Department of Agriculture, Victoria, Australia

PEDOLOGY OF THE GOULBURN VALLEY AREA, VICTORIA

PART 1 – STRATIGRAPHY OF LAYERS
PART 2 – APPLICATION IN IRRIGATED HORTICULTUR

By

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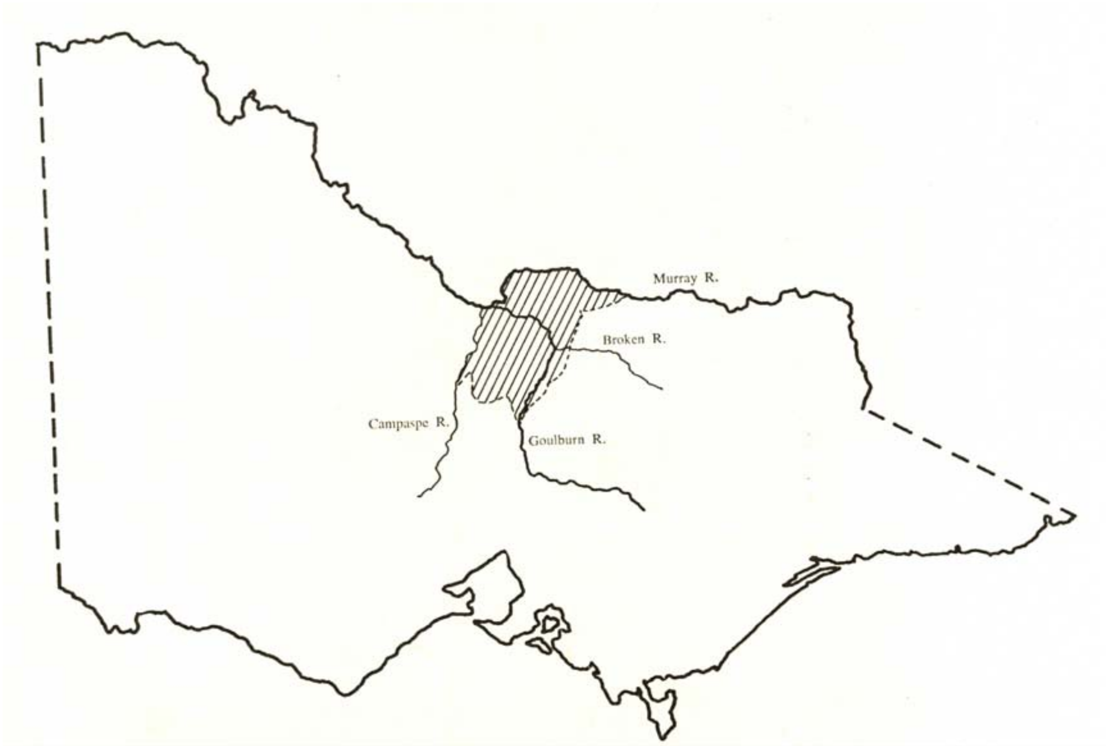
CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

Fig 1 – Locality plan of the area dealt with in this bulletin



Pedology of the Goulburn Valley Area

By B Cockroft

PART 1 STRATIGRAPHY OF LAYERS

A systematic study has been made of the depositional systems in the Goulburn Valley area of Northern Victoria in relation to soils and their problems under irrigated horticulture. The area is bounded by the Murray and Campaspe Rivers to the north and west and the main irrigation channels to the south and east (Figure 1). The area is portion of the Riverine Plain of South-Eastern Australia (Butler 1950), which has been built up from the deposition of sediments of Tertiary and Quaternary age. Most of the area is irrigated. Soil surveys have been published for practically the whole of this area (Penman 1936; Butler et al. 1942; Skene and Freedman 1944; Johnston 1952; Skene and Poutsma 1962; Skene 1963). The soils themselves are red-brown earths and their hydromorphic variants.

The soil materials are predominantly alluvial, and wide variations can be expected both laterally and in depth. The pattern of deposition has been studied mainly by bore traverses. However information was also obtained from logs of deep bores, river cuttings as deep as 60 feet, sewerage trenches as deep as 40 feet, and from commercial quarries. Of particular use in studying lateral trends has been the construction of large irrigation channels.

In these studies undisturbed material was used and patterns of variation of several properties were noted. These included mechanical composition, consistence, calcareousness, colour and mottling and most important of all degree of pedologic organisation as described by Butler (1958).

By organisation is meant the alteration of the parent material caused by its exposure as a ground surface and reflected as segregation of its constituents. There are a variety of clues but the best single criterion for degree of organisation is the size of structural units coated with glossy clay skins. The greater the degree of organisation the smaller these units are.

The Goulburn Valley area can be divided into four districts- Rodney, Shepparton, Cobram-Numurkah and Dunbulbalane-on the basis of systems of deposition peculiar to each.

Rodney

This district includes the northern part of County Rodney and is bounded by the Goulburn and Campaspe Rivers and the hills in the south, Figure 2, (in envelope at back of this bulletin). In the south there are a few outcrops of bedrock, but generally the surface conforms to a flat alluvial plain with an average gradient of 2 ½ feet per mile towards the northwest. The area has been built up from deposits from a number of prior streams as described by Skene (1963) and Skene and Poutsma (1962). Most of these prior streams have their source in the catchment of the present Goulburn River and are called Goulburn prior streams here; in the west are a few small Campaspe prior streams. The location of the major prior streams is shown diagrammatically in Figure 2, and details are given in the soil survey publications.

Prior Streams.

Transects of prior streams indicate a characteristic pattern as shown in Figure 3, (overleaf) which represents a section just east of the township of Tatura. The prior stream topography consists of an elevated ridge one mile wide flanked by a flood plain. These are called river ridges by Churchward (1958) and within them the streambeds and levees follow a braided meandering course.

As in the typical riverine situation, the deposits near the streams are the coarsest, and the soils here are referred to as the Shepparton association by Skene and Poutsma (1962). The surface soil is a brown loam or fine sandy loam with a high fine sand and silt content and very low in coarse sand. The B-horizon comes in sharply at 7 inches and continues to 24 inches as a red-brown medium. Clay containing up to 80 per cent silt plus clay. It is plastic and massive with a few visible pores and a low permeability to water. This is underlain to depths as great as 40 feet by an assortment of sandy, silty and clayey riverine deposits, which are highly micaceous. These are grey-white and yellow, and very often mottled. They are unweathered with no sign of clay skins, and are soft, and except for the very finest deposits are porous and more permeable than organised materials of the same mechanical composition. The sand is nearly always in lenses and is sometimes cross-bedded. The other materials show little stratification although they are usually coarser near the bottom, often becoming gravelly. Lime is always present as concretions and soft material within 3 feet of the soil surface. Below this, lime is absent.

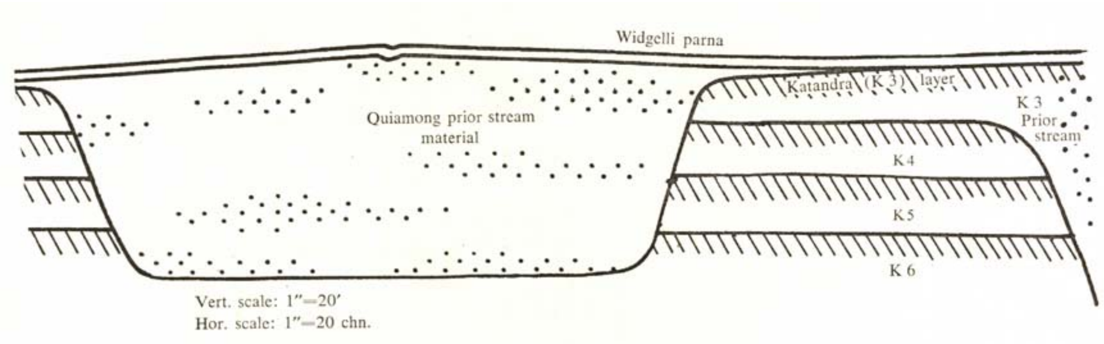


Fig 3 – Cross section of prior stream near Tatura

Flood Plain.

The soils on the near flood plain differ from those on the prior stream in that they are heavier with lower permeability's in all horizons; furthermore they have shallower surface soils, with duller colours and shallower leaching of lime. These are soils of the Lemnos association of the soil survey. Within a few feet however, there is a sudden change to a highly organised clay, usually grey in colour with heavy clay skins deposited on all ped faces. This organised material is very dense, firm, and with practically no visible pores. It has a very low permeability to water. The degree of organisation gradually decreases after 2 or 3 feet, and the underlying sediments in some places become sandy. In fact the sediments take on the conformation of prior streams, although so deeply buried that they have no influence on surface features. One of these buried prior streams is shown in Figure 3, and an example can be found on the northern boundary of Allotment 46, Parish of Toolamba. The organised clay, on being traced laterally, gives way in places to sandy material in the upper part of the buried prior streams. This sandy material feels firm and has clay skins coating individual sand grains and tending to block the pores between them; this has a lower permeability than the sandy prior stream material of the same mechanical composition described earlier. This type of fabric changes with depth to normal sands, and represents the organisation of sandy materials.

On the flood plain the soils are largely of the Lemnos association but differ from the Lemnos soils on the near flood plain in that the weathered material normally comes in at 2 feet. Where drainage is poor the soils belong to the Goulburn and Congupna associations. Here the surface soil is a shallow, grey loam with buckshot. There is some tendency to friability resulting in a higher infiltration rate than in the Lemnos. The subsoil is a yellow-brown medium or heavy clay, plastic, with a low permeability to water. Lime is usually deeper than 24 inches but can be shallower in very low situations.

Examination to a depth of 60 feet or so anywhere outside the prior stream courses reveals a whole series of layers each up to 15 feet thick. Each layer is highly organised decreasing with depth. The second buried layer is usually red and grey mottled clay with grey and white colours in the lower part. The third buried layer is not found in all situations; it is grey and white, mottled and is usually clayey. The next buried layer is usually brightly coloured, often stratified, and varies from clay to gravel. It is extremely organised, cemented, and the sand and gravel are rocklike; in fact it is so hard that it is highly resistant to erosion by the presents streams. These layers are exposed at many places by the present rivers especially the Goulburn, and all of those shown in Figure 3 can be seen in the Murray River cutting 3 ½ miles east of the Echuca Post Office, and the Campaspe River cutting at Runnymede near Elmore.

Interpretation of Depositional Systems in Rodney

An interpretation of these observations can be made in the light of work done by Butler (1950), 1958), and Butler and Hutton (1956). The surface features and the pattern of sedimentation in depth indicate a riverine situation and the riverine pattern dominates. However the top 2 feet cannot be a riverine material. Firstly, the depth of soil profile is uniform over the whole of the Rodney area, whereas riverine deposits thin out rapidly with distance from the parent stream. Also unlike riverine deposits clay content shows no trend with distance from the edge of the prior stream-that is, outside the areas of sand dilution. Its composition as a whole does not suggest a riverine origin because (a) it is clay while the riverine material below is often sandy, (b) it contains no coarse sand while the riverine does and (c) it is calcareous while the riverine is not. In addition, this same material blankets elevated situations out of reach of riverine deposition such as the low hills of non-calcareous sedimentary rock within the area, the 'plateau' near Tatura (Skene and Poutsma 1962), the levees of the older buried prior streams where they are evident at the surface, and the fault scarp between Echuca and Rochester (Harris 1938). In the three latter cases it is underlain by organized clay. These problems are solved if we interpret the top 2 feet as being Widgelli parna (L2) (Butler and Hutton 1956) and this interpretation will be used in this paper (Table 1). Most of the characteristics referred to are evident in the description and analyses given in the published soil surveys of the area (Skene and Poutsma 1962), and can readily be seen in the new No.6 main irrigation channel which cuts right across the area. Thus the whole Rodney area consists of prior stream deposits blanketed by the Widgelli parna, which has developed into a soil with a fine sandy loam to clay loam surface and a medium clay B horizon to 24 inches. These deposits are the Shepparton, Lemnos, Goulburn and Congupna associations described earlier.

The prior stream beneath the parna is the Quiamong (K2) of Butler (1958) because it underlies the Widgelli as an unweathered riverine layer; most of the prior streams in Rodney are Quiamong. According to Butler (1958) the prior stream form is a result of river incision and refilling. All these prior streams have aggraded to a higher level than old land surface, depositing sediments outside the incision and over the old land surface, becoming thinner with distance from the stream. On the east of the prior streams there has been some mixing of riverine sand with the parna.

Table 1 – Names of Depositional Systems

K Layer	Name	Material	Occurrence (District)
K1	Coonambidgal	Riverine	All (along present streams)
K2	Mayrung Widgelli Quiamong	Riverine Parna Riverine	Shepparton Rodney, Cobram-Numurkah Rodney, Shepparton
K3	Katandra (Marungi)	Riverine & parna Parna	All Dunbulbalane
K4		Riverine & parna	All
K5		Riverine & parna	All
K6		Riverine & parna	All

Section within a Shepparton prior stream, some 15 feet deep

Section within a Shepparton prior stream showing cross-bedded gravel. This picture shows 2 feet of section.

Stratigraphy of Layers

The sandhills of the area are all associated with the Quiamong streams and contain little parna, presumably because of the activity of the sand surface during the parna deposition. This sand overlies a variety of substrates. Where it rests on the normally organised Widgelli, shifting of the sand must have occurred in recent times. In some places the sand rests directly on other clay layers. However, the sand usually lies on and is often continuous with coarse sediments of the prior streams.

Depositional Systems below K2

These include the first organised layer below the surface and all deeper deposits. The first highly organised layer beneath the Widgelli is the Katandra as defined by Butler (1958), and is K3 in age. It is a separate depositional system belonging to an older cycle than the K2, because the K2 soil materials above it vary independently of it in the lateral plane. Furthermore, the buried material is organised to a depth of several feet. An essential feature in this regard is the systematic vertical variation in the degree of organisation which initially increases and then decreases with depth in each entire buried soil. It seems that at least in some areas the Katandra is in part a parna layer for similar reasons to those used in identifying the Widgelli. The buried prior streams described earlier underlying the highly organised surface are K3. These can be recognised in several places in the Rodney area, the best example being immediately south-east of Echuca-for example, in Allotment 45, Parish of Echuca North, 2 miles from Echuca on the Murray Valley Highway. These Katandra prior streams are not shown in Figure 2 or in the soil survey because either they are not evident at the surface or at best they appear as shallow depressions with subdued levees, heavy soils, and organised material; coming in at two feet.

The buried layer beneath the Katandra is also a separate entity for similar reasons and is designated K4. The next layer will be tentatively designated K5. However there is some doubt as to its separateness because it has not been shown to be independent of the overlying material and because the organisation is unlike that of the other layers.

The final layer studied is designated K6, using similar reasoning to that for the younger materials.

Shepparton

This is the area bounded by the Goulburn and Murray Rivers in the south and west, the broken Creek in the north and the main irrigation channel to the east. It does not include a small area in the Parishes of Dunbulbalane and Katandra which will be discussed later. The soils have been described by Skene and Freedman (1944) and Skene and Poutsma (1962). The Shepparton district is best divided into three on the basis of depositional systems.

East Shepparton

The orcharding area east of Shepparton consists of a number of prior streams in a fan-shaped pattern as described by Skene and Freedman (1944). These can be traced to the catchment area of the Broken river and will be called the Broken prior streams. The topography of this area is flat, with a general fall to the north-west and west. The prior stream courses appear as ill-defined ridges with no evidence of the bed and levee formation as described for Rodney. The soils here tend to have a much higher proportion of sand and gravel than those in Rodney. They are red-brown earths and their hydromorphic variants. The incisions are never more that a few chains wide and are rarely deeper than 20 feet. In this area deposits are complex and it is often difficult to distinguish the prior streams. A cross section (figure 4, overleaf) shows an incision refilled with clays, silts, and fine sands, with odd patches of coarse sand.

Within this is a narrow course usually of sand and gravel which follows the finer material.

The finer refill material is not however confined to the incision, but often extends out into a braided course. The coarse materials break out into broader deposits in many places and can be cemented into gravelly pans. The lime content of these soils is very variable. On the associations map of Skene and Freedman (1944), the material outside the prior stream is shown as Congupna Goulburn, the finer refill in the prior streams as Shepparton, and the coarse refill as Broken. The Broken association is dominated by permeable soils with deep sandy A horizons, and B horizons containing little clay, overlying stratified coarse sands and gravels. Soils of the Shepparton association have up to 10 inches of loam or sandy loam surface soil which is highly permeable to water; the B horizon is a red-brown medium clay, massive, and slowly permeable to water. The textures lighten after 30 inches. Soils of the Goulburn and Congupna associations are similar to those described for Rodney, except that the surface soils tend to be deeper and with more coarse sand.

The following interpretation is placed on these materials. The Widgelli parna has its easterly limit near the city of Shepparton, in that the parna sheet becomes discontinuous and gradually peters out thus forming an indefinite boundary. Outside the prior streams the material comprises the K2 flood plain overlying the Katandra at 8 to 10 feet. Th refill material is K2 and there is no way of distinguishing whether it is Mayrung (Butler 1958), or Quiamong because the sporadic occurrence of Widgelli parna in this area makes it impossible to demonstrate the relationships involved.

It seems likely that the cemented materials are K3 deposits.

Deposition at East Shepparton is different to other areas in that the prior stream breaks up into a closely knit system of distributaries which end within a few miles. This results in a complex depositional pattern in which levees do not form and gravel is concentrated. This can be explained in terms of a barrier imposed by the prior stream river ridge of the Goulburn to the west and the Murray to the north. This is simply an effect of the relative sizes of the smaller Broken. The barrier effect has presumably occurred in earlier systems of deposition as well, so that the deeper sediment at East Shepparton may also be very different from those elsewhere.

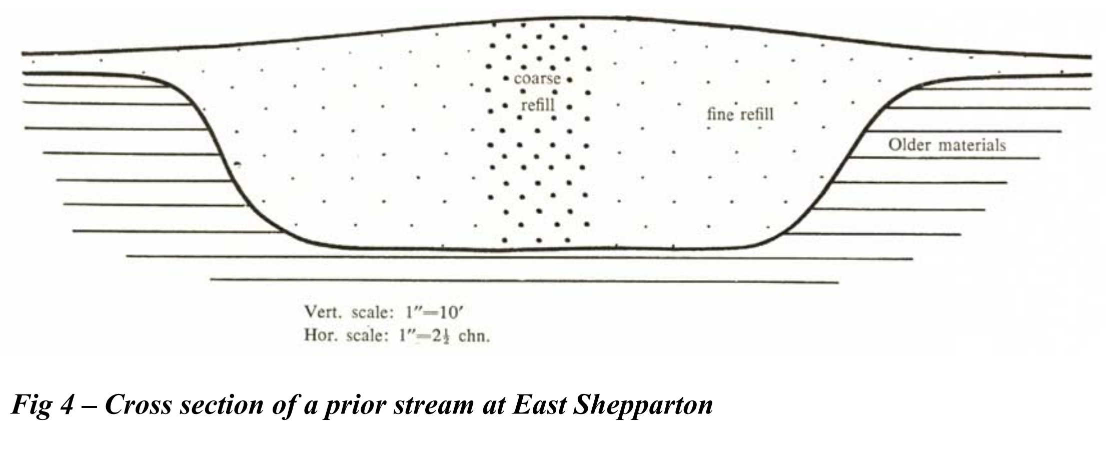


Fig 4 – Cross section of a prior stream at East Shepparton

Congupna-Numurkah

Between Shepparton and Numurkah is a large area with flat topography enclosed by hills to the east and river ridges on all other sides. Through drainage is restricted. Immediately north of Shepparton the soils are medium textured and belong to the Zeerust association of Skene and Poutsma (1962).

These have 10 inches of grey-brown loam or fine sandy loam surface soil including a well developed A2. The B Horizon is a yellow-grey light to medium clay, is usually plastic, and is slowly permeable to water. Below this textures become lighter. The materials here have the incision-refill pattern of the prior stream while retaining the flat surface. The rest of the area consists of heavy soils belonging to the Goulburn and Congupna associations as previously described. Little lime is found in any of these materials.

All prior streams entering the area are of Broken origin and probably K2 in age, but are difficult to trace. The finer fractions have been deposited further out on the flood plain. The drainage situation has resulted in the termination of the prior streams, and produced the flat contours, masking the prior streams, heavy soils and the grey colours.

Nathalia

The river ridge running from immediately north of Shepparton through Nathalia to Barmah is of the type found in Rodney, but is generally wider with a larger meander pattern and bigger stream channel and levees, coarser sediments, and many more sandhills. The channel beds themselves are usually quite sandy. The soils belong to the Shepparton and Lemnos associations, but here they contain only small amounts of lime. Where the river ridge swings westward it occupies a small part of the Cobram-Numurkah area; here the soils are described as the Barwon association (Johnston 1952), and the surface soils tend to be silty with compact clay B horizons and little or no lime.

It seems likely that this prior stream belongs to a different system to those in Rodney. It may in fact be the Mayrung of the Goulburn system. The present Goulburn River has incised into the remains in the bed of the prior stream to a point a few miles north of Shepparton where it swings away. In this way the earlier part of the prior stream course has been obliterated. The prior stream has been deflected west near Nathalia by prior stream deposits of the Murray. This stream is suggested as Mayrung because the surface materials are not like Widgelli parna which occurs on either side in the vicinity of Nathalia and further west. Therefore it presumably post dates the Widgelli.

The area between the present Goulburn river and the Goulburn prior stream just referred to is low lying, is subject to flooding, and is not suitable for irrigated agriculture. It consists of a complex of prior streams the surface evidence of which has been affaced by more recent flooding. The gravel pits at Kotupna are at least K3 in age as evidenced by the fabric of the deposits.

COBRAM-NUMURKAH

The area is bounded by the Murray River in the north and west and the Broken Creek in the south, and is the “raised flood plain of the Murray” described by Gregory (1912). The whole area slopes to the west with an average slope of 2 feet per mile. The soils are mainly red-brown earths and their hydromorphic variants, and are described by Butler et al. (1942) and Johnston (1952).

Plate 1 – K3 clay (buried) showing heavy clay skin, and absence of visible pores (x6).

Plate 2 – K2 silty clay (subsoil) showing matt face and visible pores (x6).

Plate 3 – K2 silty clay (subsoil) showing almost vesicular nature of this highly permeable material (x6).

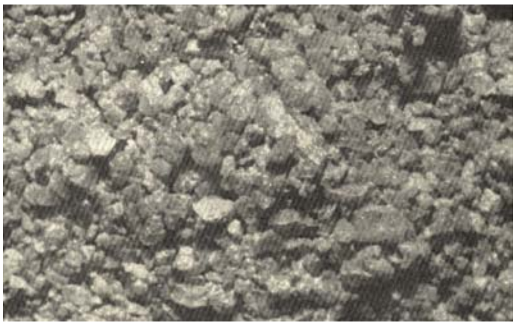


Plate 4 – K3 sand (subsoil) showing coatings of clay around all sand grains and clay bridges between sand grains (x 6).

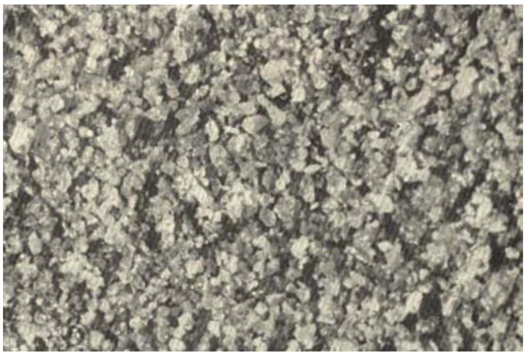


Plate 5 – K2 sand (subsoil) showing absence of clay coatings and bridges between sand grains. (x6).

The prior streams cross from New South Wales at Cobram and separate into a number of distributaries in a fan-shaped pattern as shown in figure 2. These have the same general features as the prior streams in Rodney, but differ in that they are bigger with sediments that are coarser, and have a greater depth and intensity of organisation. In fact where the prior stream material is clayey in the upper part, its organisation matches that of the Katandra surface. The soils of the prior streams include the Sandmount, Katunga and Cobram associations.

The Sandmount association comprises deep sands with a slight concentration of red-brown clay after four feet as coatings on and bridges between the sand grains. These soils are generally highly permeable although in the shallow phase water movement in the deep subsoil is sometimes restricted. These soils occur as sandhills which are very common around Cobram, but decrease in size and number with distance westward. In the Katunga association the surface soils are sandy loams and gravelly loams, but are liable to disperse during irrigation and cause water penetration problems. The B horizon is a red-brown light to medium clay. It usually underlain by a cemented gravelly a hardpan that is often slowly permeable to water and restricts root growth. The Cobram association is very similar to the Shepparton, the main difference being that the Cobram soils can be cemented in the subsoil.

Immediately west of Cobram are two prior streams that are at a lower level than the others and whose soils are greyer, more silty, and with little or no lime; these are the soils of the Koonoomoo association.

Outside the prior streams are the soils of the Moira, Boosey and Ulupna associations, and these parallel the Lemnos, Goulburn and Congupna associations respectively in Rodney. The pedological situation in the Cobram-Numurkah area is best interpreted as K3 prior stream with an overlay of Widgelli parna. The K3 age of the prior streams can be established from the fact that the highly organised Katandra layer of the flood plain is found in traverses to be continuous with the prior stream material. In addition, as expected, the K4 land surface which occurs at 15 feet on the flood plain is found to be incised by these prior streams. Further evidence of the K3 age of these prior streams is the high degree of organisation of the materials in them compared with those in Rodney and Shepparton This takes the form of cementation in gravelly materials, clay coating and bridges in sands, thick clay skins enveloping large peds in the fine sands, and glossy clay skins coating all ped faces in the clays. See plates numbers 1 to 5 for soil microphotos. Near Nathalia these prior streams are incised by, and overlain with, deposits of the K2 Goulburn prior stream immediately to the south. This is evidence of the greater age of the Cobram-Numurkah streams.

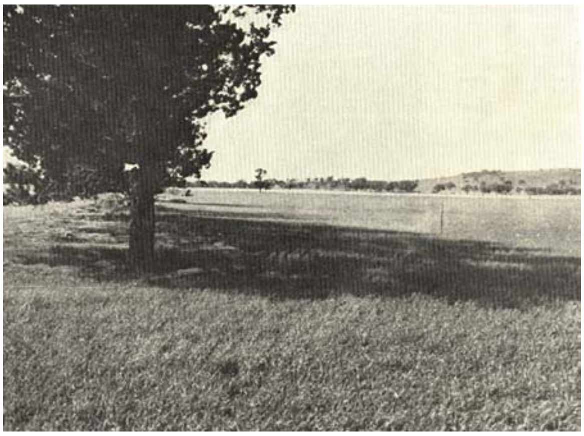
That Widgelli parna is blanketing the area is suggested by similar reasoning to that used in Rodney. In addition, if it is assumed that these prior streams are K3 in age, then the top 2 feet of soil material must be derived from the Wigelli parna because it is topographically out of reach of K2 riverine deposition but has the weathering associated with K2 surfaces. The presence of gravel at the surface in odd ares may be due to a net reduction in deposition of the parna on the originally loose gravelly surface or perhaps due to leaching of the parna down into the gravel.

The prior streams close to the Murray River immediately west of Cobram are probably Mayrung. This follows from the fact that the material from these prior streams overlies the Katandra ground surface, and that the profile development is typical of the K2. The decrease in average particle size with distance from the stream and the absence of lime further suggests that the surface material is not Widgelli but is probably Mayrung.

Dunbulbalane

This area is shown in Figure 2 and, although only small, is of considerable theoretical interest because of its differences from the rest of the Goulburn Valley, and because of the possibility of an extension of this area for irrigation.

The type of soil found here extends over large distances in the more elevated country outside the irrigation districts. The area is flat with occasional clayey depressions and the general slope is to the north-west.



Suitable orchard land near the hills of Dunbulbalane.

In the soil survey of the area (Butler et al. 1942; Skene and Poutsma 1962), the soils are described as red-brown earths and belong to the Katamatite soil association. These are uniform in mechanical composition both in depth and laterally. The surface soil is loamy with very little coarse sand, usually contains buckshot, and has a high infiltration rate. At 9 inches the grades this grades into a red-brown medium clay that is friable and usually subplastic (Butler 1955). The permeability of this and deeper layers is variable. At 3 feet the profile changes to a highly organised subplastic clay the peds of which are very dense. This clay continues to 9 feet with the subplasticity decreasing with depth. In some places this material, though starting as a highly subplastic clay at 3 feet, changes in depth to a white riverine gravel, the upper few feet of which are so highly cemented as to be almost unborable. This material has the depositional pattern of a prior stream. In other places the change after 3 feet is to a rather well sorted sand that again is highly cemented. This sandy material occurs as sheets, usually on the eastern sides of depressions and low terraces. A very characteristic feature of all of these soils is the occurrence of lime, usually as very hard and large pieces of rubble coming in between 3 and 6 feet. It is heavy initially, lessens with depth, then increases again at 7 to 8 feet. At approximately 9 feet there occurs a highly weathered grey clay that normally is very dense and plastic, but is highly subplastic where it occurs on the more elevated country.

The sandy and gravelly materials are restricted in their occurrence, but the three clay layers can be traced over extensive areas, thinning out over the hills to the south and east, and extending beneath the surface layers of the riverine plain to the north and west. The sandsheet can be seen in a bore traverse across the south-west corner of Allotment 10, Section B, Parish of Dunbulbalane and the prior stream in the north-east corner of Allotment 8, Section D, Parish of Dunbulbalane. The clay layers on the hill slope can be seen in a bore traverse across the south-east corner of Allotment 3, Parish of Katandra, while the same layers beneath the younger materials can be seen on the eastern side of Allotment 11, Section C, Parish of Congupna.

These clayey materials can be best explained as three superimposed parna layers, by using similar reasoning to that concerning the Widgelli. However it would seem that the uppermost layer of pana is not the Widgelli but is in fact a K3 parna. This will be called the Marungi in this paper. This layer has to be differentiated from the Widgelli because of its lack of lateral continuity with the Widgelli, and because the layer can be traced westward to the buried K3. In addition the depth, hardness and amount of lime and the degree of weathering are all much greater than found in the K2 soils. In fact a K3 exposure at the surface would be expected in this area because it is too high topographically for the riverine deposition and too far east of the K2 parna. Because the two deeper clay layers are buried by organised and have lateral continuity, they can be regarded as K4 and K5 panas respectively.

The gravelly material referred to must belong to a prior stream of K4 age because its weathered surface is continuous with the K4 layer. The cemented sand likewise belongs to the K4 and its occurrence to the leeward of sand sources, in this case prior streams, in sheet like formation suggest that they are windblown sandsheets.

Recent Entrenched Flood Plains

Along most of the streams in the area is a terrace below the general level of the plain and this represents an entrenched flood plain that is periodically flooded by the streams. It can be found occupying the incision into all other layers and is therefore the youngest. The soils are grey, heavy and show only a small amount of profile development. This is the Coonambidgal of Butler (1958) and is K1 in age.

Conclusions

It is clear from this paper that a knowledge of the depositional systems in the Goulburn Valley has possibilities in the understanding of problems of irrigated horticulture; this is discussed in Part 2 of this bulletin. It is also clear that the study of pedology is essential to the understanding of soil variability; this includes variation in such properties as permeability to water, infiltration, drainage status, water storage, soil management reactions and impedance to root growth. Three levels of variation are indicated from this study.

1. Within any particular fruit block rapid changes can occur. These include changes over short distances from sandy soils, and rapid texture variations within any particular profile.

2. On a broader scale the Goulburn Valley area can be divided into districts as described, each being distinct in its soil properties.

3. In the third type of variation, the whole Goulburn Valley area is found to be unique in many regards when compared with other irrigation areas in south-eastern Australia.

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Pedology of the Goulburn Valley Area

Part 2 Application in Irrigated Horticulture

PART 2 APPLICATION IN IRRIGATED HORTICULTURE

Part 1 of this bulletin outlines the stratigraphy of the depositional layers (Figure 2). This part is concerned with the application of this information in irrigated horticulture and shows how soil physical problems are related to the depositional systems and how this helps in the understanding of the problems. This relationship can be used in predictive and diagnostic work within the area, and in explaining apparent anomalies in soil properties between districts.

The soil physical requirements for plant growth have been long established and are reviewed for example by Shaw (1952) and Russell (1962). These requirements include water, aeration, unimpeded rooting and correct soil temperature. In this paper soil temperature is not considered. Investigational work in the Goulburn Valley area such as that reported by Penman (1936a, 1936b), Skene and Freedman (1944), Harper (1945), Goudie (1950), Goudie and Jarvis (1952), Webster (1957) and Skene and other data yet to be published, indicate which soil physical properties can present important problems in the Goulburn Valley. This is supported by experience of fruit-growers in the area.

Soil problems and their relation to pedology

The simplest way to relate soil problems to pedology is to discuss the problems in terms of various components of the field profile – surface topography, surface soil, B horizon, cemented pans and watertables.

Surface Topography

Surface slope is important because of its effect on soil drainage. Poor drainage is associated with flat land because it provides little opportunity for run-off of rain and irrigation water, and this is aggravated if it is in a low situation receiving run-off from higher surrounding land. There is an interaction between topography and other soil factors including infiltration rate, permeability of B horizon and depth of A horizon. In peach orchards, slopes of less than 2 inches per chain are hazardous in a wet year where subsoils are heavy. However this varies from district to district, a given slope being more dangerous in the Shepparton and Dunbulbalane districts than in Rodney and Cobram-Numurkah.

The drainage problems associated with surface topography are far more serious in the flood plain situation where the flood plain is covered with parna or not. Topographically the river ridge situation is the best for horticulture because of good drainage provided by the elevation and slopes. The ridges wind across the plain in a fan-shaped pattern as shown in Figure 2. They are clearly distinguishable on the soil, contour, and aerial maps and can be seen in the landscape as undulating country in direct contrast to the flat flood plain on either side. Most orchards in the area are situated on river ridges, although the Shepparton East orchards are actually sited on the alluvial fan. It is in keeping with the drainage position that almost all towns in the area are situated on river ridges.

The variation between districts in slopes required for adequate drainage is largely associated with differences in infiltration rate – as will be shown later, the Widgelli parna tends to have lower infiltration rates than the riverine soil and the Marungi parna.

Surface Soil

The surface soil is the most important part o the profile because so much root activity is concentrated there, because it is the entry point of water, oxygen and nutrients, and because it is the only part of the profile that can be readily modified by management. The most important cause of problems in Goulburn Valley surface soils is dispersion during irrigation. This has a serious effect on tree performance by causing shallow water penetration, on certain soils following irrigation (Goudie 1950). In years of severe trouble water may penetrate no deeper than 4 inches no matter how long it is held on the surface. Poor penetration results in a rapid onset of moisture stress; in medium textured soils, for each additional inch of penetration, an increase of about a day in the interval between irrigations is obtained. Repeated moisture stress results in small tress and small fruit size.

This problem is not found over the whole of the Goulburn Valley area, but is confined to the Rodney and Cobram-Numurkah districts outside the sandhill soils. It is not found in the orchards in Shepparton and Dunbulbalane. It is interesting to note that this problem is not very common in the Murrumbidgee Irrigation Area and is completely non-existent in the Mallee Irrigation areas.

The liability to dispersion is almost exclusively confined to the areas where Widgelli parna is exposed at the surface, and the problem does not occur on windblown sandhills, the riverine materials or old parna layers.

The parna soils are loams or fine sandy loams at the surface. The Widgelli parna always has a low coarse sand content, with fine sand, silt and clay levels usually of the same order. This is contrasted with riverine surface soils which are very variable in their coarse sand content, and except in the heaviest soils are rather low in silt and clay. It seems that dispersion of the surface soils is associated with mechanical composition; the parna with its high silt and fine sand content tends to be mechanically weak and therefore liable to disperse because it has not enough coarse sand to remain permeable and not enough clay for aggregation. The riverine materials on the other hand tend to resist dispersion because they can have a high coarse sand content or have sufficient clay to form stable aggregates. In the Marungi parna, surface soil dispersion is somewhat less than in the case of the Widgelli. These soils are K3 in age and differ from the Widgelli in two ways which may affect the penetration of water. They contain buckshot which acts mechanically as coarse sand and gravel, and they are subplastic at the surface which makes them behave as do lighter soils. The fact that surface soil dispersion does not occur in the Mallee area is associated with the pedological situation in which the soils have a much lower silt and higher coarse sand and lime content than the Widgelli parna of the Goulburn Valley. Soils in the Murrumbidgee Irrigation Area are intermediate between Mallee and Goulburn Valley soil sin respect to liability to dispersion, mechanical composition, lime content and origin of the parent material.

Final bed and levees of a large prior stream north-west of Shepparton

B Horizon

The B horizon when it is heavy (greater than approximately 60% silty plus clay) presents several problems in fruit growing, the two most important of which are impedance to root penetration and low permeability to water.

Other effects are low aeration of the B horizon itself and low amounts of available water.

Development of feeding roots has been discussed by Wallbrink, Hughan and Cockroft (1963), and they show that up to one half of these feeding roots occur in the three or four inches of non-cultivated surface soil. The attributed this to the unfavourable nature of the B horizon as a medium for root growth, owing to its massiveness and its low volume of larger pores. B horizon permeability becomes the dominant factor in restricting the penetration of irrigation water when the surface soil is light or in an otherwise permeable condition. This is evident after heavy irrigation when the surface soil may take as long as five days to drain to field capacity. The permeability of the B horizon is also important in waterlogging since low permeability causes wet surface soil conditions in wet years. For instance in 1956 low permeability of B horizons resulted in saturated surface soils almost continuously for five months. Cockroft and Bakker (1963) define the lower limit of hydraulic conductivity in the B horizon for a “safe” profile (for peaches) as 0.25 feet/day in such a year.

The problems of B horizon permeability vary from district to district. For example a B horizon with a silt plus clay content of 60% is found to have an average hydraulic conductivity of 1.0 feet/day in Rodney and 0.25 feet/day in Shepparton East. On the other hand the clayey B horizon at Dunbulbalane in its upper part has a hydraulic conductivity of 5.0 feet/day (silt plus clay 70%). Another anomaly is the change of permeability from site to site within fruit blocks. This is important in irrigation practice, because a large change in permeability within an irrigation run leads to over watering. Most difficulties of this type occur in Shepparton, and this in contrast to the lack of trouble in Rodney and especially in Dunbulbalane. B horizons in general in the Goulburn Valley are much more massive and less permeable than those of the other soils used for irrigated horticulture in Australia, even allowing for external differences.

Restriction in the B horizon of water movement and root development is associated with mechanical composition and the number of macropores. These in turn are linked with the depositional layers. The differences found from district to district in hydraulic conductivities of the B horizons with the same silt plus clay content, are due to the proportion of coarse and fine sand. Riverine materials tend to have more coarse sand than the parnas. Differences can also be due to age – for instance the Widgelli parna has far fewer large pores in the B horizon than the Marungi parna. The changes in permeability within individual fruit blocks are greatest on riverine soils because of the way in which alluvial materials are deposited. Changes in the parna are slow. The changes that do occur can be due to dilution by sand from prior streams, and to changes in drainage status as described by Butler and Hutton (1956).

The differences in the hydraulic conductivity and massiveness between Goulburn Valley B horizons on the one hand and those in the Mallee and the Murrumbidgee Irrigation Area on the other, seem to due to mechanical composition (the Widgelli parna in the Goulburn Valley has a high silt content) and perhaps lime content.

Cemented Pans

These pans occur at varying depths but not shallower than 18 inches; they are naturally occurring, and consist of cemented sands and gravels. The pans are cemented with colloidal clay material, presumably sequioxides, which is found coating the sand or gravel grains and forming bridges between them, or simply filling the spaces between them. These pans are often slowly permeable to water and usually restrict root growth. The main problem is low permeability because the pan can prevent deep wetting of the profile, but more important it causes the build up of wet soil conditions in the root zone. The cements of sands and gravels to form these pans is common in the Cobram-Numurkah district and at Dunbulbalane, but is rare in Shepparton and totally absent in Rodney. The hydraulic conductivity of these pans is usually less than 0.03 feet/day in the Cobram-Numurkah district, and at Dunbulbalane less than 0.002 feet/day, but in places they are much more permeable, and in fact water sensitive varieties like peaches will grow on them.

The occurrence, formation and variation in permeability of these pans is associated with definite pedological situations. These pans all have two characteristics in common – they are all sandy or gravelly, and are all K3 or older. Younger and heavier materials can appear to be cemented when dry but soften when moist, and they are usually much more permeable to water than the genuine cemented pans. These pans are formed in:

1. K3 riverine material overlain by either Widgelli parna or K2 riverine in the Cobram-Numurkah district; and
2. In K4 riverine materials and sandsheets overlain by K3 parna at Dunbulbalane.

The pans form where there is a layer of clayey material overlying a gravel or coarse sand in such a position that the sand or gravel dries out soon after rain. Presumably the clay is washed down into the coarse material, sediments there, and becomes irreversible when it dries. It seems that sand and gravels of K2 age have not been subjected to this cementing action for long enough to have formed a cemented pan.

The higher permeability of these pans in some places may be due mainly to old root channels that not been filled completely and therefore are able to conduct water while remaining very stable. This situation occurs when the pans have developed in sandy deposits of the K3 prior streams at Cobram-Numurkah or K4 prior streams at Dunbulbalane, but only in those situations where uncemented sands and gravels continue with depth.

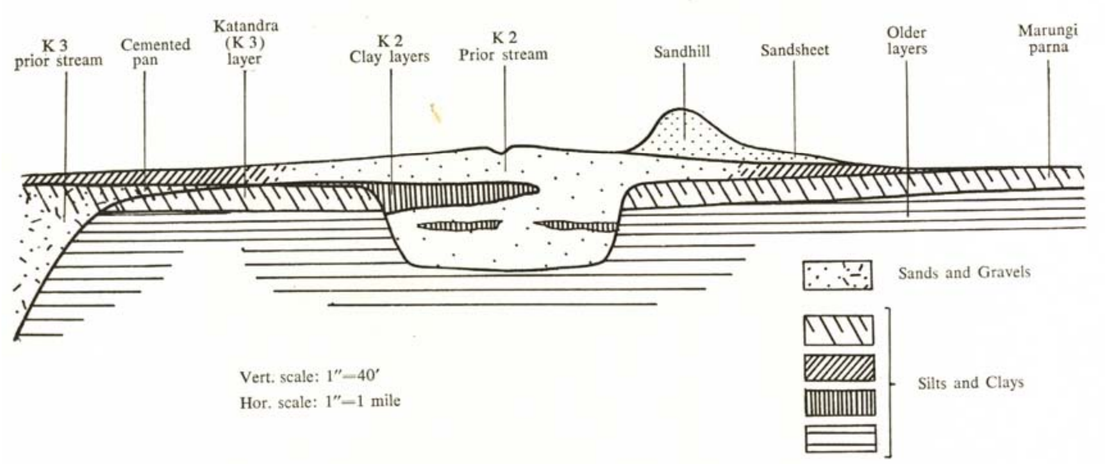

Fig. 5. Diagrammatic representation of layers important in watertable development.

Fig 5 – Diagrammatic representation of layers important in watertable development.

Watertables

Waterlogging caused by watertables should not be confused with that caused by B horizons or cemented pans, where the surface soil only is concerned. In south-eastern Australia there have been periodic wet years including 1931, 1939 and 1956, when heavy damage occurred (Skene and Freedman, 1944; Cole *et al*. 1957). In 1956 over half the peach tress in the Goulburn Valley had to be removed. On these occasions the watertable rises to within the root zone and remains there for a prolonged period during autumn and winter. However the death of trees from watertables is confusing because in each wet year some trees died and others did not. In other words there are safe and unsafe watertables (Cockroft, Bakker and Wallbrink 1961), and this will be discussed further in another paper. Another anomaly here concerns the rise of the district watertable to within a few feet of the surface which took place in the Rodney and Shepparton East districts within two or three decades of the first irrigation. However there is no evidence that this type of watertable has ever directly caused the deaths of fruit trees. A further puzzle is the fact that salt has not risen with the watertable even though the deep district watertable is known to be salty.

An understanding of the nature of watertables may be gained through a knowledge of the depositional layers. For many years three types of watertables have been recognized by horticulturalists in the area.

Perched Watertables – are usually found in prior stream deposits –

1. Where they overlie clay layers within the prior stream coarse.
2. On an older buried soil layer just outside the prior stream coarse.
3. In sheets of windblown sand overlying less permeable materials (see Figure 5).

These situations can be seen in Allotment 90A, Parish of Toolamba, Allotment 20, Parish of Toolamba West respectively. Not all clayey materials restrict water to the extent that permanent watertables develop. Generally K2 layers where they are buried are more permeable than buried K3 or older. For example a series of measurements of a K2 deposit with a silt plus clay content of 88%, showed it to have an average hydraulic conductivity of 2.2 feet/day while K3 at the same depth with a silt plus clay of 81% gave an average hydraulic conductivity of 0.01 feet/day.

Prior Stream Watertables – occur in the refill material of the prior stream incision; they are connected to an are supplying the district watertable. As would be expected the incisions by the prior streams before aggradation and filling often cut across older prior streams. An example of this can be seen in Allotment 8, Parish of Congupna, about 7 miles north-east of Shepparton where a K2 prior stream cuts across a K3. Thus there is a slow drainage along the prior stream, and then down, and this is demonstrated by the fall of these watertables after the cessation of rain or irrigation. Both the infiltration rate at the intake areas and the rate of escape of this water to the district watertable are important in determining the safety of the watertable. It is rare for this water is to be saline.

The District Watertable – is the body of groundwater found throughout each district; it is the water found in nearly all deep bores and was used extensively as a source of supply before installation of the present irrigation system. District watertables are often saline. They occupy a complex of deeply buried prior streams, large sheets of coarse sediments, and other porous materials. The configuration of these materials is now known. District watertable levels have been studied by Webster (unpublished data) in the Cobram-Numurkah district, and he has found that levels fall away from the irrigation district indicating a net flow away from the area being irrigated.

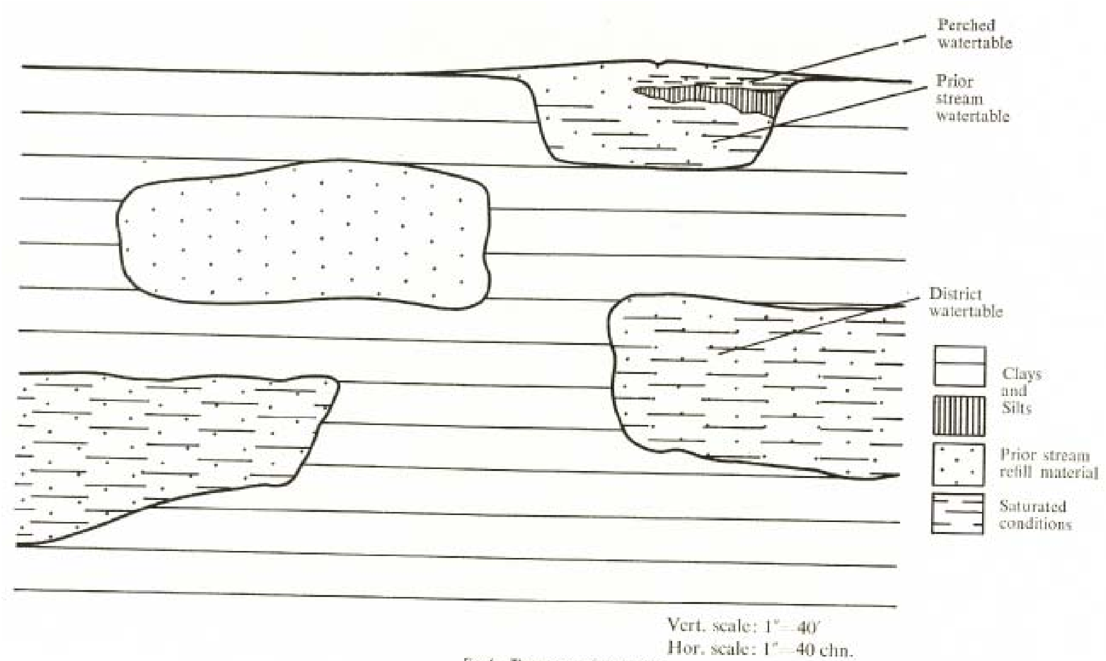

Fig. 6. Three types of watertables.

Fig 6 – The types of Watertables

The lack of damage caused since the rise of district watertables in Rodney and Shepparton East in the early years of irrigation is due to the drainage along the prior streams and down into older deposits, and although this is slow, the intake area comprises only a small proportion of the total surface area in the Goulburn Valley. The net result is that the district watertable only reaches the surface during very wet years, and even then damage does not always occur.

The variation in the degree of damage caused by watertables will be discussed in a later paper.

With regard to salt, the Goulburn Valley area differs from other irrigated areas to the north and west in that the soil profile originally contained little salt. The only source of salt here is that of the original deep district watertable, and the only way in which this watertable can rise is from water intake within the irrigation area. This is shown by the drop in watertable level with distance from the boundary of the area. Thus the district watertable has been built up by a continuous flow of fresh water from all intake areas. A net downward movement results, and if little mixing of saline and fresh water can be presumed, salt will not come to the surface -–the saline watertable would tend to fall rather than rise. Furthermore it is unlikely that saline water would rise by capillarity in areas where no intake occurs because these are very clayey and extremely thick.

Salting in areas outside the Goulburn Valley is usually associated with the originally high salt content of the whole profile. In the Mallee soils for instance, the high salt content together with restricting clay layers within a few feet of the surface, result in saline watertables that cause a rapid concentration of salt in the root zone.

Relation between Pedology and Horticulture

At this stage an appraisal of the horticultural soils of each district can be made in the light of the understanding of the depositional systems. In addition, an assessment can be made of other areas of land at present not being sued for horticulture.

Rodney

The pedological situation in the Rodney district consists of Quaimong (K2) prior streams with the old K3 land surface between them, and all overlain by 2 feet of Widgelli parna. Most orchards are on the prior stream situation.

This situation provides for good surface drainage, uniform soils and no cemented pans. Furthermore the rise of the district watertable has caused no concern in itself and has not resulted in any salting. However the parna origin makes the surface soil prone to dispersion and all its attendant problems, and the B horizon tends to restrict root development and water penetration.

Any expansion of horticulture in the Rodney district should be confined to the river ridges and these are shown in the soil survey. These areas would respond in much the same way as those already developed. However soils become less suitable for horticulture with distance towards the north-west because the parna is influenced by the increasing clay content of the underlying prior stream deposits and because of higher salt levels.

Shepparton

Here the orchards are practically confined to and occupy the whole of the alluvial fan of the Broken prior streams. These are Quaimong and Mayrung with little or no overlay of Widgelli.

The surface soils are deep so that the B horizon is of little importance as a restriction to root growth and water penetration; furthermore they are not prone to the problems caused by dispersion. Cemented pans are rare, and district watertables cause no damage nor do they provide a means of salt accumulation in the root zone. However the flatness of the alluvial fan is a disadvantage in that excess water is slow to run off in a wet year. Where B horizons are heavy, surface waterlogging can occur. The rapid changes in soil type within orchards is a big problem in orchard management in this district.

As far as future expansion is concerned in the Shepparton district, the large river ridge running from just north of Shepparton to Nathalia (Figure 2) should be ideal, because as it is Mayrung (post-Widgelli) in age it has all the advantages of the prior stream situation without those problems associated with an overlay of Widgelli parna.

Cobram-Numurkah

The situation here is mainly one of K3 prior streams overlain by 2 feet of Widgelli parna, with a small area of Mayrung near Cobram. The orchards are planted on the prior stream situation.

The river ridge topography usually provides adequate surface drainage. Furthermore soils are uniform because they are developed from parna. The K3 prior streams have left deposits much coarser than the K2 and therefore the parna in this area has been modified more than in Rodney by way of dilution and structural changes due to underdrainage. This has resulted in somewhat deeper A horizons, and more permeable B horizons. Furthermore, even though the district watertable is still rising, the possibility of damage due to it directly or due to it brining up salt is very slight. However the overlay of Widgelli parna makes these soils prone to dispersion and its attendant problems under irrigation. Cemented pans cause wet soil conditions in many orchards. In spite of the higher permeability of the B horizon developed on Widgelli in this district compared with Rodney, water and root restriction by the B horizon is still a problem.

For any expansion of irrigation horticulture in the area there are many river ridge situations available and these are shown in the soil surveys. In this event the soils would respond in much the same way as those already planted. However the greatest areas of best soils are nearest the source of the prior streams; that is, around Cobram. The small area of prior streams of Mayrung age near Cobram has not been used for horticulture but should be suitable if protected from the flooding of the Murray River.

Dunbulbalane

In this district the Marungi (K3) parna occurs as a continuous layer overlying older parna layers and some deeply buried riverine deposits.

Orchards in this area are only a few years old and experience of the soil reaction to irrigated horticulture is limited. The soils are uniform and the surface soil does not seem to be prone to dispersion. Watertables are not a problem because they rarely develop in the clayey parna layers, and the prior stream sediments are limited to a small area. For this reason, and because of the original low salt content of the soils, salt should not be a problem either. The B horizon restricts neither penetration of water during irrigations, nor the development of tree roots. However these soils are prone to waterlogging problems because of the low permeability of the underlying parna layers and the cemented pans. This situation is aggravated by the flat topography.

In any future expansion on these depositional layers the soil reaction should be similar to that described, and in view of the danger of waterlogging, any areas with a slope are preferable. These layers seem to be widespread near the eastern fringe of the Riverine plain of south-eastern Australia. The soils developed in these layers have many advantages, and therefore their response to irrigation at Dunbulbalane should be of considerable interest.

Conclusions

It seems inevitable that under irrigated conditions, problems associated with the physics of the soil sooner or later develop. This has happened in most irrigation areas of Australia and has certainly happened in the Goulburn Valley area. These problems have been studied for the Goulburn Valley area to a depth of understanding at which a working solution to each is available. This paper shows that these soil problems can be related to the layer situation, so that a study of the layer situations helps in an understanding of the problems, in a knowledge of their distribution, in sorting out any apparent anomalies and in predicting their occurrence. It seems likely that in any similar situation – that is, where soils are of mixed origin, where water is being applied artificially, and where the land is being intensively used – a knowledge of the origin of the soil material is essential in understanding field problems concerned in soil-plant relations.

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