plain landscapes, each distinctive in regard to its original tree species and soils.

Each of the seven landscape units referred to has its own soil pattern. In each unit, the soil types are related to one another according to their position in the landscape, i.e., they form a slope, or toposequence. The seven toposequences recognized are shown in Figure 2 and described below. The component soil types in each sequence are shown in italics; but each member of the toposequence is not necessarily present. The illustrative diagrams that follow represent idealized arrangements. A soil type as found in the field does not necessarily occur next to the soil types shown adjoining it in the diagram. The main distinguishing features of adjacent soil types are given in the descriptions that follow while, in some cases, reference is made to differences with equivalent soil types in other sequences.

### PRIOR STREAM SEQUENCE.

The soil types directly controlled by the prior streams and their deposits comprise this toposequence. An idealized arrangement with all members of the sequence present is illustrated in Figure 3.

The focal point of this sequence is the prior stream channel. The soils in the beds of the channels are variable and range from well drained brown soils with light (*Type* 1) and medium textured (*Type* 1H) profiles to poorly drained, grey soils with clay profiles (*Type* 2).

*Sandmount sand* and *Type E* are developed on sand blown up by wind action from the prior stream bed. In Sandmount sand, the sand is always deeper than 7 feet with a weak B horizon of clay accumulation *below* 3 feet. In *Sandmount sand shallow phase,* this horizon always occurs *before* 3 feet, but then reverts to sand in the deeper subsoil. In contrast, the deep subsoil textures of Type E are sandy clay loam or heavier.

*East Shepparton fine sandy loam, Shepparton fine sandy loam* and *Lemnos 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 East Shepparton fine sandy loam to Lemnos loam, while the parent material becomes finer. Thus East Shepparton fine sandy loam and Shepparton fine sandy loam are distinguished from Lemnos

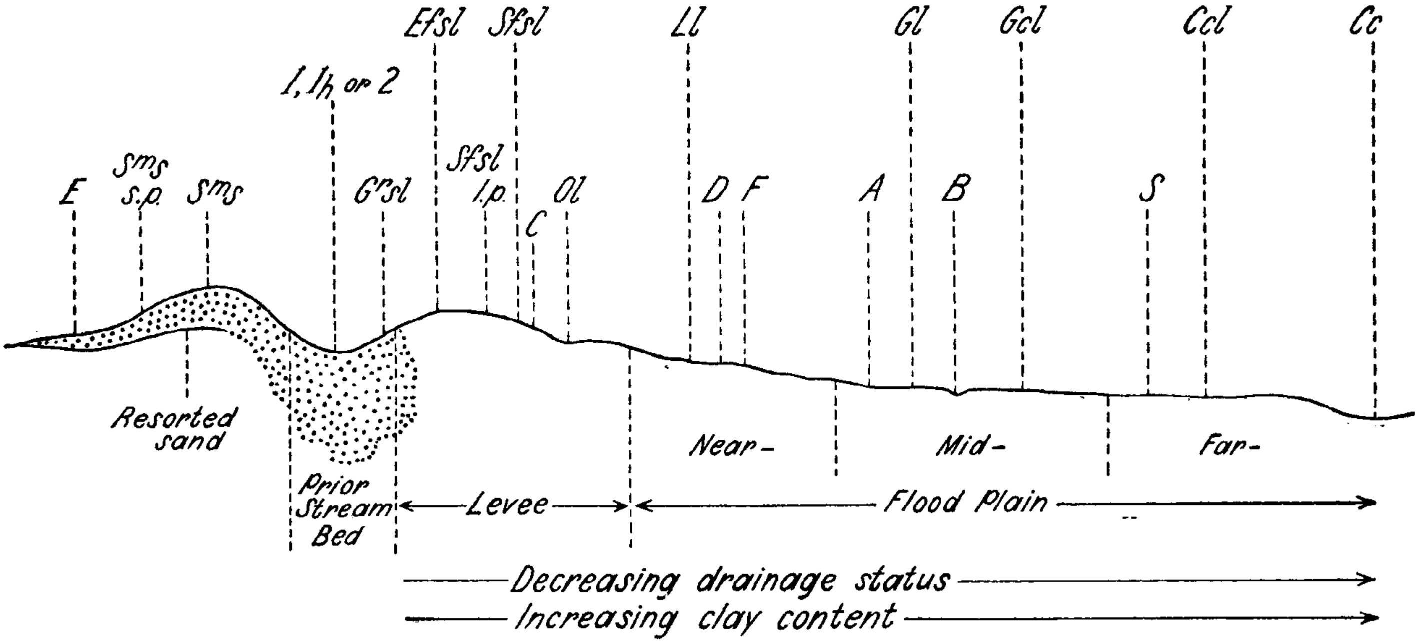


Fig. 3. Toposequence of soil types on the prior stream landscape.

Ccl = Congupna clay loam ; Cc = Congupna clay ; Efsl = East Shepparton fine sandy loam ; Gl = Goulburn loam ; Gcl = Goulburn clay loam ; G$^{r}$sl = Grahamvale sandy loam ; Ll = Lemnos loam ; Ol = Orrvale loam ; S$^{ms}$ = Sandmount sand ; Sfsl = Shepparton fine sandy loam ; Types A, B, C, D, E, F, S ; l.p. = light phase ; s.p = shallow phase.

loam by the presence of fine sandy clay or lighter textures in the deep subsoil; Lemnos loam has light or medium clay there. East Shepparton fine sandy loam differs from Shepparton fine sandy loam in that a fine sandy loam texture occurs before 3 feet in the profile, whereas fine sandy loam, if present at all in the subsoil of Shepparton fine sandy loam, occurs below 3 feet.

*Grahamvale sandy loam* is a very minor soil type in the present area, sometimes occurring with East Shepparton fine sandy loam. The texture profile is slightly lighter than in East Shepparton fine sandy loam while the subsoil may be yellow-brown instead of red-brown.

*Orrvale loam* has a similar texture profile to that of Shepparton fine sandy loam, but, by virtue of its position in locally poorly-drained areas, it has a colour profile dominated by grey-brown and yellow-brown instead of bright colours.

The catena *Lemnos loam, Goulburn loam* and *Congupna clay loam* forms a colour sequence, surface colours passing from brown through grey-brown to grey, and subsoil colours from red-brown through yellowish brown to yellow-grey. Texturally, Lemnos loam and Goulburn loam are almost similar. Ideally, the brown surface and red-brown subsoil colours of Lemnos loam are distinctly different from the grey-brown and yellowish brown of Goulburn loam. However, these colours may merge gradually down-slope without any break in the topography. An arbitrary separation has been made at the point where the subsoil clay becomes bright brown. Such soils have been assigned to Lemnos loam provided the surface colour is brown, but to Goulburn loam where the surface is grey-brown.

Goulburn loam is readily distinguishable from the greyer and heavier textured Congupna clay loam, but not so *Goulburn clay loam,* as these clay loam types are texturally similar and sometimes merge without an evident break in the topography. The types are separated at the point where an increasing greyish influence changes the dull yellow-brown colouration of the Goulburn clay loam subsoil to a brownish yellow-grey.

*Congupna clay* is the lowest member of the prior stream landscape and occupies the more definite depressions and superimposed drainage ways.

The minor soil types, *Type A* and *Type B* occupy small, ill-defined depressions usually in Lemnos loam and Goulburn loam occurrences. Unlike the other types in the sequence, they both have well developed bleached $A_2$ horizons. Type A otherwise is similar in colour and texture to Goulburn loam. Type B has a grey profile and appears to be identical with Congupna loam described in the Shepparton Irrigation Area (Skene and Freedman 1944).

*Types C, D, F* and *S* are only of minor and local importance.

## ZEERUST SEQUENCE.

This is a minor sequence peculiar to the south-central part of the North Shepparton Irrigation Area. The landscape is grey box woodland plain and the soils are dominantly grey. It is part of the prior stream topography, occurring in an expanse of mid- and far-flood plain where the riverine sediments are coarser than usual for these positions.

*Zeerust fine sandy loam* occupies imperceptible rises and *Gupna fine sandy loam* and *Gupna loam* low plain.

Zeerust fine sandy loam is a grey-brown soil with a bleached subsurface horizon and a mottled yellow-brown clay subsoil. The deep subsoil is variable, ranging usually from clay to sandy clay. Some profiles resemble Orrvale sandy loam, but, whereas Orrvale sandy loam occurs in low positions on the prior stream levees, Zeerust fine sandy loam occupies low rises on plain away from the levees.

Gupna fine sandy loam and Gupna loam are found on rather extensive low plain. The surface soils are grey and strongly bleached in the subsurface. The subsoils are yellow-grey medium clays which usually lighten somewhat in texture with depth.

## FLOODED CLAY PLAIN SEQUENCE.

The flooded clay plain adjoins the Goulburn River only in the northern part of the Rodney Irrigation Area. It is flanked on the far side by members of the prior stream toposequence, usually the levee soil types. Flooding has extended up to, and on to the near-flood plain and levee positions of the prior streams. This has imparted dull colours to the surface and subsoil, but not to the deep subsoil. In consequence, bright deep subsoil variants are common. In addition to the duller colours in the upper part of the profile, the soil types differ from their counterparts elsewhere in having thicker surface horizons and more gradual transitions between the surface and subsoil. Also, gypsum occurs irregularly in the heavier grey soils. The sequence of soil types is illustrated in Figure 4.

*Type J* is the highest member in the sequence. It corresponds texturally and in position to Shepparton fine sandy loam, but is distinguished mainly by a yellow, instead of a red-brown coloured subsoil.

*Type K* is included rather arbitrarily in this sequence. It is like Lemnos loam, but differs in the deep subsoil which is reddish brown instead of being mottled. It also differs in being more calcareous and more distinctly structured.

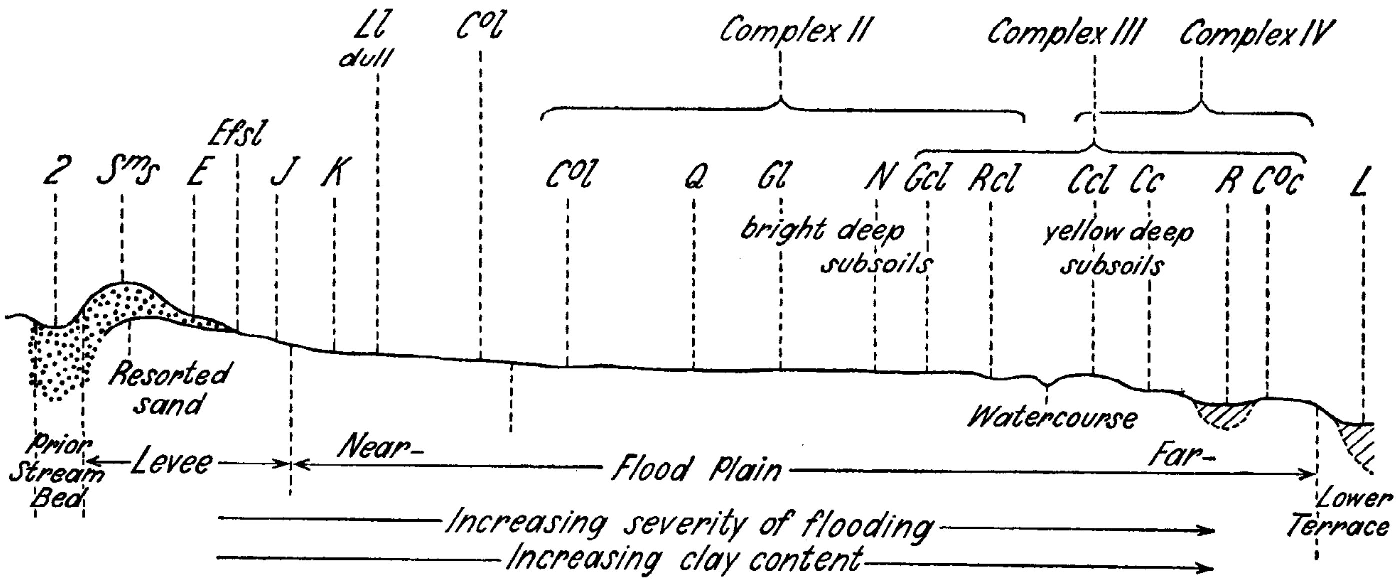


Fig. 4. Toposequence of soil types on the flooded clay plain landscape.

Ccl = Congupna clay loam ; Cc = Congupna clay ; Col = Coomboona loam ; Coc = Coomboona clay ; Efsl = East Shepparton fine sandy loam ; Gl = Goulburn loam ; Gcl = Goulburn clay loam ; Ll = Lemnos loam ; Rcl = Rooka clay loam ; Sms = Sandmount sand ; Types E, J, K, L, N, Q, R.

*Variants* of *Lemnos loam* and the *Goulburn* and *Congupna series* occur, and these soils are positionally related in the same manner as in the prior stream toposequence.

A further soil type, *Coomboona loam,* occupies intermediate, level situations similarly to Goulburn loam which it resembles in colour and texture; but it has a deeper surface, and a gradual instead of a sharp transition from the A to the B horizon.

*Type Q* is a minor soil type also associated with Goulburn loam in the landscape. It differs in the deep subsoil. Typically this is a reddish brown, calcareous clay instead of the mottled yellowish brown clay found in Goulburn loam.

*Type N,* a grey version of Type Q, occurs at slightly lower levels. It resembles Congupna clay loam in the upper part of the profile, but the deep subsoil is brownish instead of yellow-grey. It is also more calcareous.

The more definite depressions on the plain are occupied by *Congupna clay, Coomboona clay, Rooka clay loam* and *Type R.* These are all grey soils. The first two soil types have surface horizons less than 7 inches thick, but the transition to the B horizon is sharp in Congupna clay whereas it is gradual in Coomboona clay. Rooka clay loam and Type R have surface horizons more the 7 inches deep. In Type R, the surface depth varies from 18 to 36 inches.

*Type L* occurs on the lower terraces between the plain proper and the Goulburn River. It is distinguished by silty and undifferentiated mottled profiles at least 3 feet thick.

It has not been possible to delineate separately on the soil maps all the soil types found on the flooded clay plain. Three associations of soil types have been recognized and used as mapping units. The component soil types in these complexes are shown in Figure 4.

## YOUANMITE SEQUENCE.

In the north-east of the area, four soil types combine to form a toposequence on " brown high plain " which originally was wooded with grey box, buloke and Murray pine. This plain has no prior streams on it and it rises several feet above a conventional prior stream plain to the west. Superimposed drainage ways are also absent on the plain, and, apart from fairly frequent land-locked depressions, the land surface is almost level. The sequence of soil types is illustrated in Figure 5.

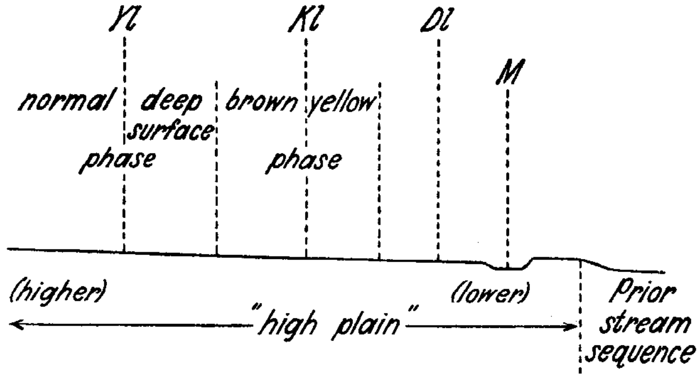


Fig. 5. Youanmite toposequence of soil types on the " high plain " landscape.

Dl = Dunbulb loam ; Kl = Katamatite loam ; Yl = Youanmite loam ; Type M.

A subplastic clay in the deep subsoil is characteristic of all the soils in the Youanmite sequence. This clay is very friable and breaks up into small, distinct, angular blocky peds with black flecks on the faces. Scattered surface buckshot, although variable, is a distinctive feature, since it is unusual to find iron concretions in brown surface soils in the Goulburn Valley, although they are common enough in grey soils.

There are two soil types with brown surface colours and each has two phases. Of these *Youanmite loam normal phase* resembles Lemnos loam, but differs in the features described above, and also in having a generally darker red and more friable clay in the subsoil. A deep surface phase is markedly thicker in the A horizon, averaging 12 inches instead of 5 inches as in the normal phase, and shows also a more gradual transition to the red-brown clay subsoil.

*Youanmite loam deep surface phase* grades into *Katamatite loam,* usually without any evidence showing in the topography. Both soils have the same thick surface and gradual transition to the subsoil clay, but the colour of the clay is normally brown or yellow-brown in Katamatite loam. In the *brown phase,* the subsoil is brown, or if reddish brown is less than 10 inches thick; whereas in the *yellow phase* it is yellow-brown or dull brown. Buckshot is also more plentiful in the yellow phase.

*Dunbulb loam* is a grey-brown soil occupying slightly lower postions than Katamatite loam. It has about 7 inches of surface which passes rather sharply to a yellowish brown clay subsoil. In this Dunbulb loam is similar to Goulburn loam, but differs in that its subsoil is more friable and its deep subsoil clay is subplastic.

The lowest member of the Youanmite sequence is *Type M* which occupies the well-marked land-locked depressions. It has a grey surface about 18 inches deep, strongly bleached in the sub-surface with much buckshot, and a mottled grey-yellow-brown clay subsoil which becomes subplastic in the deep subsoil.

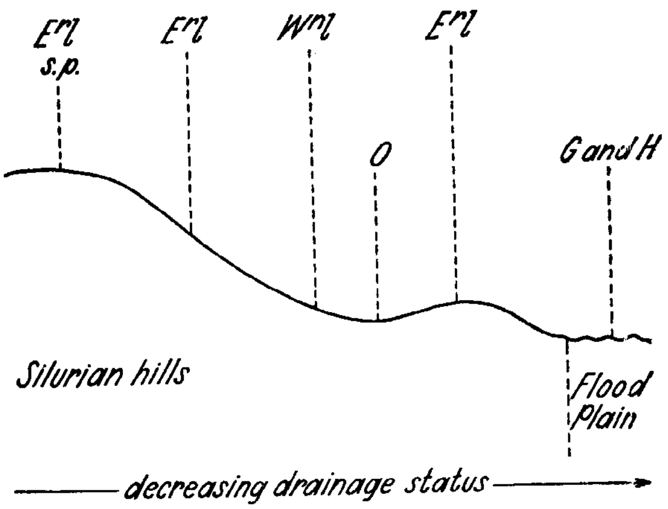


Fig. 6. Toposequence of soil types on the Silurian hill landscape.
Erl = Erwen loam ; Wnl = Wenora loam, Types G, H, O; s.p. = shallow phase.

## SILURIAN HILL SEQUENCE.

The soil types in this toposequence are found on the Silurian hills and adjacent plain in the southern part of the Rodney Irrigation Area. Figure 6 illustrates the usual topographic relationships.

*Erwen loam* is widespread on the crests and upper slopes of the Silurian hills, and even on the gentle lower slopes where these merge with the prior stream flood plain. It is a brown soil with a red-brown clay subsoil and is generally similar in the upper part of the profile to Lemnos loam. The main difference is in the presence of scattered, iron-impregnated fragments of the Silurian sandstone on the surface, and sometimes in the soil profile. The deep subsoil differs from that of Lemnos loam according to the depth to the Silurian rock beneath. Usually this is deeper than 6 feet, but on some of the crests of the hills it occurs *within* 30 inches. Here the soils belong to *Erwen loam shallow phase.*

*Wenora loam* is a grey-brown soil with a yellowish brown subsoil occurring on middle and lower slopes below Erwen loam. It may be compared with Goulburn loam, differing mainly in the presence of sandstone fragments.

The depression member of the hill sequence is *Type O,* although it sometimes replaces Wenora loam and Erwen loam on the higher parts of the hills. It has a grey, compact surface overlying grey-brown heavy clay, with sandstone fragments and buckshot conspicuous on the surface.

Strongly gilgaied soils occupy some sites on the flood plain adjacent to the hills. These are covered by *Type G* and *Type H.* The former has a grey, and the latter a brown profile.

## TREELESS PLAIN SEQUENCE.

While this toposequence is extensive further west, it is only a very minor part of the landscape within the surveyed area. The landscape is naturally devoid of trees, and there is but little alteration in surface relief. There are three soil types present forming a catena equivalent to the Lemnos-Goulburn-Congupna catena of the prior stream sequence. These soil types are *Koyuga clay loam* on the fractionally highest situations, *Koga clay loam* on intermediate levels and *Yuga clay* on low plain. Differences between the two catenas lie in the slightly heavier and shallower surface horizons, the somewhat darker, duller, and more intractable subsoil clays, and the occasional presence of gypsum in the deep subsoils of the treeless plain soil types.

### KAROOK SEQUENCE.

The three soil types in this toposequence are minor components of the present soil pattern, but are somewhat more extensive in the southern part of the adjoining Deakin Irrigation Area. There, the sequence occupies land between frequent swamps and carries a greybox-yellowbox-buloke woodland.

The soils range from brown to grey and are distinguished by a comparatively thick (9 to 18 inch) surface and an underlying gradational horizon. These horizons are noticeably friable and bleaching is absent. A more or less mottled subsoil clay is intractable when moist, but breaks up into distinct angular blocky peds when dry.

The three soil types comprise a catena equivalent to the Lemnos-Goulburn-Congupna toposequence. The equivalent soil types are respectively: *Karook loam,* a brown surface soil with red-brown subsoil found on low rises, *Arkoo loam,* a grey-brown soil with mottled yellowish brown subsoil occupying intermediate levels, and *Rooka clay loam,* a grey soil with mottled yellowish grey subsoil found in shallow depressions. The depth of surface and degree of friability decreases passing from Karook loam to Rooka clay loam.

No occurrences of the unbroken catena have been mapped in the present area. The soil types mostly occur in very small areas or in association with other soil types.

## 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.

A soil association is a grouping of adjoining soil types which occur in a pattern that is 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.

Ten soil associations have been recognized. Four of these coincide closely with four of the toposequences described in the section, "Landscape Relationships". Four other associations are contained mostly in one toposequence (*prior stream sequence*), while two others are mostly within another toposequence (*flooded clay plain sequence*). The areas of the individual soil associations are as follows:

| Soil Association. | Acres. |
|---|---|
| Congupna .. .. | 18,100 |
| Coomboona .. .. | 19,700 |
| Erwen .. .. | 9,900 |
| Goulburn .. .. | 103,800 |
| Katamatite .. .. | 16,700 |
| Koyuga .. .. | 2,900 |
| Lemnos .. .. | 217,500 |
| River Frontage .. .. | 16,900 |
| Shepparton .. .. | 137,600 |
| Zeerust .. .. | 14,700 |
| Total .. .. | 557,800 |

The soil associations are described below in terms of their dominant, subdominant and minor soil types. With two or three exceptions, each soil association has been given the name of its dominant soil type. The dominant soil type, together with co-dominant types where present, occupies at least two-thirds of any occurrence shown on the map.

### CONGUPNA ASSOCIATION.

The soils in the lower lying and generally poorly-drained parts are grouped together in this soil association. It takes in heavy textured soils and represents the soil pattern on the far-flood plain of the depositional landscape.

*Dominant soil types:—*

Congupna clay loam.
Congupna clay.

*Subdominant soil types:—*

Goulburn clay loam.
Goulburn loam.

Lemnos loam is a minor component, while near Stanhope some Rooka clay loam is included and in the South Shepparton Irrigation Area some Type S and river frontage soils.

This association is of comparatively small extent. West of the Gouburn River it is confined mainly to low-lying areas near the foothills. In general, it delineates areas needing special provision for surface drainage under irrigation. In consequence, this association defines areas either unsuitable for irrigation or suitable only for limited irrigation. It is used mainly for dry-land farming at present.

### COOMBOONA ASSOCIATION.

This soil association coincides with the *flooded clay plain sequence,* except that it excludes the lower terrace soils on the river frontage.

*Dominant soil types:—*

Goulburn loam } bright deep subsoil
Goulburn clay loam } variants.
Congupna clay loam } yellow subsoil variants
Congupna clay }

*Subdominant soil type:—*

Coomboona loam.

Minor soil types in this association are Lemnos loam, Coomboona clay, Types K, N, Q, R and a few minor occurrences of prior stream soils. These embrace Sandmount sand, East Shepparton fine sandy loam, Shepparton fine sandy loam and Type J.

The Coomboona association is confined to the northern part of the Rodney Irrigation Area along the Goulburn River. Lower areas are recurrently flooded, while water courses and drainage ways traversing the plain make it difficult to take irrigation water to some parts. The soils are used for the greater part for dry-farming, although some irrigation of annual and perennial pastures is practised successfully.

### ERWEN ASSOCIATION.

The Erwen association corresponds to the *Silurian hill sequence.*

*Dominant soil types:—*

Erwen loam, normal and shallow phases.

*Subdominant soil types:—*

Wenora loam.

Small areas of Goulburn clay loam, Congupna clay loam, Complex I. and Types G, H and O are minor components.

Nearly all of this association is above the present gravity irrigation supply system, consequently it is used exclusively for dry-farming. However, if water were available, much of the association would be suitable for irrigation of pastures.

### GOULBURN ASSOCIATION.

The heavier and less well drained soil types found on the mid-flood plain section of the *prior stream sequence* are grouped together in this soil association.

*Dominant soil types:—*

Goulburn loam.
Goulburn clay loam.

*Subdominant soil types:—*

Congupna clay.
Congupna clay loam.

In places the Congupna soil types approach co-dominance with the Goulburn soil types. Minor components are Lemnos loam, Shepparton fine sandy loam and Type A, and near Wyuna, Koga clay loam and Arkoo loam.

The Goulburn association is most extensive in the central parts of the North and South Shepparton Irrigation Areas. There are only small areas west of the Goulburn River. The soils are used for irrigated annual and perennial pastures and for dry-farming pursuits. A small part of the association is suitable for irrigation of a limited variety of fruit trees.

### KATAMATITE ASSOCIATION.

The Katamatite association is identical with the *Youanmite sequence* which occurs only on the "brown high plain" in the Dunbulbalane district. The land surface is almost level with some scattered depressions.

*Dominant soil type:—*

Katamatite loam.

*Subdominant soil types:—*

Youanmite loam.
Dunbulb loam.

Type M and Congupna clay are the minor types present.

Recently this association has been planted extensively to stone fruits, pears and perennial pastures. Elsewhere, the soils are used for cereal cropping and dry-land grazing.

### KOYUGA ASSOCIATION.

This association corresponds to the *treeless plain sequence.* It is of very small extent and is restricted to a few small areas in the north of the Tongala-Stanhope Irrigation Area.

*Dominant soil types:—*

Koyuga clay loam.
Koga clay loam.

*Subdominant soil types:—*

Yuga clay.
Goulburn clay loam.

A few small areas of Goulburn loam, Congupna clay loam and Congupna clay are present as minor components.

The soils are used for the greater part for dry farming, but some are under irrigated annual pasture.

### LEMNOS ASSOCIATION.

The Lemnos association ideally occupies the near-flood plain parts of the *prior stream sequence,* but it extends also on to the levees where these carry Lemnos loam. The land-surface varies from a very slightly undulating to a nearly level plain.

*Dominant soil type:—*

Lemnos loam.

*Subdominant soil types:—*

Goulburn loam.
Goulburn clay loam.
Shepparton fine sandy loam.

The subdominant soil types vary in importance. The Goulburn soil types often occupy comparatively large areas, and in some parts they assume co-dominance with Lemnos loam. Shepparton fine sandy loam may be absent or reduced to a minor component. In some parts where the soil pattern permits, prior stream bed soils have been included as a minor component. Other minor soil types are Congupna clay loam, Congupna clay and Types

A, B and F. Karook loam and Arkoo loam are minor constituents in the Wyuna and Stanhope areas. There are small areas of other soil types, but these are unimportant.

This is the main association and is particularly extensive west of the Goulburn River. A great deal of it is under irrigation, mainly for annual and perennial pastures, but it is also used extensively for stone fruits, pears, tomatoes and peas in the horticulturally developed areas. However, not all the soils are suitable for peaches and apricots and, in general, the association is regarded unfavourably for these fruit trees.

### SHEPPARTON ASSOCIATION.

The soil types occurring on the levee and near-flood plain parts of the *prior stream sequence* comprise this association. It occurs on very gently, but distinctly undulating to nearly level plain, and covers the highest and best drained situations on the depositional land surface.

*Dominant soil type:—*

Shepparton fine sandy loam.

*Subdominant soil types:—*

Lemnos loam.
East Shepparton fine sandy loam.
Prior stream bed soils: Types 1, 1h and 2.

East Shepparton fine sandy loam varies markedly in prominence. It is absent from some areas; occurs as a minor component in others; and in yet others may dominate the soil pattern.

The more important of the minor soil types are Sandmount sand and Type E. Sandmount sand assumes some importance in certain areas of the association, such as near Mooroopna, but generally it is absent, or only of very small extent. The Orrvale, Goulburn and Congupna series are sometimes present in small amounts. Various minor soil types found in specific localities are included where they intrude into the soil pattern. Such inclusions are small and unimportant.

The Shepparton association is important agriculturally since it defines the area most suitable for horticulture and vegetable growing, and, in particular, it points to the localities where soils suitable for growing stone fruits are to be found. Most of the association is taken up by the present horticultural districts around Ardmona, Tatura and Kyabram.

Practically all of the association is under irrigation, and where not given to fruit and vegetable growing is under dairy pastures.

### RIVER FRONTAGE.

This unit delineates all the areas subject to recurrent flooding along the Goulburn and Broken Rivers, although it also includes some higher land outside the flood protection banks in the north of the Rodney Irrigation Area.

*Dominant soil type:—*

Type L.

The soils have not been mapped in detail. Type L occurs on the extensive lower terrace adjoining the Goulburn River, but there may also be other soil types there. Where the unit includes remnants of the main plain, Sandmount sand, East Shepparton fine sandy loam, Shepparton fine sandy loam and the Goulburn and Congupna series are minor components. The unit also takes in transitional soils separating the lower terraces from the main plain.

Frequent flooding excludes most of the land from agriculture, the only pursuit being intermittent grazing of the natural ground cover. The original timber of river redgum is for the most part intact and much of the unit is reserved as State Forest. This supplies timber and firewood and some honey.

### ZEERUST ASSOCIATION.

This small association coincides with the *Zeerust sequence.* It occurs only in the south-central part of the North Shepparton Irrigation Area where it occupies mid- and far-flood plain positions in relation to the nearest recorded prior stream.

*Dominant soil types:—*

Gupna fine sandy loam.
Gupna loam.

*Subdominant soil types:—*

Zeerust fine sandy loam.
Goulburn loam.

Congupna clay loam and Congupna clay are minor components.

The soils are used satisfactorily for annual and perennial pastures in the irrigated parts, and for cereal cropping in the non-irrigated areas. The association does not appeal for horticulture because of the risk of flooding.

## CHEMICAL AND PHYSICAL PROPERTIES

Fifty-four representative profiles taken from the principal soil types have been examined in the laboratory. Their locations are shown by numbers on the soil maps. The analyses of a selection of 42 of these profiles are presented in Appendix I. This, therefore, provides a reference to the more important measurable characteristics of the principal soil types.

### PARTICLE SIZE DISTRIBUTION.

The prior stream soil types, except Sandmount sand and the associated Type E, are very fine textured, coarse sand being almost negligible in all horizons. Further, particle size distribution analyses not reported here show that most of the fine sand is less than 50 microns, i.e., it approaches silt in size. A little secondary coarse sand in the form of fine iron oxide concretions is present in some profiles of the more poorly drained soil types such as Goulburn clay loam and Congupna clay loam.

In Sandmount sand, the coarse sand to fine sand ratio is variable and no attempt has been made in the field work to separate dominantly coarse sandy soils from dominantly fine sandy soils.

While the soil types of the *Zeerust, Youanmite and Silurian hill sequences,* can be distinguished from the soil types of the *prior stream sequence* on the basis of a narrower coarse to fine sand ratio, nevertheless fine sand is always still very dominant over coarse sand in the former soils. Also, in these soils, fine iron oxide concretions contribute materially to the coarse sand fractions, particularly in the surface horizons.

The particle size data in Appendix I. illustrate well the clay pan nature of practically all the soil types. This characteristic, as well as the over-all texture profiles of the principal soil types, can be envisaged readily from the clay contents of a number of selected profiles presented in Table 2. Only Sandmount sand does not show a marked increase in clay content between the surface and subsoil.

The data in Table 2 have been arranged to 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. Two profiles of Shepparton fine sandy loam illustrate the range in texture in this soil type. Other illustrations of the textural ranges likely to be found in this and other soil types are given in the more complete data presented in Appendix I.

The $B_2C$ horizons represent the materials which, by eluviation of clay, have given rise to the textural A and B horizons above them. Illuvial calcium carbonate may be present in these $B_2C$ horizons, but sometimes may even be leached to slightly greater depths than those shown in Table 2. Except in the Erwen loam and Wenora loam profiles, unrelated depositional layers occur below the $B_2C$ horizons, but usually not immediately following the depths given in Table 2. Sometimes the material below the $B_2C$ is similar; in other cases, particularly in East Shepparton fine sandy loam and Shepparton fine sandy loam, the materials gradually become lighter in texture before resting on a dissimilar depositional layer. These points are evident from the analytical data for some of the profiles illustrated in Appendix I.

The very high clay contents of the subsoils of the soil types in the *Youanmite sequence* are worth noting. These are subplastic clays, and lower clay contents would be expected from field texture evaluations.

The fine grading of the non-clay fraction is a reason for the poor permeability of many of the surface soils under irrigation, unless countered by management practices to improve aggregation and macropore space. Also, this grading, coupled with high clay content, produces many subsoils of poor permeability. However, not all the clayey subsoils have poor permeability, presumably because of structural characteristics.

## CALCIUM CARBONATE.

Calcium carbonate is absent from the profiles of Sandmount sand and the Coomboona series illustrated in Appendix I. Amounts varying from a trace to moderate are present in all other profiles but generally the amounts are small.

TABLE 2.
Clay Content of Principal Soil Types.

| Soil Type | Profile No. | Surface | | Subsoil | | | |
|---|---|---|---|---|---|---|---|
| | | A horizon | | $B_1$ horizon | | $B_2C$ horizon | |
| | | Depth | Clay | Depth | Clay | Depth | Clay |
| | | in. | % | in. | % | in. | % |
| *Prior Stream Toposequence*— | | | | | | | |
| Sandmount sand | 2 | 0–40 | 10 | 40–49 | 19 | 49–84 | 15 |
| East Shepparton fine sandy loam | 26 | 0–7 | 10 | 7–22 | 38 | 22–29 | 21 |
| Shepparton fine sandy loam (*a*) | 43 | 0–8 | 10 | 8–19 | 48 | 19–24 | 34 |
| " " " " (*b*) | 9 | 0–7 | 20 | 7–16 | 56 | 16–23 | 40 |
| Lemnos loam | 8 | 0–5 | 23 | 5–21 | 50 | 21–33 | 47 |
| Goulburn loam | 7 | 0–4 | 27 | 4–20 | 63 | 20–29 | 58 |
| Congupna clay loam | 10 | 0–4 | 43 | 4–15 | 68 | 15–23 | 64 |
| *Zeerust Toposequence*— | | | | | | | |
| Zeerust fine sandy loam | 29 | 0–10 | 9 | 10–26 | 39 | 26–32 | 27 |
| Gupna fine sandy loam | 28 | 0–7 | 16 | 7–27 | 43 | 27–37 | 38 |
| *Youanmite Toposequence*— | | | | | | | |
| Youanmite loam | 21 | 0–4 | 25 | 11–31 | 68 | 31–44 | 68 |
| Katamatite loam | 20 | 0–10 | 27 | 16–37 | 74 | 37–54 | 63 |
| Dunbulb loam | 19 | 0–6 | 30 | 6–34 | 70 | 34–46 | 70 |
| *Silurian Hill Toposequence*— | | | | | | | |
| Erwen loam | 30 | 0–4 | 24 | 4–23 | 66 | 23–37 | 57 |
| Wenora loam | 54 | 0–5 | 25 | 5–20 | 62 | 20–32 | 56 |

In the prior stream soil types, traces or slight amounts of calcium carbonate are present from about 2 feet. The maximum concentration is usually at 30 to 36 inches and seldom exceeds 1 per cent. in the fine earth. A notable exception, however, is Lemnos loam profile No. 5 which has 8·6 per cent. at 18 to 27 inches. Concretionary calcium carbonate of gravel size may or may not be present in association with the carbonate in the fine earth. The greatest amount found was 8 per cent. in East Shepparton fine sandy loam profile No. 3, but more often the amount is less than 5 per cent.

Lime appears to have been leached rather more deeply in the Katamatite and Youanmite profiles. In these soil types, it does not occur until below 30 inches, with the maximum zone of accumulation below 3 feet. Appreciable concretionary calcium carbonate of gravel size may be present, e.g., 11 per cent. at 31 to 44 inches and 13 per cent. at 44 to 63 inches occurs in the Youanmite loam profile No. 21.

Moderately large amounts of calcium carbonate (about 8 per cent.) occur in the fine earth of the C horizons of both of the profiles of Erwen loam illustrated in Appendix I. Whether the carbonate originates from the underlying rock, or is evidence of parna deposition, has not been investigated.

The gilgai soils Type G and Type H which occur on the plain at the foot of Erwen loam are also calcareous. Both their puff components contain lime from the surface downwards while it is present in their depression components below 1 or 2 feet. The data suggest that the grey soil Type G is more leached of lime than Type H.

## pH.

Excepting the Coomboona series and some of the minor soil types, all the A horizons are slightly acid, with pH values mostly within the limits 6·2 to 6·8. The B horizons are variable. Generally they are slightly alkaline, mostly ranging from pH 7·3 to 7·7, but a few range up to pH 8·6 while others are slightly acid. These variations apparently bear no relationship to soil type. Deeper horizons are strongly alkaline, the pH values varying from about 8·4 to 9·6.

In the Coomboona series, the surface soils are either moderately or strongly acid. The subsoils gradually become less acid with depth and may be slightly alkaline below 2 feet.

Liming as a general practice is unnecessary on Goulburn Valley soils; the pH data substantiate this, except possibly on Coomboona loam. However, lime may be needed where use of sulphate of ammonia has lowered the pH excessively. This has happened in some horticultural situations.

## EXCHANGEABLE CATIONS.

The exchangeable calcium, magnesium, potassium and sodium in selected horizons of fourteen profiles are given in Appendix I. Exchangeable hydrogen has not been determined, but the pH values indicate that only the surface horizons, and a few of the subsoils, are likely to have any exchangeable hydrogen, and then only in small amount. Thus the surface soils are all slightly unsaturated and, with a few exceptions, the subsoils are 100 per cent. or more saturated (pH 7·0 reference).

The cation exchange capacity of the clay fraction is a guide to its mineralogy and, although cation exchange capacity has not been determined, the sum of the exchangeable metal ions in the subsoils of high pH might equally do to indicate broad differences in the constitution of the clay. There is insufficient data to make valid comparisons between the individual soil types, but some interest lies in differences between the materials of the *prior stream sequence* and those of the *Youanmite sequence*. Selecting twelve subsoils with pH values of 8·1 or more, it is found that, with one exception, nine of the horizons from the Shepparton, Lemnos, Goulburn and Congupna series have total exchangeable metal ion levels varying from 40 to 53 m.e. per 100 g. of clay, whereas the other three horizons from the Youanmite, Katamatite and Dunbulb series have values of 28 to 37 m.e. per 100 g. of clay. The former values are in line with those found in the same soil types in the Shepparton Irrigation Area (Skene and Freedman, 1944) and are of the usual order for mixed, but dominantly illite type, clay minerals. The exception referred to is the $B_1$ horizon (Sample No. 11339) in the Shepparton fine sandy loam profile No. 9 in which the exchangeable metal ions total only 31 m.e. per 100 g. of clay. There is no reason for this apparent discrepancy.

Although the data are rather meagre, it does seem that the cation exchange capacities of the clay colloids in the soils of the *Youanmite sequence* are somewhat lower than in the soils of the *prior stream sequence* and their mineralogy, therefore, is different. The subplasticity and crumbliness of these soils and the apparently higher iron oxide content also support this conclusion.

Calcium is nearly always the dominant exchangeable metal ion in the surface soils, averaging 52 per cent. of the total exchangeable metal ions in the fourteen profiles examined. In several instances magnesium is co-dominant with calcium, but on the average it is lower and represents about 32 per cent. of the exchangeable metal ions. About 13 per cent. of the total exchangeable metal ions is exchangeable potassium. Actual levels are fairly high, often exceeding 1·0 m.e. per 100 g. of soil. This is well above the deficiency level for pasture plants and fruit trees. Even in the light textured Sandmount sand, the surface soil has the good level of 0·9 m.e. per cent. Exchangeable sodium is low to very low in all of the surface soils except those from the Congupna clay loam profile No. 47 and the Erwen loam profile No. 30. In these two soils, sodium contributes 7 and 8 per cent. respectively, of the exchangeable metal ions, but the average for all the surface soils is only 3 per cent.

Compared with the surface soils, exchangeable calcium and potassium are lower and magnesium and sodium are higher in the $B_1$ horizons. In these, the average proportions of the exchangeable metal ions are, calcium, 38 per cent.; magnesium, 47 per cent.; potassium, 6 per cent.; and sodium, 9 per cent.

The main agricultural interest is in the exchangeable sodium percentage, as levels above 15 per cent. are considered to materially impair the physical properties of the soil. Such levels occur in the $B_1$ horizons of an East Shepparton fine sandy loam profile and in the Erwen loam profile, and are approached in a Congupna clay loam and a Lemnos loam profile. If Sandmount sand is excluded, it seems that high exchangeable sodium can occur in any of the $B_1$ horizons of the prior stream soils irrespective of soil type. But low exchangeable sodium in the $B_1$ horizons of the soil types in the Youanmite sequence may be characteristic, since these horizons in the Youanmite loam, Katamatite loam and Dunbulb loam profiles have 5 per cent. or less of the exchangeable metal ions as sodium.

In the $B_2C$ horizons of the prior stream soil types, exchangeable sodium increases still further, the values ranging from 11 to 23 per cent. and averaging 19 per cent. for seven horizons. By contrast in the Katamatite loam and Youanmite loam profiles, the values are 9 per cent. and 3 per cent. respectively.

## 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 0·09 to 0·16 per cent. in fourteen surface soils, averaging 0·12 per cent. In the same soils, organic carbon ranges from 1·06 to 2·32 per cent. and averages 1·43 per cent. The average carbon-nitrogen ratio is 12.

In eight $B_1$ horizons, total nitrogen varies from 0·04 to 0·08 per cent. (average 0·07 per cent.) and organic carbon from 0·28 to 1·06 per cent. (average 0·54 per cent.). The average carbon-nitrogen ratio is 8.

## SOLUBLE SALTS.

*Total Soluble Salts.*—Very low amounts, usually less than 0·03 per cent., are present in the surface soils. The highest amount recorded in a surface soil is 0·09 per cent. in Goulburn loam profile No. 53.

Slightly higher levels occur in the $B_1$ horizons, but these are usually less than 0·07 per cent. One exception is 0·46 per cent. in the 7 to 15-in. depth of East Shepparton profile No. 3.

While total salts are generally low throughout the whole profile, in a few cases concentrations reach 0·2 or 0·3 per cent. in the horizons below 2 feet.

The constituent cations and anions (except chloride) of the soluble salts have not been determined in view of the general low values and the dominance of sodium chloride.

*Sodium chloride.*—Chlorides have been estimated in all the profiles shown in Appendix I. and are reported as sodium chloride. Levels in general are low and parallel the total salt values, and, in most cases, sodium chloride comprises one-half to one-third of the total salts.

The distribution of salt in the soils of the area has also been investigated systematically in order to assess salinity hazards under irrigation. During the course of the field work about 15,000 soil samples were taken from this number of profiles and analysed for chloride content. The 3 to 4-ft. depth was selected for analysis as this is usually the zone of maximum salt concentration under the pertaining climatic conditions of the area. Redistribution of salt occurs, of course, under irrigation and where salinity was suspected samples from other depths were also taken.

The vast majority of the subsoils have less than 0·10 per cent. of sodium chloride, although there is a scattering of values in the 0·11 to 0·15 per cent. range. Remembering that much lower concentrations than these exist in the 0 to 3-ft. zone above, there is little risk of salinity troubles over most of the area with either irrigated pastures or fruit trees.

There is an erratic distribution of soils with subsoil salt contents in the 0·16 to 0·30 per cent. range. These soils would present definite hazards to fruit trees, but are mostly outside the developed horticultural areas. There is some risk to pastures on these soils if irrigation practices are faulty. While there are no clearly defined areas in this salt category, the more susceptible situations appear to be a small area east of Merrigum and along the Goulburn Waranga Main Channel in the south of the Rodney Irrigation Area, low areas between Wunghnu and Nathalia in the North Shepparton Irrigation Area, and in the south-east of the South Shepparton Irrigation Area.

Situations with more than 0·30 per cent. of sodium chloride in the subsoil occur only rarely.

## CLASSIFICATION AND FORMATION

*Great Soil Groups.*—The area lies in the red-brown earth zone originally defined by Prescott (1944) and more recently modified by Stephens (1961).

All soils on the well drained positions are typical red-brown earths (Stephens, 1956); examples, among others, are East Shepparton fine sandy loam, Shepparton fine sandy loam, Lemnos loam, Youanmite loam, Erwen loam. Downslope, as drainage becomes restricted, the soils lose their red-brown colouring and are commonly considered to be hydromorphic variants; examples are Goulburn loam, Arkoo loam, Wenora loam and others. The lowest, and poorly drained grey members seem out of place as hydromorphic red-brown earths and are sometimes thought of as grey soils of heavy texture. While the heaviest textured of these, Congupna clay, probably approximates to the morphology of a grey soil of heavy texture (Stephens, 1956), Congupna clay loam has a well developed A horizon which seems to exclude it from this great soil group. The $A_1$ and $A_2$ horizons are even more pronounced in Gupna fine sandy loam and this grey soil type seemingly remains a hydromorphic variant on present concepts of classification.

*Formation.*—The principal soil types except Sandmount sand are formed from fine textured parent materials. Practically all of the material is less than 50 microns and much of it is less than 2 microns. Some of the parent material is known to be riverine and some of it may be parna. But, irrespective of whether the depositions are riverine, aeolian or both they contain much clay. It is suggested that the various texture profiles illustrated in Appendix I. can be explained from the particle size data by eluviation of this parent clay, and that little clay formation by weathering of coarse particles *in situ* has taken place.

The presence of appreciable exchangeable sodium in the subsoils of the prior stream soil types (see "Chemical and Physical Properties") suggests that clay may have moved from the surface downward under the solonising influence of sodium ions. But the columnar solonetzic morphology of the $B_1$ horizon commonly attributed to sodium has not been found in these soils.

Less exchangeable sodium was found in the soils of the Youanmite sequence. These soils seem to be developed on an older land surface and, therefore, may be more leached, for not only is exchangeable sodium lower but so also are soluble salts and pH.

## 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 here.

The parishes covered by the soil maps, either wholly or in part, are: Arcadia, Barwo, Congupna, Drumanure, Dunbulbalane, Kaarimba, Karramomus, Katandra, Kialla, Mundoona, Narioka, Pine Lodge, Shepparton, Tallygaroopna, Waaia, Youanmite, in County Moira; Girgarre, Girgarre East, Koyuga, Kyabram East, Mooroopna, Mooroopna West, Murchison North, Taripta, Toolamba, Toolamba West, Tongala, Undera, Wyuna in County 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 a few of the soil 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 area surveyed is part of the Goulburn-Murray Irrigation District and includes the Rodney, Tongala-Stanhope, North Shepparton and South Shepparton Irrigation Areas. These are administrative divisions set up by the State Rivers and Water Supply Commission for the control and distribution of irrigation water. The general location of these Irrigation Areas is shown in Figure 2, but the actual boundaries are not shown on any of the maps. The situations of the adjoining Katandra, Shepparton, and Deakin Irrigation Areas are also shown in Figure 2.

*Settlement, Water Supply and Government Centres.*—Land settlement commenced when Edward Khull, James Cowper and Gregor McGregor "squatted" on the country along both sides of the Goulburn River in 1841. Cowper's "Ardpatrick", the largest run, covered nearly 400 square miles, or most of the present day Rodney Irrigation Area.

The subsequent history of the region is a story of progressive subdivision of the land holdings, with an increasingly intensive use of the land for agriculture. Wheatgrowing expanded and rivalled the raising of stock in importance after the gold boom passed. With the natural rainfall comparatively low, seasonal and irregular, the landholders early turned towards utilizing the water in the rivers passing through the region. A weir to provide water for stock and domestic purposes was constructed on the Broken River in 1882. Land was first irrigated on a sizeable scale at Ardmona near Mooroopna in 1886 by pumping from the Goulburn River. In 1892 the Goulburn Weir near Nagambie was completed. This supplied water by gravitation to the country on both sides of the Goulburn River, but the quantity of water it provided soon proved inadequate, and supplies were increased by the construction of the Waranga Reservoir between Rushworth and Murchison, the Eildon Reservoir, and finally the latter's enlargement in recent years. These structures now hold some 3,000,000 acre feet of water.

Water diverted at the Goulburn Weir reaches the North and South Shepparton Irrigation Areas via the East Goulburn Main Channel, and the Waranga Reservoir via the West Goulburn Main Channel. The two latter supply water to the Rodney and Tongala-Stanhope Irrigation Areas.

The State Rivers and Water Supply Commission administers the Irrigation Areas from district offices at Shepparton, Tatura and Tongala.

The four Areas total 507,814 acres* of which 320,000 acres is classified as irrigable. The area actually irrigated in 1959-60 was about 222,000 acres while the total amount of water delivered was 307,000 acre feet. By far the greatest part of this was used for the irrigation of pastures, both annual and perennial, with fruit trees, lucerne and vegetables in that order, the other crops requiring substantial amounts. Small areas of native pasture, cereals and summer fodder crops are irrigated. The acreages of the above crops irrigated in 1959-60 were:—

| | Acres. |
|---|---|
| Pastures—annual .. .. | 95,909 |
| perennial .. .. | 95,012 |
| native .. .. | 2,823 |
| Lucerne .. .. .. | 10,310 |
| Cereals .. .. .. | 2,540 |
| Summer fodder crops .. .. | 2,038 |
| Orchards .. .. .. | 10,835 |
| Market gardens .. .. | 2,311 |

The irrigated pasture lands support dairy cows, beef cattle, fat lambs and pigs, while the orchards produce a large proportion of the State's canned peaches, apricots and pears. Tomatoes and peas are important market garden crops.

It is somewhat surprising to find that about 280,000 acres in the statutory Irrigation Areas is not irrigable. This land is given either to wheat-growing combined with sheep, or to grazing sheep on the native and volunteer pastures.

The Department of Agriculture has two research stations within the area, the Horticultural Research Station at Tatura, and the Irrigation Research Station, Kyabram. These offer research and advisory services to orchardists, pastoralists and vegetable growers in the Goulburn and Murray Valleys. Other advisory officers are located at Shepparton and Numurkah.

*This and other statistics given in this section are taken from the 1959-60 Annual Report, State Rivers and Water Supply Commission.

## CLIMATE.

Average annual rainfall varies from 21·8 inches at Murchison in the south to 16·6 inches at Nathalia in the north. The isohyets shown in Figure 1 illustrate that the rainfall diminishes more nearly in a north-westerly direction. The average monthly rainfalls for Tatura which is fairly centrally situated are given in Table 3. These show that the winter rainfall is a little higher than the summer rainfall, 10·70 inches falling on the average in the period April to September and 7·54 inches in October to March.

TABLE 3.
Meteorological Data.

| Month | Rainfall | | Temperature | | | Evaporation |
|---|---|---|---|---|---|---|
| | 1956 | 60-year | 15-year | | | 15-year |
| | | | Max. | Min. | Mean | |
| | in. | in. | °F | °F | °F | in. |
| January .. | 3·25 | 1·19 | 85·4 | 57·2 | 71·3 | 9·25 |
| February .. | 0·25 | 1·01 | 82·8 | 57·9 | 70·3 | 7·24 |
| March .. | 6·71 | 1·26 | 78·8 | 53·8 | 66·3 | 5·84 |
| April .. | 4·25 | 1·48 | 69·4 | 47·6 | 58·5 | 3·64 |
| May .. | 5·01 | 1·65 | 62·2 | 43·1 | 52·7 | 2·21 |
| June .. | 2·83 | 2·26 | 56·8 | 39·8 | 48·3 | 1·49 |
| July .. | 4·05 | 1·82 | 55·2 | 38·9 | 47·0 | 1·36 |
| August .. | 1·94 | 1·85 | 58·0 | 39·8 | 48·9 | 2·04 |
| September | 2·05 | 1·64 | 64·0 | 42·9 | 53·4 | 3·08 |
| October .. | 3·84 | 1·71 | 68·7 | 46·5 | 57·6 | 4·36 |
| November.. | 2·07 | 1·18 | 74·5 | 49·9 | 62·2 | 6·12 |
| December.. | 0·08 | 1·19 | 81·5 | 54·1 | 67·8 | 8·25 |
| Year .. | 36·33 | 18·24 | 69·8 | 47·6 | 58·7 | 54·88 |

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.

Mean monthly rainfalls for the very wet year of 1956 are given in Table 3. These illustrate the severe conditions in the autumn and winter months responsible for the death of large numbers of orchard trees. In 1956, 22·85 inches of rain fell during the March-July period compared with an average of 9·06 inches.

Yearly evaporation exceeds the rainfall by 35·6 inches. June and July are the only months in which rainfall is higher than the evaporation.

## PHYSIOGRAPHY AND GEOLOGY.

All but a small part of the surveyed area is situated on the Riverine Plain of south-eastern Australia, a huge depositional plain extending over northern Victoria and southern New South Wales. This physiographic unit is in turn a component of the Murray-Darling basin. Although it covers much of the region popularly known as the Goulburn Valley it shows none of the features of stream erosion, such as watersheds, divides, converging drainage patterns, &c., which the name "Valley" implies.

The plain is flat with the monotony of the landscape broken by an occasional watercourse or swamp and by isolated low sandhills. Hills flank its southern margin, and it is traversed by the Goulburn and Broken Rivers, together with some smaller waterways. The main streams have cut themselves narrow, steepsided valleys, some 25 to 40 feet below the general level of the plain. The present streams are essentially " rivers of transit ", i.e., they carry mainly water from the mountain catchments to the Murray, and the plain itself normally contributes but little to their flow.

The area slopes very gently in a north-westerly direction towards the Murray River (Fig. 1). It ranges in elevation from 400 feet at Murchison in the south to 320 feet at Koyuga in the north-west. West of the Goulburn River the over-all fall of the land averages 2½ feet to the mile. East of the Goulburn, grades are more variable, ranging from 1 to more than 4 feet to the mile. The foregoing are average gradients; locally, slopes may depart considerably from these figures.

The Riverine Plain is built up of a considerable thickness of unconsolidated sediments of Tertiary and Quaternary age.

An elaborate braided system of non-functional or prior streams traverses the Plain. These streams have ceased to carry water and materials from the mountain catchment and their old courses are now largely filled. Usually they are recognizable features of the landscape, but in places they have been obliterated. Also, the present day streams sometimes occupy the old prior stream channels for short distances, although in general they follow separate courses. The pattern of prior streams in the surveyed area is shown on the Soil Association Map with this bulletin.

The exposed prior streams have been held responsible by Butler (1950) and others for most of the superficial deposits over the Riverine Plain. However, more recent thought led by Butler (1956) places the uppermost layer as aeolian over parts, but not all, of the Plain. He has proposed the names, parna for the aeolian material, and Widgelli for the extensive uppermost parna sheet. Butler describes parna as a more or less calcareous, clayey material originating during arid climatic periods from the erosion of soils formed on sand dunes to the west of the Riverine Plain. Moreover, there is a relationship between the particle size of the Widgelli parna and the distance leeward from the sand dune source (Butler and Hutton, 1956).

Bores to 32 feet put down by Skene and Freedman (1944) in the Shepparton Irrigation Area showed older riverine sands below the superficial prior stream alluvium. Interposed clay layers were regarded, in accordance with then current thought, as fine alluvium. Butler (1958) has studied such depositional systems and the soils formed on them, elsewhere on the Riverine Plain, and recognizes several layers each of parna and riverine alluvium. Widgelli parna has been mentioned above. Butler postulates riverine activity (Mayrung) immediately following the Widgelli parna phase and later still minor parna (Colongulac) and riverine (Coonambidgal) depositions. Riverine depositions (Quiamong), states Butler, occurred immediately preceding the Widgelli parna, and before the Quiamong both parna and riverine depositions during a Katandra phase.

The widespread occurrence of Widgelli parna reported by Butler and Hutton (1956) has suggested that it may mantle the present area. Actually Butler and Hutton show the southern limit of the Widgelli parna zone to transect the area; but there is no obvious reason for this separation. Widgelli parna is not visually distinguishable from riverine material, nor can it be identified at present by laboratory means. Thus, evidence for its presence is circumstantial, and as such the evidence needs to be examined most exhaustively before identifying parna in a riverine landscape. There is no question that widespread riverine sheets are present; channel deposits of sandy materials are visually recognizable, while outlying clayey sheets arising from companion clay are to be expected. This is original theory (Butler, 1950). It is tempting, but at this stage it would be speculative, to assign the layers observed during the course of the soil survey to the depositional phases described by Butler.

There are no discernible prior streams in an area of " high plain " in the Dunbulbalane district. This high plain is a distinct physiographic unit rising slightly above prior stream plains to the west.

The most recent alluvial deposits occur as comparatively narrow and discontinuous strips along the Goulburn and Broken Rivers. They represent a body of alluvium laid down in a valley previously cut by these streams into the older deposits. The alluvium has only partly refilled the valley, and near Murchison the recent terraces are about 10 feet below the general level of the plain. Going northward, this difference in height becomes progressively less, and the transition from recent terrace to older plain is often less distinct. In places, the younger alluvium may even extend as a thin irregular sheet on to the lower parts of the plain. This is described as flooded clay plain.

The hills fringing the southern part of the area are a maturely eroded part of the Eastern Australian Highlands, rising in most instances abruptly above the plain. They are composed of Silurian or late-Devonian sedimentary rocks, mostly fine grained sandstones and siltstones. Some higher remnants of this eroded land-surface also occur as outliers of various sizes on the plain. The largest of these is Mount Scobie on the western boundary of the area. Together, these outliers probably mark the divide separating the now buried parts of the drainage basins of the Goulburn and Campaspe Rivers.

Six geomorphic units have been mentioned above. These, and the soil toposequences that occur on them, described in the section "Landscape Relationships," are, (i) channel deposits of the prior stream systems; *Prior stream sequence,* (ii) clay plains, comprising broadly still-water deposits on the far-flood plain positions of the prior streams; *Prior stream, Karook, Treeless plain,* and *Zeerust sequences,* (iii) high plain; *Youanmite sequence,* (iv) Silurian hills; *Silurian hill sequence,* (v) flooded clay plain and (vi) river terraces; *flooded clay plain sequence.*

Additional minor features of the landscape are gilgaies, "pitted country" and water courses and water holes.

*Gilgaies or crabholes* are widespread on the heavier textured and lower lying soils in the area. They fall in Hallsworth's class of normal or round gilgaies (Hallsworth *et al.* 1955). They are well expressed on Types G and H, and on most of the heavy soils on the flooded clay plain. Mostly however, they are only moderately developed with a vertical interval of less than 6 inches, and with the puffs relatively widely spaced.

*Pitted country* is confined to the plain northwest of Murchison near the hills, where it is an irregularly occurring, but striking feature of the landscape. The ground surface is marked by distinct pits from 10 to 20 yards across, and from 1½ to 6 feet deep. The pits are quite distinct from gilgai depressions.

*Watercourses and waterholes* in the northern part of the Rodney Irrigation Area have been scoured into the ground surface by moving floodwaters. Some of these are quite large and deep, and in places they follow older prior stream courses.

A "plateau" some 3 miles long and averaging three-quarters of a mile in width should also be mentioned here. It extends northwards from the Silurian hills near the Waranga Reservoir and rises some 10 feet above the general level of the plain. It is separated by quite a sharp topographical boundary, and it could be the result of minor faulting in comparatively recent times.

## VEGETATION.

Most of the surveyed area originally carried a woodland tree cover. In the north-western part it takes in some grassland communities, while the land subject to flooding along the Goulburn River supports a grassy forest.

Grey box (*Eucalyptus hemiphloia*) is by far the most important tree in the woodland communities. Where it occurs with other trees, it nearly always dominates the tree stratum, and over large areas of the heavier soils it is the sole component.

Yellow box (*E. melliodora*) is a widespread subdominant, found commonly, but by no means only, on the higher situated, coarser textured soils such as Shepparton fine sandy loam and East Shepparton fine sandy loam. It has been irregularly noted on areas of Lemnos loam and occasionally even on Goulburn loam.

Buloke (*Casuarina Luehmanni*) is another widespread associate of grey box. With yellow box it also is a common component of the tree story on some of the coarser soils. It also occurs irregularly, but extensively, on the heavier Lemnos loam and Goulburn loam soil types. In some parts, as on the Silurian hills and on the soils of the Karook sequence, buloke becomes sufficiently prominent to form a distinct lower storey in the tree stratum. White ironbark (*E. leucoxylon*) occurs occasionally on the Silurian hills and on nearby heavy textured soils.

Murray pine (*Callitris columellaris*), with yellow and grey box and buloke, forms a distinct community. It is the only woodland community in which grey box may be reduced to a subdominant. It occurs on the coarser textured, best drained soils, viz., Shepparton fine sandy loam, East Shepparton fine sandy loam and Sandmount sand. Murray pine also is prominent on Katamatite loam and Youanmite loam on the high plain in the Dunbulbalane area.

White box (*E. albens*) is irregularly present as a sub- or co-dominant in the tree storey on the better drained soils (Shepparton fine sandy loam and Lemnos loam) in the country between Murchison and Toolamba.

The grassland or treeless plain areas were orgininally dominated by wallaby grasses (*Danthonia* sp.) and spear grasses (*Stipa* sp.). Grazing, burning off and cultivation have caused these to be largely replaced by various annual herbs and grasses.

The grassy forest along the Goulburn River comprises a tree storey composed exclusively of river redgum (*E. camaldulensis*). The ground cover consists of a well developed layer of grasses and sedges, mostly growing in tussocks.

Little remains of the original woodland, and this has been modified to varying degrees by logging, bushfires and grazing. The hills in the south-eastern part are still timbered to a considerable extent while some larger remnants also survive in the north near the Goulburn River. The redgum forest along the Goulburn River is still largely intact, partly because recurrent flooding prevents the land from being used for agriculture, and partly because certain sections have been kept as State Forest Reserves.

The present plant cover variously reflects the hand of man. About two-fifths of the area now receives water from irrigation in addition to the natural rainfall and carries sown pastures. These are annual pastures of subterranean clover (*Trifolium subterraneum*) Wimmera rye grass (*Lolium rigidum*), and perennial pastures usually based on perennial rye grass (*L. perenne*) and white clover (*T. repens*). Paspalum (*Paspalum dilatatum*), cocksfoot (*Dactylis glomerata*), lucerne (*Medicago sativa*) and strawberry clover (*T. fragiferum*) are other plants commonly, but less widely sown. Sorghum millet and saccaline are grown over small areas for summer fodder. A small, but most important proportion of the area is under orchards and vegetables. It amounts to about 13,600 acres, or 2 per cent. of the total area.

The non-irrigated land carries native or volunteer pastures, or it is cropped to cereals. The volunteer pasture comprises mostly annual grasses and herbs, and it varies considerably in composition with Capeweed (*Cryptostemma calendula*), barley grass (*Hordeum murinum*) and wild geranium (*Erodium* sp.) widespread components.

*The Plants as Soil Indicators*.—The relation of the various tree species to the soil types has already been indicated. In addition the following relationships have been noted:—

Well developed stands of black or common rush (*Juncus polyanthemus*) often indicate a transition from Lemnos or Shepparton soils to the Goulburn or Congupna series. Nardoo (*Marsilia drummondii*) grows only on heavy textured soils which are waterlogged in winter. Billy button (*Craspedia uniflora*) is a striking component of the native or volunteer plant cover on Congupna clay and Yuga clay, and sometimes on Koga clay loam and Goulburn clay loam. In common with nardoo, it reflects wet conditions, heavy textured soils and low salt content. Wild peppercress (*Lepidium hyssopifolium*) is prominent in native pasture on the higher, well drained, soil types, Shepparton fine sandy loam and East Shepparton fine sandy loam.

It is emphasized that the presence of a single tree or other plant does not by itself indicate a particular soil type or soil condition. Its relative prominence in a plant community, and the other plants with which it is associated are equally important. The foregoing has also indicated that some plants are much more specific in their soil requirements than others.

*Weeds*.—Many weeds, some proclaimed noxious weeds, are found in the area. Of these the black rush (*Juncus polyanthemus*) is the most widely spread. It competes with and often displaces sown pasture species in lower and wetter situations. Bathurst burr (*Xanthium spinosum*) with heliotrope weed (*Heliotropium europeaum*) and skeleton weed (*Chlondrilla juncea*) are common in the Dunbulbalane area. Poor management will allow cabbage or variegated thistle (*Silybum marianum*) to establish in dense stands, particularly on the well drained Shepparton fine sandy loam and East Shepparton fine sandy loam. Saffron thistle (*Carthamus lanatus*) is prominent in some areas on the heavier textured soils, while spear thistle (*Cirsium vulgare*) is widely found with docks (*Rumex* sp.) as a minor component in irrigated pastures.

Patterson's curse or Salvation Jane (*Echium plantagineum*) and wild Mignonette (*Reseda luteola*) are less important weeds occurring scattered along the road sides. Tomato weed (*Physalis viscosa*) is widespread in the eastern part of the North Shepparton area, while horehound (*Marrubium vulgare*), wild sage (*Salvia verbenaca*) and Noogoora burr (*Xanthium pungens*) occur along the Goulburn River.

Of the several weeds in the irrigation and drainage channels, the most spectacular is Cumbungi (*Typha* sp.) because of the dense, tall stands it forms. The most difficult to control, and therefore the most serious threat to efficient water distribution is water couch (*Paspalum distichum*).

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