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Land Resources Bulletin

Soils and Agricultural Suitability of the Gundiah - Curra Area, Queensland

P R Zund

Queensland Government
Natural Resources, Mines and Energy

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Summary

The Mary River is a major coastal river in south-east Queensland, arising in the Conondale Mountains and running in a northerly direction, entering the sea at Maryborough. The main channel is about 260 km in length, and the study area is located in the middle reaches (being about 50 km of the main channel). It has a subtropical climate and the surrounding countryside is a mix of agricultural and beef grazing industries, although in recent years it has come under pressure for rural residential.

In 1993, the Lower Mary River Land Use Advisory Committee identified the need for land resource information over an area of 315 400 ha in the Maryborough district. In response to this need, the Maryborough Sugar Factory, Sugar Industry Reference Panel (SIRP), Department of Primary Industries (DPI) and Department of Natural Resources (DNR) funded a survey covering 73 805 ha in the Hervey Bay, Beaver Rock, Susan/Prawle, Churchill Mines, Tuan Forest, and Yerra Pilerwa areas (Wilson *et al.* 1999). Subsequently, an additional area of 50 571 ha between Maryborough and Emery's bridge road, Gundiah was surveyed (Zund and Brown 2001). During 1998, DNR with financial assistance from the National Heritage Trust surveyed land resources adjacent to the Mary River from Imbil to Curra (central reaches of the Mary River).

This survey fills a gap in land resource information along the middle reaches of the Mary River between Gundiah and Curra. This survey aims to provide detailed land resource information for rural industry strategic planning, enhanced sustainable farming practices, catchment management, property management planning and regional planning. This report and the accompanying maps describes in general, the natural resources of the study area and in detail, the soils, their attributes, associated landscape processes and limitations to agricultural use.

A total of 37 soils, 5 phases and 7 variants were identified in the study area. Soils have been grouped according to soil orders of the Australian Soil Classification and subdivided based on geology and landscape position.

Several characteristics (hardsetting soil surface condition, narrow moisture range for machinery operations, soil wetness and low soil water holding capacity) are the major limitations to sustainable agriculture in this area. Clearing of remnant vegetation and irrigation practises on recharge areas have aggravated salinity. Currently salt affected land is a minor occurrence in the study area, however if on-farm and catchment management strategies that prevent salinity are not maintained or implemented, salinity has the potential to effect a quarter of the study area.

There are 21 limitations to irrigated land use which were used to determine the irrigated land suitability of the 36 land uses. Land suitability is presented using a five-class system. The study shows 4563 ha are suitable (class 1–3) for sugarcane using travelling irrigators or other overhead irrigation systems. The areas of each class for each land use are outlined in the report.

The highly variable nature of the summer dominant rainfall makes creates the need for irrigation to obtain adequate yields for most agricultural land uses. Water supply and associated infrastructure are the main limitations to agricultural development. There is, however, potential for development outside the irrigation areas, especially where water harvesting and on-farm storages can be implemented.

A Geographic Information System (GIS) allows rapid retrieval and presentation of site information, soil and land attributes, limitations and suitability for 36 different land uses. All of the information is beneficial in providing information through a decision support systems for land use planning, improved farming systems and land management. The report also provides a key for easy identification of soils in the area, detailed descriptions of the soils, an outline of the land suitability classification scheme and accompanying soil and land suitability maps.

The results of this study are useful to industry bodies, community groups, government departments, landholders and other land managers who have a commitment to managing the land and maintaining it in a productive and sustainable condition.

1. Introduction

The town of Maryborough was established in the 1860's as a port for exporting agricultural products and as an immigration entry point to Australia. Gympie in contrast was founded on a gold rush. Agricultural industries in the region were thriving by the late 1960's and included wool, beef, sugarcane, timber, fishing and horticultural production.

Today, local agricultural industries are under pressure from competing land uses such as urban and rural residential development. This has brought with it the need for expansion of recreational areas, conservation areas, water storage for irrigation and domestic use, roads and other infrastructure to sustain an expanding population.

The future of rural industries, particularly sugarcane, is affected by a number of factors which include:

* limited availability of suitable land for industry expansion
* strong competition between existing and new rural land users for good quality agricultural land;
* lack of appropriate information to identify areas suitable for agricultural production;
* limited understanding of soil and landscape attributes and how they behave under various management options;
* degradation of existing agricultural land following inappropriate land use and management;
* lack of appropriate land resource information for strategic planning by rural industries, local authorities and government;
* lack of user friendly, relevant land resource information to assist producers and other land managers to develop and adopt more sustainable natural resource management systems.

One of the overriding factors affecting agricultural development in the Maryborough–Gympie area is the highly variable, summer dominant rainfall. Average annual rainfall for Maryborough is 1158 mm and for Gympie 1137 mm, but for the last 20 years, annual rainfall has been consistently below average. Out of this average rainfall, approximately 700 mm is effective rainfall, which is benefical for crop growth. The remaining rainfall generally occurs in small amounts, which is lost to evaporation and not available to plants. Because of this variable effective-rainfall, irrigation is needed to obtain reasonable yields for most agricultural uses. Irrigation water can be supplied from declared irrigation schemes, on-farm water harvesting and water storages, and sewerage effluent irrigation schemes. Due to the geology in the study area, bore water is generally unreliable and/or salty (Wilson *et al.* 1999).

The Gundiah–Curra soil survey and land use study of 21 800 ha (not including rural residential and urbanised area, waterways and water storages, and mountainous areas) on the Maryborough 1:100 000 map sheets (Figure 1) began in 2001. The survey was to supply land resource information for the whole area in a uniform format, incorporating information from previous surveys whenever possible. Previous land resource information (apart from Wilson 1994, Wilson 1997, Wilson *et al.* 1999) was generally fragmented conducted for a specific purpose, or in insufficient detail to address today's land use and management issues.

The survey and maps use the same land suitability criteria and soil profile classes where appropriate as has been used in the Childers, Bundaberg, Maryborough–Hervey Bay and Maryborough–Tiaro surveys.

The outcomes of the survey are to provide:

- information for improved sustainable farming systems
- information suitable for regional planning, catchment management, and property management planning
- information for improved irrigation management strategies

- an evaluation of the land suitability for a wide range of land uses
- information on the current state of land use and land degradation
- an inventory of the land resources on part of the Maryborough 1:100 000 map sheet
- detailed description of the physical and chemical attributes, and the limitations of the soils and land for agricultural production.

This report describes the natural resources of the study area, the soils in particular, their distribution and their limitation to agricultural production and land suitability. This report should be used in conjunction with the soils and suitability maps. An expanded form of this report has also been published on CD-ROM which includes all 36 land suitability maps, an agricultural land class map and colour photographs of soils in chapter three.

2. Description of study area

Location

The study area is located between Emery's Bridge, Gundiah and Reibels Crossing, north of Curra on the Mary River. A majority of the study occurs in the Tiaro Shire. Part of the study area south of Wide Bay creek and west of the Mary River, falls within the Kilkivan Shire. The study area is also part of the Wide Bay Region and wholly within the Mary River Catchment. The Wide Bay region is adjacent to Hervey Bay in the northern part of South East Queensland (see locality diagram on accompanying soils map).

Climate

The study area has a sub-tropical climate. Over half of the annual rainfall falls between November and March. The winter months are the driest months of the year, receiving less than a third of the rainfall that falls during summer. Effective rainfall (the difference between rainfall and evaporation) is positive only during February and March for Theebine. For all other months, there is more evaporation than rainfall. See Figure 1.

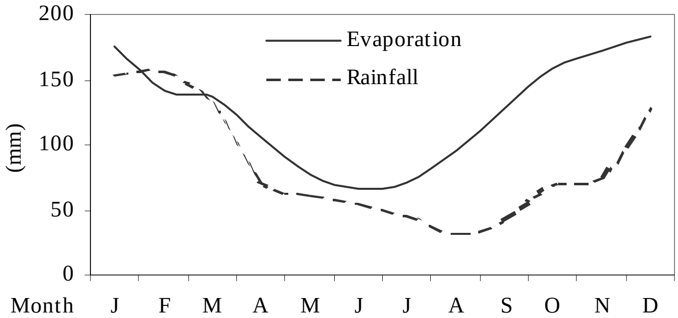

Figure 1. Monthly rainfall and evaporation for Theebine derived from SILO Patched Point Dataset supplied by Natural Resources and Mines, 2002.

Mean maximum temperatures for Maryborough are between 21^{o} and 32^{o}, mean minimum temperatures are between 6^{o} and 21^{o}. The mean number of days upon which rain fell per month ranges between 6 and 14 days. The number of rainy days is twice as high between December and May compared with June to November. The highest recorded monthly rainfall in 131 years is between 4 and 11 times that of the median monthly rainfall, which indicates a high variability in rainfall for this area. For further information, see Table 1.

Table 1. Summary of temperature and rainfall data for Maryborough weather station

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (^{0}C)	30.7	30.1	29.2	27.3	24.6	22.3	21.9	23.3	25.6	27.7	29.3	30.5	26.9
Mean minimum temperature (^{0}C)	20.6	20.5	19.3	16.5	13.1	10.2	8.6	9.2	12	15.3	17.8	19.6	15.2
Mean monthly rainfall (mm)	165	174	158	90	80	67	53	40	43	75	86	127	1158
Median monthly rainfall (mm)	135	134	125	69	65	47	38	32	35	62	78	108	1118
Mean no. of rain days	13	14	14	12	11	8	7	6	6	8	9	11	118
Highest monthly rainfall (mm)	763	899	1026	338	343	347	406	322	164	497	301	551	
Lowest monthly rainfall (mm)	5	7	5	5	3	0	0	0	0	0	3	8	

* Bureau of Meteorology, 2002

Water resources

The study area is part of the ‘Mary Valley Irrigation Area’, which extends from the Borumba Dam to the section of the river flooded by the Lower Mary Barrage at Tiaro. The irrigation scheme receives its water from Borumba Dam. The dam also provides water to the ‘Lower Mary Irrigation Area’. The dam was built in two stages, the main dam on Yabba Creek in 1964 and the raising of the spillway in 1998. ‘Supplemented supply water’ is supplied to irrigators *via* Yabba Creek and the Mary River. The scheme is administered by ‘Sunwater’ and has the capacity to provide 46 000ML of water per year to both schemes: 37 000ML is allocated to Mary Valley irrigators and 7000ML is allocated to Lower Mary Irrigation Area irrigators (Water Planning Group 2002). Currently 81% of this water is supplied for irrigation purposes and 19% for town water supplies.

The Mary Valley does have a groundwater resource, however the water quality and quantity is very variable throughout the catchment. In areas downstream of Gympie, groundwater quality is generally poor, this includes the study area. Groundwater is mostly used for house and stock watering in the study area. Groundwater in the Mary catchment is not regulated or controlled.

The Department of Natural Resources, Mines and Energy is currently preparing a Water Resource Plan for the Mary catchment, which includes Sunshine Coast streams and the Burrum River. The plan seeks to provide a framework for water allocation to domestic, agriculture, irrigation, industry and recreational users, as well as allow adequate water to sustain ecosystems that depend on river flow.

Geology

Information for this section has been obtained from geology reports (Cranfield 1993, 1994, 1999 and Ellis 1968) and from field observations. The study area is almost entirely located within the geological Maryborough Basin. This basin consists of a series of marine and freshwater sediments and volcanic lava flows and pyroclastics. These deposits have been folded and intruded by igneous rocks mainly along the western margin of the basin. During the Tertiary period, fresh water sediments covered the folded landscape of the basin. These sediments underwent a long period of weathering during the mid-Tertiary period. The Tertiary surface has since been tilted and most of the surface has been removed (within the study area), reworked and/or deposited in Hervey Bay. In the Pleistocene and Holocene period, creeks and rivers have deposited and eroded material forming different levels in the landscape related to Pleistocene sea level changes. The effect of these processes has been to form relict alluvial terraces along the Mary River. The Mary River continues to be an actively meandering river with regular flood events accompanied by aggradation and erosion of the river channel. Figure 2 shows the geomorphic relationships in the study area.

Geological history

The study area is located in an area of transition between the depositional landscape of the *Maryborough Basin* and the erosional landscape of the *Gympie Province* to its west and south. The boundary of these two landscapes lies in a northwest to southeast direction parallel to the coastline. The study area is located within a transition zone between the basin and province and consequently some different soils are encountered than in previous studies in the Bundaberg, Childers, Hervey Bay, Maryborough and Tiaro areas.

The oldest rocks in the study area are fine marine sediments of the *Kin Kin Beds* (Rk), which were deposited during the early Triassic period. These rocks were subsequently folded and faulted and then eroded and provided some of the fluvial and lacustrine sediments of the *Myrtle Creek sandstones* (RJdm) and *Tiaro Coal Measures* (Jdt), which were deposited during the late to middle Triassic Jurassic period. These rocks were subsequently folded and faulted before being covered in part, by andesite, rhyolitic flows and pyroclastics from volcanic activity during the Jurassic period. The rocks formed during this period form what is known as the *Grahams Creek Formation* (JKg).

During the middle Jurassic to early Cretaceous, the landscape was intruded by *Mount Bauple Syenite* (JKb) south of Tiaro and *Unnamed Hornblende-Phyric Microdioritie* (JKi). 'Sill-like' bodies of *microdiorite* composition occur throughout the study area inter-bedded with sediments of the *Tiaro Coal Measures*.

During the early Cretaceous period, fine sediments were deposited in a marine environment, over the *Grahams Creek Formation*. These sediments are the *Maryborough Formation* (Km). The upper layer of siltstones and mudstones of the Maryborough Formation were silicified to form the *Silicified Maryborough Formation* (Kms). Following a lowering in sea level, freshwater sediments of the *Burrum Coal Measures* (Kb) were deposited on top of the *Maryborough Formation* and folding and faulting of the landscape followed this. The *Burrum Coal Measures* do not outcrop in the study area.

During the Tertiary period alluvial, colluvial and lacustrine sediments were laid down unconformably over all the other formations to form the *Elliott Formation.* The *Elliott Formation* and any other exposed formation was subsequently subjected to periods of deep weathering and silicification to form duricrusts in parts. The *Elliott Formation* has been tilted and has a gentle dip to the northeast. Since the Tertiary period, the study area has had a relatively benign geomorphic history with only the *Elliott* surfaces being stripped away by rivers and creeks that drained the landscape. Where the tertiary surface (includes all deeply weathered surfaces) has been stripped away, underlying older less-weathered rocks have been exposed.

During the Quaternary, (Quaternary includes both Pleistocene and Holocene periods, recent time), alluvial deposition has occurred along the Mary River and its tributaries. Due to sea level change, the river recut down into these depositional layers creating a number of relict alluvial terraces (Qpa, Qha1, Qha2). Figure 2 shows a map of the results of geomorphic activity in the area. More detailed geology information of the area is available from Cranfield (1994 and 1999).

Sedimentary rocks

The *Kin Kin Beds* are the oldest formation in the study area and have been extensively folded, faulted and intruded. They occur mainly as metamorphic phyllite rocks, which outcrop in the south east of the study area at Harvey Siding. The phyllite rocks formed originally from fine sediments, which were laid down in a quiet marine environment and later metamorphosed. As a result, soils derived from the phyllites are high in silt. n the southeast of the study area, the *Myrtle Creek Sandstone* overlies the *Kin Kin Beds.*

The *Myrtle Creek Sandstone* comprising quartzose sandstones outcrop along the Mary River near Munna Creek, Scotchy Pocket and east of Harvey Siding and Gunalda. Sandy surfaced soils have formed on these moderately weathered sandstones. The *Myrtle Creek Sandstones* are overlain by *Tiaro Coal Measures*, which are composed of shale, mudstones, siltstone, fine sandstones, and coal seams. The finer sediments dominate this unit and consequently form soils with loamy surfaces and sodic clay subsoils. The *Grahams Creek Formation*, although mostly andesite and rhyolite flows with pyroclastics within the study area, is interbedded with fine-grained sediments. The *Maryborough Formation*, in the northern part of the study area, overlies the *Grahams Creek Formation*. The *Maryborough Formation* is comprised mainly of mudstones, shale, siltstones, and fine-grained sandstones. The hard and resistant *Silicified Maryborough Formation* outcrops on distinct ridgelines, which form southeast to northwest trending ridges throughout the Maryborough area. Some of these ridges extend into the northern part of the study area. Soils high in fragmented rocks have formed on the ridges and adjacent slopes (eg Takura beds). The *Elliott Formation* unconformably overlies all the formations. The *Elliott Formation* comprises of sandstones, mudstones, siltstones and conglomerates that were unconformably deposited on an undulating, eroded older land surface.

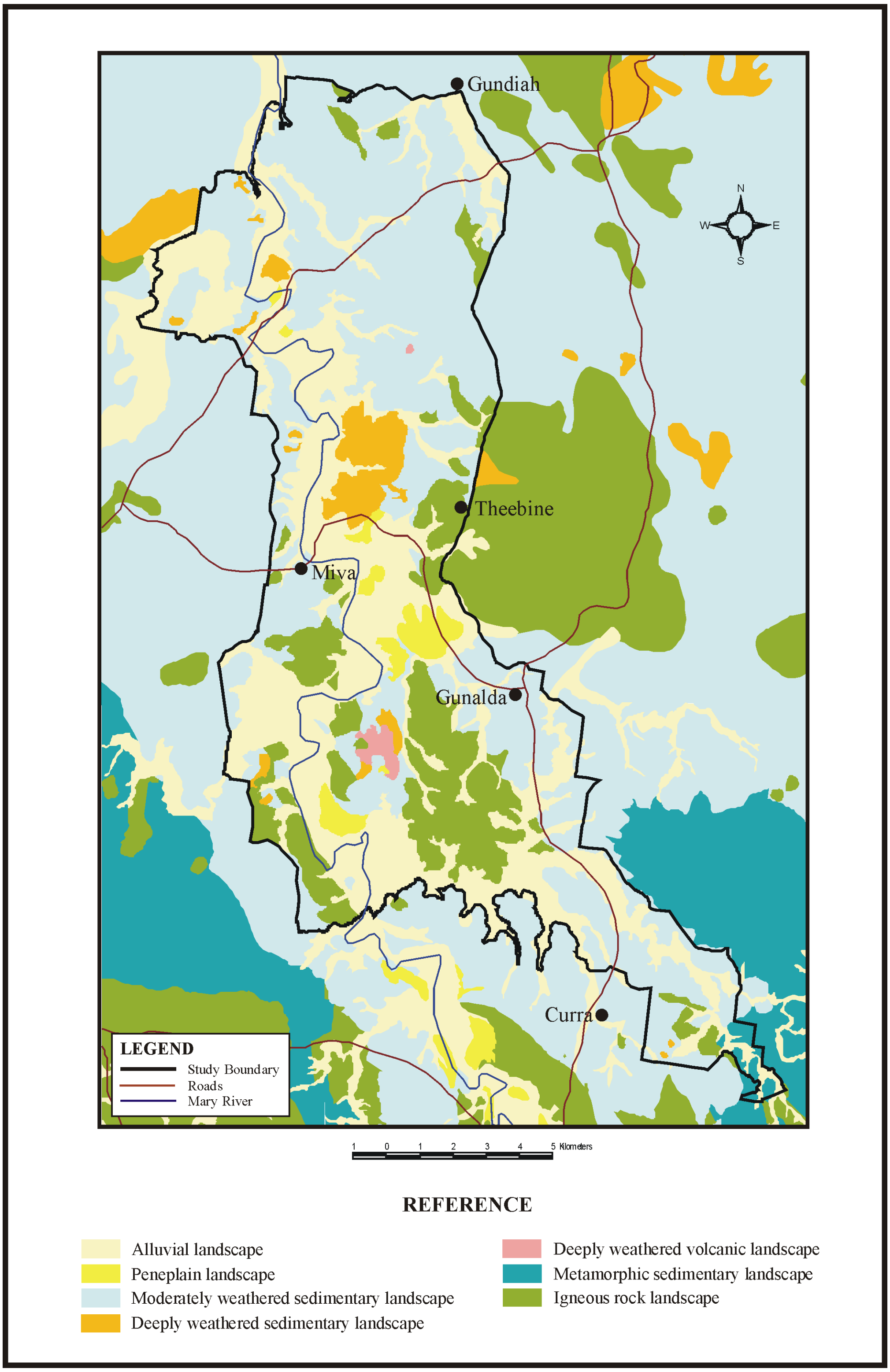

Figure 2. Map of geomorphic landscapes

All of the *Elliott Formation*, and parts of the *Maryborough Formation*, *Grahams Creek Formation* and *Tiaro Coal Measures* which were exposed to the effects of weathering during and since the Tertiary period have been deeply weathered. The underlying moderately weathered rocks are generally softer than the deeply weathered rocks resulting in undulating rises and low hills. These rocks can be distinguished from the deeply weathered rocks because they retain strata bedding and evidence of primary minerals (eg. feldspars). These features are lost during deep weathering (Wilson 1997). Similar lithology under similar landform and climatic condition, regardless of the formation, gives rise to similar soils.

A period of deep weathering after the formation of the *Elliott Formation* sediments resulted in extensive silicification forming a duricrust. The duricrust surface forms elevated level plains (peneplains) and hillcrests. The undulating landscapes on fine-grained sedimentary rocks (mudstones, shales, siltstones, fine sandstones) generally give rise to soils with loamy (fine sandy loam to clay loam) surfaces. The coarse-grained sedimentary rocks (sandstones) generally give rise to a wide variety of sandy (sand to sandy loam) surfaced soils. Local hydrology is reflected in soil colour with red or yellow colours generally occurring on the upper slopes, while grey or gleyed colours occur on lower slopes. The level plains have predominately formed seasonally wet, relatively deep soils (Wilson 1997).

Where coarse-grained sediments (sandstones) of the *Elliott Formation* occur, sand moves down slope over other formations, predominantly the moderately and deeply weathered sedimentary rocks (Wilson 1997).

Igneous rocks

The Jurassic–Cretaceous *Grahams Creek Formation* (JKg) is exposed as a sporadic belt of moderately weathered rocks making up the Gunalda Range, Mt. Scotchy and other isolated remnants. Some deeply weathered andesite of the *Grahams Creek Formation* occurs at Scotchy Pocket. Dark clayey soils have formed on moderately weathered andesite, while deep red soils have formed on the deeply weathered andesite. Rhyolitic rocks from the same formation occur near Harvey Siding and have formed loamy surfaced soils with acid clay subsoils.

Within the study area, Jurassic-Cretaceous intrusive (JKi) microdiorite is also associated with the *Grahams Creek Formation*. This formation has intruded into older formations and outcrops sporadically throughout the study area. Microdiorite is the dominant rock and at times is difficult to distinguish from andesite. Soils similar to those formed on moderately weathered andesite occur on these rocks.

Alluvium

The alluvial plains along the Mary River are the largest continuous area of alluvium in the study area. The remaining alluvia are generally restricted to narrow areas along creeks (Qa), which drain the local landscapes and alluvial fans off Mt. Scotchy and Gunalda Range and along Curra Creek.

The alluvium of the Mary River comprises channel benches, scrolls, flood plains, terraces, alluvial plains and swamps. The channel benches, scrolls and flood plains (Qha1 and Qha2) occur low in the landscape adjacent to the Mary River. Regular flooding and associated silt deposition or occasionally scouring and bank slumping are a feature. Mineral composition of the alluvium reflects the geology of the Mary River catchment.

The terraces and alluvial plains (Qpa) may be subject to rare flooding but generally represent alluvial deposition from the past. Elevation and proximity to past stream channels are the main geomorphic processes determining soil attributes. Alluvial deposits become finer further away from stream channels while wetness generally increases as elevation decreases. Therefore, better-drained, sandier soils occur on the elevated edge of terraces and alluvial plains, and poorly drained clays occur on backplains and swamps.

The alluvium associated with creeks draining the local geology (Qa) comprises narrow alluvial plains and minor levees. Mineral composition of the alluvium reflects the local geology from which the creek originates. For example, Gutchy, Durramboi and Curra creeks originate in country dominated by sedimentary rocks and Slaty and Slogertys creeks originate in country dominated by andesite/microdiorite rocks. Rivers generally have incised drainage lines with adjacent narrow sandy levees and finer sediments on the backplains. Streams within the study area often have multiple channels (or overflows) with a strongly meandering pattern over a wide part of the alluvial plain resulting in a uniform deposition of sediment and thus soils over the plain. These plains are generally poorly drained with fluctuating seasonal watertables.

Physiographic Features

The study area follows the Mary River between Emery's bridge, Gundiah and Reibels Crossing, Curra. The riverine landscape can be divided into four distinct levels.

The lowest level which is within the river banks, consists of narrow (less than 250m wide) gently undulating (2–7%) channel benches, scroll plains and flood-outs which all are expected to flood on a regular basis (annually on average). These areas can receive or lose significant amounts of soil, sand and coarse fragments, depending on the severity of the flood.

Still within the river's high banks, an intermediate level usually exists which consists of gently undulating (2–7%) levees, scrolls and swales and swampy backplains or prior streams. This level experiences flooding occasionally (1 in every 10 years). Flood frequency and depth is not consistent over this level and depends on river constrictions and/or other tributaries entering the river downstream. There are major constrictions upstream of Emery's bridge and Dickabram bridge. Flood flows in Munna Creek and Wide Bay Creek can 'dam up' the Mary River at their confluence and cause floods in the Mary River. The Mary River follows a much confuted path through the study area and this can increase flood severity. During floods, some of the prior streambeds may become the rivers main channel.

The third highest level consists of relict levees, very gently (<4%) sloping or level plains and poorly drained back plains. This level can be up to 1.5 km wide and usually is above current flood heights. When these relict alluvial plains occur on the inside bends of much confuted parts of the river and up stream of major constrictions, these plains will flood occasionally (1 in more than 10 years). Parts of the back plains and areas adjacent to creeks may also experience flooding. This level is absent in narrow parts of the river upstream of Emery's bridge.

The highest level is a very gently to gently sloping peneplain (<5%), which never floods and may represent a Quaternary to Tertiary alluvial plain. Water-worn cobbles dominate the surface of this plain. At times, this plain is only represented by a stranded narrow band of cobbles, upslope of the alluvial plain proper. From existing outcrops it can be hypothesised that the peneplain has an evenfall from a height of greater than 65 m at Bell's Bridge to 40 m at Tiaro. At Tiaro, the plain plunges steeply to a new level that also has an evenfall from 22 m to 18 m at Tinana.

The intermediate two levels discussed above, occur in the lower reaches of Munna and Wide Bay creeks as well as along the Mary River.

Beyond the river, the landscape consists mostly of gently to moderately (4–20%) undulating rises and low hills. The more resistant rock of the *Myrtle Creek Sandstone* (Ortho-Quartzite) and silicified mudstones of the *Maryborough Formation* have formed northwest to southeast trending hills with steep to very steep slopes in the northern part of the study area and at Scotchy Pocket. In the eastern part of the survey at Theebine and between Scotchy Pocket and Gunalda there exists a gently to moderately (4–15%) undulating lava plain of andesite adjacent to the probable sources of lava, Mt Bauple and Mt. Kanigan (Cranfield 1993). These plains have 'steep' rounded off slopes at the margins of the lava plain. The adjacent steep to very steep (>30%) sloping hills and mountains form the eastern boundary of the study area and Mt. Scotchy.

Broad (up to 1.3 km) valley flats have formed along Curra, Durrumomboi, and Gutchy creeks. These creeks meander over the valley flats resulting in poor drainage and for some flats or tributaries, salinity is part of the ecosystem (see next section for a discussion on salinity) The creek usually forms a deep channel with no terraces or other features present. Occasionally the valley flats may experience flash floods of one to two days duration.

Salinity

Within the study area, there is one published study relating to salinity (Wylie *et al.* 1993). The study linked tree decline to poor water quality due to salinity in the Mary catchment. Salinity is known to occur in the lower part of the Mary River Catchment; early studies (Bevege and Simpson 1980, Collings 1987, Hughes 1987, Hughes 1989, Hughes and Kingston 1988, Pearce 1988, Rolfe 1987, Turner and Hughes 1983) include areas in the Maryborough Basin (Cranfield 1994).

During the soil survey, soil salinity at the time of fieldwork was recorded using field and laboratory measurements, and notes were made of any surface or stream expressions of salinity. Seepage salinity on lower slopes and at the margins of valley flats, is the most common form. Broad valley flats with shallow watertables and poor drainage also had evidence of salinity (salt scalds and reduced yields in agricultural crops). There are also a number of creek catchments with constrictions causing shallow watertables to form which in turn causes a build up of soil salinity. Less than 175 ha or less than 1% of the survey area was effected by salinity at the time of fieldwork (April 2001 to April 2002). Table 2 details some sites where salinity was expressing itself during the survey. The occurrence of salinity is recorded in the study database.

Outbreaks of salinity will fluctuate with climate (DNR 1997) and because this study only conducted fieldwork between April 2001 and April 2002, not all areas susceptible to salinity may have shown field evidence of salinity. During wet years, the effects of salinity will be more extensive. The fieldwork for the study was conducted in a relatively dry year. The ‘moving average annual rainfall’ for Theebine in 2001/2002 is below the median annual rainfall (Figure 3) for the last 113 years.

Table 2. Examples of the common forms of salinity, approximate areas affected and locations within the study area

Form of salinity	Area affected (ha)	Location	Details
Seepage salting	15	Slaty creek, “The Reedy”	Lower slopes
Seepage salting	2	East of Kadina siding	Lower slopes
Seepage salting	1	Near Harvey siding	Lower slopes
Shallow watertable	93	Gutchy Creek, Gootchie	Watertable 0.6 to 1.2 m below the surface
Shallow watertable	42	Slaty creek, Scotchy Pocket	Watertable 0.3 to 0.6 m below the surface
Shallow watertable	2	Unnamed tributary of Durramboi creek, Kadina siding	Watertable at surface, scald areas
Restricted drainage	8	Pots creek, Patterson	
Poor stream water quality		Gutchy Creek, Gootchie and Kanigan	
Poor groundwater		West of Mt Scotchy	Footslopes and drainage lines

A ‘moving average’ is calculated by averaging annual rainfall over a short period such as 5 or 10 years rather than over all years. The years against which the annual rainfall is averaged against is moved forward a year for each year. For example, for a hundred year period, annual rainfall for year one is averaged against years one to five. Year two is averaged against years two to six and so on. This has the effect of smoothing out yearly fluctuations and allows us to determine if periods were wetter than others.

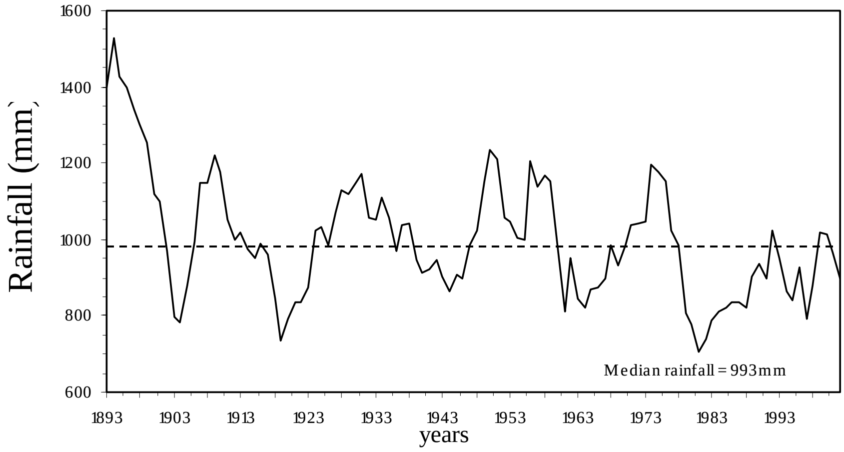

Figure 3 Five year moving average rainfall for Theebine over 113 years. Source: Climate applications group, Department of Natural Resources and Mines.

Salinity has been shown to be associated in the 'Maryborough Basin' with sedimentary formations that where laid down in a marine environment (*Maryborough Formation*), sediments which were laid down in a fresh water environment (Cretaceous *Burrum Coal Measures* and Jurassic *Tiaro Coal Measures*) and igneous rocks and interbedded sediments of the Jurassic Grahams Creek Formation. Apart from *Burrum Coal Measures*, all these geologies are present in the study area.

Groundwater resources are expected to be of poor quality and only suitable for stock watering in most of the study area. Pearce (1988) found conductivity levels of 0.095–1.350 dS/m in aquifers contained in the fractured shale of the *Maryborough Formation* and 1.0–3.0 dS/m in aquifers of the fractured interbedded shales/sandstones of the *Tiaro Coal Measures*. Pearce (1988) also found that the fractured andesite and tuffs of the *Grahams Creek Volcanics* had aquifers with conductivity greater than 0.095–1.350 dS/m. Collings (1987) found similar trends with piezometers intersecting the mudstone and siltstone of the *Maryborough Formation* to have conductivity levels of 4.8 to 17.6 dS/m with a mean of 11.7 dS/m. The dominant form of salts in solution is NaCl (Pearce 1988; Rolfe 1987; Bevege and Simpson 1980). Groundwater occurring in the overlying Tertiary *Elliott Formation* as perched watertables was found to have very good water quality (Turner and Hughes 1983). However, these watertables contributed to raised groundwater levels in nearby drainage lines and to seepage in lower slopes causing salting.

No significant soil salt concentrations were found within the top 1.2 m of soil profiles within the Vacant Crown Land study (Turner and Hughes 1983). These results reflect the relatively undisturbed nature of the study area and are consistent with the latertic sediments, which cover the area. However, Hughes and Kingston (1988) found significant amounts of salts in the root zone which led to growth restrictions to sugarcane on land, where cleared and dominated by *Burrum Coal Measures.*

Melaleuca quinquenervia, M. nodosa, M. cheelii, Casuarina glauca, C. cunninghamiana, Eucalyptus tereticornis and *Banksia robur* have been found to be associated with poorly drained areas susceptible to salinity (Kingston 1987, Rolfe 1987, Wylie *et al.* 1993). *C. glauca* and *M. nodosa* are common in saline areas within the study area.

During the development of pine plantations at Wongi State Forest, Rolfe (1987) reported that salt outbreaks occurred after large scale clearing (1000–2000 ha) of native vegetation in 1978. Groundwater rose to within 0.5 m from the surface in places after clearing. In 1983, salt seepage appeared to be eliminated when clearing was conducted in a mosaic pattern of 20–400 ha plots and natural vegetation was retained along drainage lines (Rolfe 1987). No salt outbreaks were found in forested areas of the survey however in such situations, salt adapted species would be growing at the site and therefore salinity may not be apparent even though present. Clearing has cause changes in the hydrology of the area and resulted in the existing salt outbreaks.

Decline of *Casuarina* and *Eucalyptus* species in the Mary River Catchment has been linked to land clearing and subsequent decline in stream water quality. Wylie *et al.* (1993) found that trees suffering from poor water quality were more susceptible to defoliation by the beetle, *Rhyparida limbatipennis*. Susceptibility of landscapes to secondary salinisation is discussed chapter 4.

Vegetation

The vegetation of Queensland has been systematically classified using a hierarchal system, which has four levels: Bioregions; provinces; regional ecosystems/land zones; species; and genotypes (Sattler 1999). The native vegetation described in this report uses this system.

The Gundiah–Curra study area is situated centrally within the *South-East Bioregion*, which is characterised by moderate to high rainfall (800–1500 mm per year) and a subtropical climate (See previous section for more detail on climate). This bioregion lies to the east of the Great Dividing Range and includes a number of mountainous areas and as well as a distinctive coastal plain with low relief. It is divided into 10 provinces (Sattler 1999), with the Gundiah–Curra area located entirely in the '*Burnett-Curtis Coastal Lowlands*' province. This province is largely based upon the Maryborough Basin (See Section 2.4 for detail on geology), and is drier than the *Great Sandy* (Fraser Island and Cooloola areas) and *Southern Coastal Lowlands* (Nambour basin) provinces to the south. It has a marked tropical component to its biota (Sattler 1999) and major vegetation types include heath lands, *Melaleuca quinquenervia* open forests, and eucalypt woodlands or open forests (Sattler 1999). Eucalypt open forests are most dominant in the study area.

Fourteen regional ecosystems occur within the study area. A regional ecosystem describes the relationship between the major vegetation and the environment described as land zones (Sattler 1999). There are 145 regional ecosystems within the *South-East Bioregion*, 7% (10 ecosystems) occur within the study area which occupies 0.3% of the bioregion. The study area is located in an area of vegetational change with the most easterly, southerly and northern extent of species. For example, Silver-leaved ironbark (*Eucalyptus melanophloia*) which is common in the Burnett region, is uncommon and nearly at its most easterly extent in the study area (pers. comm.). The study area lies at the southern margin of the Maryborough basin where there are many changes in land zones and thus many ecosystems.

There are six land zones in the study area. Land zones are geomorphic categories that describe the geology and landform of a regional ecosystem (Sattler 1999). Table 3 correlates land zones with that of the 1:250 000 geology map of the area and the geomorphic units used to group soils in the study area.

Table 4 shows: the regional ecosystem number, gives a simple form of the ecosystem, lists the dominant and associated species for that ecosystem, shows the land zone to which it belongs, and indicates where it occurs and how much area it covers in the study area. The ecosystem description may differ to that provided by Sattler (1999) because regional ecosystems cover a wider area and some associated species are not always present. Land zones are also more precisely defined due to the small area this survey covers.

Table 3. Land zones, related geological units and corresponding geomorphic units for the study area.

Land Zone	Description (Sattler 1999)	Geological Units	Geomorphic Units (i.e. landscape headings from the soil map reference)
3	Cainozoic alluvial plains	Qa, Qha1, Qha2, Qpa	Alluvial plains of the Mary River and local creeks
5	Cainozoic sand deposits often over laterite	TQa, Td, Te, Jkg	Deeply weathered sedimentary rocks; deeply weathered andesite rock
9	Cainozoic to Proterozoic unaltered fine-grained consolidated sediments	Kms, Km, Jdt	Moderately weathered fine-grained sedimentary rocks
10	Cainozoic to Proterozoic unaltered coarse-grained consolidated sediments	RJdm	Moderately weathered coarse-grained sedimentary rocks
11	Mesozoic to Proterozoic metamorphic rocks	Rk	Phyllite rocks
12	Mesozoic to Proterozoic igneous rocks	JKi, JKg	Moderately weathered microdiorite/andesite

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Table 4. Regional ecosystems of the Gundiah–Curra area

No.	Ecosystem concept	Land zone	Dominant species	Location
12.3.1	Complex to simple notophyll rainforest on alluvial soils	Alluvial plains	Fringing notophyll/microphyll vine forest of rough-leaved elm (*Aphananthe philippinesis*) and red kamala (*Mallotus philippensis*) and emergent forest red gum (*Eucalyptus tereticornis)* and swamp box mahogany (*Lophostemon suaveolens*).	Mary River and local creeks
12.3.11	Tall open forests on alluvial plains	Alluival plains	Ironbark (*Eucalyptus siderophloia*), pink bloodwood (*Corymbia intermedia*), forest red gum (*E. tereticornis*) with smooth-bark apple (*Angophora leiocarpa*), Queensland peppermint (*E. exserta*), swamp box (*Lophostemon suaveolens*), Moreton Bay ash (*C. tessellaris*), lemon-scented spotted gum (*C. citriodora* ssp.*varigata*), and paperbark (*Melaleuca quinquenervia*).	Mary River and local creeks
12.9.3	Gum-topped box/lemon-scented spotted gum open forest on mudstones	Unaltered fine-grained consolidated sediments	Gum-topped box (*Eucalyptus moluccana*) and lemon-scented spotted gum (*Corymbia citriodora* ssp. *varigata*) with grey ironbark (*E. siderophloia*) or narrow-leaved red ironbark (*E. crebra*), and forest red gum (*E. tereticornis*). Understorey sparse.	Curra Estate, west of Munna–Miva Road and Sexton Road
12.9.19	Ironbark open forest on fine-grained sedimentary rocks	Unaltered fine-grained consolidated sediments	Broad-leaved ironbark (*Eucalyptus fibrosa* ssp. *fibrosa*) with lemon-scented spotted gum (*Corymbia citriodora* ssp.*varigata*), white mahogany (*E. acmenoides*), smooth-bark apple (*Angophora leiocarpa*) and large-fruited grey gum (*E. major*). Understorey sparse.	Patterson
12.10.2	Lemon scented spotted gum open forest on sandstone	Unaltered coarse-grained consolidated sediments	Lemon-scented spotted gum (*Corymbia citriodora* ssp. *varigata*) and narrow-leaved red ironbark (*Eucalyptus crebra*) with forest red gum (*E. tereticornis*), and pink bloodwood (*C. intermedia*). Understorey grassy with brush box (*Lophostemon confertus*).	West of Scotchy Pocket Road
12.10.21	White mahogany open forest on sandstone	Unaltered coarse-grained consolidated sediments	White mahogany (*Eucalyptus acmenoides*) with pink bloodwood (*Corymbia intermedia*) and smooth-bark apple (*Angophora leiocarpa*), large fruited grey gum (*E. major*), gum-topped box (*E. moluccana*), Queensland peppermint (*E. exserta*), and brush box (*Lophostemon confertus*).	Sexton
12.11.5	Mixed tall open forest with lemon-scented spotted gum on phyllite	Metamorphosed sediments	Lemon-scented spotted gum (*Corymbia citriodora* ssp.*varigata*) with grey ironbark (*Eucalyptus siderophloia*), narrow-leaved red ironbark (*E. crebra*), Large-fruited grey gum (*E. major*), mountain grey gum (*E. longirostrata*), and white mahogany (*Eucalyptus acmenoides*).	Corella-Harvey Siding
12.12.7	Narrow-leaved red ironbark grassy woodland on andesite	Igneous rocks	Narrow-leaved red ironbark (*Eucalyptus crebra*) with Queensland peppermint (*E. exserta*), forest red gum (*E. tereticornis*), Moreton Bay ash (*C. tessellaris*), and lemon-scented spotted gum (*Corymbia citriodora* ssp.*varigata*).	Mount Scotchy
12.12.8	Silver-leaved ironbark grassy woodland on andesite	Igneous rocks	Silver-leaved ironbark (*Eucalyptus melanophloia*) with narrow-leaved red ironbark (*E. crebra*) and Queensland peppermint (*E. exserta*), forest red gum (*E. tereticornis*), Moreton Bay ash (*Corymbia tessellaris*), and lemon-scented spotted gum (*C. citriodora* ssp. *varigata*).	Patterson
12.12.12	Forest red gum and narrow-leaved red ironbark woodland on andesite	Igneous rocks	Forest red gum (*Eucalyptus tereticornis*) and narrow-leaved red ironbark (*E. crebra*) with silver-leaved ironbark (*melanophloia*), Moreton Bay ash (*Corymbia tessellaris*), broad-leaved apple (*Angophora subvelutina*) and smooth-barked apple (*A. leiocarpa*).	Theebine

Land use

Grazing for beef production is the dominant land use in the study area. Grazing for milk production was until recently (2000) the second most common agricultural land use in the area, however with the deregulation of the dairy industry in 2001, four of the nine dairy farms have left the industry. Prior to deregulation, the dairy industry had been gradually contracting in the study area. In 1997, a land use study of the Mary River Catchment (Pointon 1998) shows that there were thirteen diary farms within the study area. At the time of the survey, nine and post deregulation, five farms. A total of 27% of grazing is carried out on improved pastures in the study area, with 12% of this being for milk production. Native pastures dominate the beef grazing industry.

Land for rural residential and urban purposes (lots <10 ha) is now the second biggest land use in the study area (12% or up to 2700 ha). Land used for rural residential purposes is expected to increase due to current holdings being made up of multiple lots, an ageing farming population and proximity to high growth areas such as Gympie and the Sunshine Coast.

Land for timber production accounts for 8% of the study area. This consists of 510 ha of State Forest and 1329 ha of freehold land. There are no exotic or native timber plantations in the study area, however east of the study area there is an extensive area of state forest with both native hardwood and exotic softwood plantation timber. Timber production from the lands within the study area are expected to decline due to unsustainable timber harvesting and lack of plantation establishment. The area has great potential for a plantation and native timber industry due to suitable land, proximity to timber industry infrastructure and proximity to a rapidly expanding population and market.

Land used for sugar cane production accounts for 4% of the study area. A number of former dairy and grazing properties on the alluvial soils of the Mary River have converted to sugar cane growing in recent times. The industry is expanding in the area. In 1997, 398 ha (Pointon 1998) was used for cane production; in 2002, 840 ha is being used. The cane is trucked to, and milled in Maryborough.

Mangoes, avocados and cut flowers (Scotchy Pocket, Miva, Harvey Siding) are the only horticultural crops grown in the study area and account for 0.3% of the land. Other minor land uses observed in the study area included meat goats, yabbies, prawns, nursery, horse spelling, forage crops, stud cattle, and minor light manufacturing industry.

There are four very small towns in the study area (Gundiah, Gunalda, Miva at Dickabram Bridge and Theebine). Gundiah (hotel and school), Gunalda (hotel, shop, school), and Theebine (hotel and school) provide services. Table 5 shows a breakdown of land uses in the area and how it has changed since 1997.

Table 5. Land use within the study area

Land Use (categories)	Land use change				
	1997		2002		
	Area (ha)	% of total area	Area (ha)	% of total area	Change %
Total livestock grazing	**18769**	**87%**	**16029**	**75%**	-15
Beef cattle grazing – native pasture	15815		11179		
Beef cattle grazing – improved pasture	?		3876		
Dairy cattle grazing – native pasture	1887		384		
Dairy cattle grazing – improved pasture	1067		486		
Other livestock grazing (meat goats, horses)	?		104		
Total urban and rural residential	**1314**	**6%**	**2700**	**12%**	+105
Rural residential			2674		
Urban			26		
Total timber production	**510**	**2%**	**1839**	**8%**	+261
Freehold native forest used for timber production	?		1329		
State forest used for timber production	510		510		
Total cultivation (excluding cultivation for pasture establishment)	**711**	**3%**	**966**	**4%**	+36
Sugar cane	398		840		
Horticulture (avocados, mangos, cut flowers)	19		73		
Maize	0		14		
Forage crops	294		39		
Other (minor industry, aquaculture, nurseries)	**3**	**-**	**12**	**1%**	+300

* from Pointon, 1998.

3. Soils

Previous investigation

The survey area is part of the Coastal Lowlands of Southern Queensland (Coaldrake, 1961). This area has a similar range of soils to the study area. The first detailed account of any soils of this region was given by Tommerup (1934) who mapped ten soil series north of Maryborough. Other soils studies relevant to this area are by Bryan (1939), Hubble (1954), Teakle (1950), Thompson (1966), Bridges *et al.* (1990), Ross and Thompson (1991).

A reconnaissance soil survey had been undertaken by Coaldrake (1961) for his study into the ecosystems of the coastal lowlands. Subsequently, work by Hubble (1954) and others had been incorporated into the Atlas of Australian Soils, Sheet 4 by Isbell *et al*. (1967). The work of DPI Staff (1992) for the Maryborough District Land Management Manual and the work by Dwyer (1990) for the Gympie/Nambour Soil Conservation project report can be considered as soil landscape mapping.

A number of medium intensity soil surveys have also been conducted in the area. These include an unpublished report on the Soil associations in the Maryborough–Tinana Area (Smith *et al.* 1981); Soils of the Beaver Rock Area (Wilson, 1994); Soils of Maryborough–Hervey Bay Area (Wilson *et al.,* 1999), and two adjoining soil surveys by Zund and Brown (2001); and Pointon and Collins (in prep.).

Within the lower Mary River Catchment, a number of investigations into land use have been undertaken. They have resulted in the Coastal Land Use Study (Queensland Coastal Lowlands Land Use Committee 1976a) and Maryborough–Elliott River Land Use Study (Queensland Coastal Lowlands Land Use Committee 1976b) reports. Since those studies were completed, a number of land evaluation studies have also been undertaken in the survey area. These include a sugar cane land suitability survey of vacant crown land surrounding Maryborough (Turner and Hughes, 1983), a study of irrigated sugar cane land suitability for the Maryborough Sugar Factory by Leverington (1986 and 1993) and Macnish and Leverington (1984), and a planning study for the Maryborough Sugar Factory area (DPI, 1988) which assessed the suitability of cane assigned areas.

Survey methodology

Soil and land suitability information for the Gundiah–Curra study area has been mapped, described and published at a scale of 1:50 000. Mapping used 1:25 000 colour aerial photographs (August 1993) and fieldwork was undertaken between April 2001 and April 2002. During the reference making phase a number of transects that were representative of the geologic landscapes in the study area, were described. From these transects, dominant soil profile classes were identified, most of which had been previously described in other soil surveys from the Wide Bay area (Wilson 1997, Wilson *et al.* 1999, Zund and Brown 2001, Pointon and Collins 2004). Airborne radiometric data, field information from transect sites and a digital elevation model were used to model and map soil parent material in the study area.

During the mapping phase, soils associations were mapped using aerial photo interpretation, the predicted parent material map and field inspection. An understanding of local landscape processes and vegetative indicators was used to predict the soil distribution during field mapping. Field sites were selected to confirm soil predictions or to understand complex soil patterns. At least one site every 50 ha was described in the field and the data recorded in the NR&M Soil and Land Information (SALI) database. Areas with better soils and more agricultural potential were surveyed more intensely. The above methodology is based on standards set by Reid (1988) and McDonald *et al.* (1990).

Soils were examined and described in the field from undisturbed intact cores. These were collected using a 1.8 m (0.05 m diameter) coring tube and a light truck-mounted hydraulic ram. In addition descriptions from road cuttings, root mounds, termite mounds and hand augered profiles were also used. Changes in surface texture, vegetation and landscape features were used in conjunction with photo pattern interpretation to determine soil boundaries.

In all, 393 field sites were described, with a survey intensity consistent with a publication scale of 1:50 000. As such, the study represents a medium intensity survey (Reid 1988) in which final map units are at least 5 ha in size or larger. Areas smaller than 5 ha are recorded as minor soils within a mapping unit. Fifty five soil and land characteristics were described according to McDonald *et al.* (1990) at all 393 sites. The recorded site information is stored in the NR&M SALI database.

Each polygon on the map represents a Unique Map Area (UMA) and has been assessed individually for a range of soil and land attributes. It is important to note that an area of uniform soil can sometimes be subdivided into more than one UMA because other land attributes change over the area (eg. an adjacent UMA may have the same soil but different slope classes). For each UMA, 22 limitations to land use were determined from the soil and land attributes recorded for that map unit. These limitations identified were used to determine land suitability for 36 different land uses and the overall agricultural potential of the UMA. For further information on land evaluation methodology, see Chapter 4 and the *Guidelines for Agricultural Land Evaluation in Queensland* (Land Resource Branch Staff 1990). All soil and land attribute, limitation and land suitability data for each UMA (mapping unit) is stored in the NR&M SALI database.

Soil mapping units

The main factors controlling soil formation in the study area are parent material (lithology), landscape position, drainage and time. Soils have been grouped into soil-landscapes (as defined by Gunn *et al.* 1988) according to parent material and landscape. Table 6 correlates the five soil-landscapes identified in the study area with the corresponding Land Resource Areas (LRA) described in the *Coastal Burnett Land Management Manual* (Thwaites 1991).

Table 6. Soil landscapes and corresponding Land Resource Areas

Soil Landscapes	Land Resource Areas (DPI Staff 1992)
Alluvial Plains of the Mary River	Alluvium LRA
Hillslopes on moderately weathered sedimentary rocks	Uplifted Coastal Plains LRA
Hillslopes and plains on deeply weathered sedimentary rocks	Coastal Plains LRA
Plains on deeply weathered intermediate rocks (Andesite)	Acid Volcanic LRA
Hillslopes on moderately weathered acid to intermediate rocks (Rhyolite, microdiorite and andesite)	Acid Volcanic LRA

Within a soil landscape, a range of soils can be developed depending on lithology, landscape position and drainage. In all, 37 soil profile classes were identified and are described in detail in Appendix I. The distribution of these soils is shown on the accompanying soils map. The mapping units are named after the dominant soil, but represent soil associations that often contain more than one soil. Associated soils do not necessarily occupy a predictable distribution and at any particular point, the dominant soil may not always be encountered. It is important to note that the boundary between two adjacent soil mapping units may occur over some distance (hundreds of metres) because soils typically change gradually and often form a continuum. The mapping units have been grouped according to the dominant orders from the Australian Soil Classification (Isbell 1996) and subgrouped on a soil landscape basis (see Table 6).

A key to the soils is available in Appendix II to assist in the identification of soils at any point in the landscape and should be used in conjunction with the soils map. All soil morphological terms used in this report are defined in McDonald *et al.* (1990) and Isbell (1996). General texture groups referred to in the text are: sandy (sand, loamy sand, clayey sand and sandy loam which have less than 20% clay); loamy (fine sandy loam, loam, sandy clay loam and clay loam which have 20–35% clay); and clayey (light clay to heavy clay which have greater than 35% clay).

Soil analyses

A total of ten representative profiles were sampled for detailed laboratory analysis from the study area. Sampling locations were carefully selected to represent typical examples of the major soil profile classes. Full profile morphology, landscape characteristics, vegetation and analytical data for each of the representative profiles are presented in Appendix III.

In addition, analytical data from 394 analysed sites from other projects in the region have been used where relevant and appropriate. Analytical methods and nutrient ratings are based on Baker and Eldershaw (1993). Discussion of the physical and chemical properties of each soil is based on the representative analytical sites and information from the Childers and Maryborough studies (Wilson, 1997, Wilson *et al.* 1999).

Soil chemistry is discussed in terms of soil pH, salinity, sodicity, soil nutrients and plant available water capacity (PAWC). Soil pH represents the degree of acidity (pH <7) and alkalinity (pH >7) in a soil, while salinity is a measure of the concentration of soluble salts in the soil solution. Electrical conductivity (measured as $EC_{1:5}$ = 1 part soil to 5 parts water) measures total soluble salts in dSm^{-1}, while levels of soluble chloride are presented as percentages (w/w). Sodicity is defined as the ratio of exchangeable sodium to cation exchange capacity and expressed as a percentage (ESP). Soils with an ESP <6 are non sodic, while those with ESP 6–15 and ESP >15 are sodic and strongly sodic respectively. High levels of exchangeable sodium ions cause poor soil physical conditions due to dispersion of clay particles. Soil fertility measures the ability of a soil to supply nutrients for normal plant growth.

PAWC is an estimate of the amount of water stored in the soil profile (after normal drainage) down to the effective rooting depth. It represents the stored moisture available for plant growth. The model developed by Littleboy (1997) based on the work of Shaw and Yule (1978) was used to estimate plant available water capacity (PAWC). The model uses moisture content at a matric potential of –1500 kPa and percent rock, sand, silt, and clay to estimate the amount of stored water in the soil profile that is available for plant growth. Effective rooting depth was taken to be 1.0 m or the depth to rock, hardpans, high salt levels ($EC_{1:5}$ > 0.8 dS/m) or where a rapid rise in profile EC (ie. salt bulge) indicates the depth of regular wetting if <1.0 m.

Soil – landscape relationships

This section outlines the relationships between geologic landscapes and soil development. It describes the origins of each soil and reasons for soil changes across the landscape. Soils have been placed into groups that share similar landscape positions and lithology. Reference to individual soil profile classes in the text are indicated by (*bracketed italics*). Further detail on each soil is available later in this chapter and Appendix I. Soil – landscape relationships are illustrated diagrammatically in Figures 4–7.

Soils overlying alluvium

These soils have developed from alluvial sediments such as clay, sand and gravel. This landscape includes all alluvial soils along the Mary River and major creeks in the study area. The alluvial landscape along the Mary River is a mature system and consists of a series of distinct terraces. The terraces are the result of stream incision and refilling in response to oscillating sea levels during the last two million years (Ferguson 1969, cited in Bridges *et al.* 1990). Sediment age increases from the lowest terrace to the highest plain. The highest terrace has been cut into country rock prior to the Pleistocene period and consists of bed load material (mainly cobbles) from an ancestral Mary River (Bridges *et al.* 1990). This high terrace is not consided part of the present day alluvial landscape. For more information on geological history and landscape development, refer to Chapter 2.

During the late Pliocene to Pleistocene epoch, when sea levels were much lower than now, incision of the present day inner river valley occurred (Bridges *et al.*, 1990). Within the inner valley there can be up to four levels. The highest and oldest level, which is not always present, is a residual peneplain of bed load material (mainly cobble size fragments). This plain was most probably laid down during the early Pleistocene epoch (TQa). It was subsequently incised during the Pleistocene epoch and later built up again with fine sediments to form extensive plains (Qpa) above the present terraced land. Clayey soils have formed on these plains which have been exposed to weathering since the Pleistocene epoch.

The high level plains were further incised during the Holocene epoch in response to more recent sea level changes (Qha2). The new terraces that formed are regularly flooded and have actively built up as a result of sediment deposition. A lower terrace or channel bench (Qhal) has formed along parts of the river which flood annually.

Alluvial sediments have also built up at low points in the landscape along modern creeks (Qa). These sediments vary depending on the lithology of the catchment. There is little evidence of active incision into the local alluvium, apart from that associated with gully formation. A small levee is present along some of the major creeks in the study area. Figure 4 illustrates the relationships between geology, landscape position and soils within the alluvial landscape.

Soils on the older plains (Qpa) and the peneplain (TQa) of the Mary River have formed from sediments deposited in the Pleistocene epoch. The peneplain (TQa) is mainly composed of bed-load gravels and cobbles of an ancient Mary River. The coarse fragments are between 0.04 and 0.20 m in diameter and have smooth rounded shapes, which confirm their alluvial origin. These rocks are composed of a variety of hard igneous and metamorphic lithologies that have withstood the river's erosive environment. The *Johnson* soil has formed where deposits of relatively softer rocks are present within the sediments. Despite being exposed to weathering processes since the Pleistocene epoch, only a thin layer (<0.3 m) of sand to sandy clay loam has formed between the large cobbles. Some deeper profiles have a thin bleached horizon indicating the age of the soil.

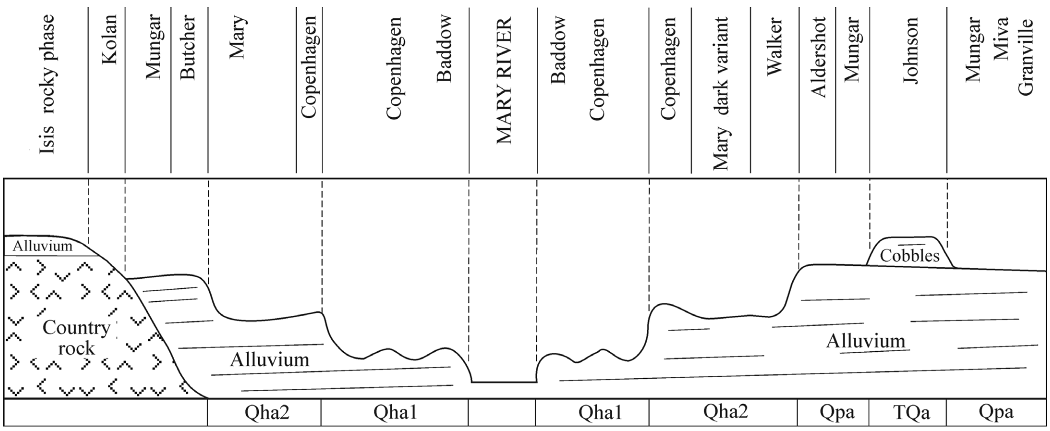


Figure 4. Geology, lithology and associated soils of alluvial landscapes.

The extensive plains (Qpa) adjoining the Mary River consist of fine sediments that were deposited in a quiet environment. These sediments gradually become finer further from the river, with the river margin usually marked by a relict levee of sandier sediments. In some bends of the river, a series of relict levees can occur with shallow swales in between. All the soils in this landscape have been subject to weathering since the Pleistocene epoch (up to 2 million years). Sodosols *(Butcher)* have formed where sandier sediments occur on slightly elevated levees while on the finer sediments of the backplains uniform clay soils have mainly formed (*Miva, Mungar* and *Granville*).

The better drained levees are typically more weathered and have developed distinct texture contrast profiles. (ie. large texture difference between the surface and subsoil horizons). Surface horizons are usually thicker and sandier than other alluvial soils. Some of the levees along the margin of the plain are better drained and red brown structured soils (*Aldershot*) have formed. In all other soils however, sodium has accumulated in the subsoil and bleached surface horizons are usually evident in undisturbed profiles. These features indicate the soils have undergone significant weathering. The better-drained parts of the plains (other than the levees) are occupied by the darker, alkaline *Miva* soil. In areas with poorer drainage (drainage depressions and backplains) soils are either alkaline and brown (*Mungar)* or acid and grey (*Granville),* depending on the origin of the parent material.

Below the high level plains and within the present active river system, landform elements include terrace and channel bench components, often as a series of scrolls and/or terraces. Fresh sediments are deposited regularly in these areas and include fine gravels and sands to fine clay sized sediments (grading finer further from the stream channel). All soils are dark and structured and range from loamy soils on levees (*Copenhagen*) to light clay soils on scrolls and swales (*Mary*) and medium to heavy clays in back swale areas. Floods occur on a regular basis and can change the surface characteristics of the soil depending on sediment deposition.

Soil salinity within the profile is below critical levels (EC < 0.8 dS/m) in all soils on the alluvial plains and terraces of the Mary River. Subsoils of the clay soils (*Miva, Mungar* and *Granville*) on the older high plain approach critical levels at depths below 0.8 m, indicating impermeable lower subsoils.

On alluvial plains associated with local creeks, a number of different soils have developed depending on the dominant lithology of the surrounding catchment. Alluvial sediments derived from sedimentary and meta-sediment (phyllite) rocks, are typically associated with acid non cracking grey clays (*Woober*). Alluvium derived from both sedimentary and andesitic rocks is associated with alkaline non-cracking grey or brown clays (*Timbrell*). Alluvium derived solely from andesitic rocks is associated with grey or black cracking clays (*Pelion*). Sandy alluvium derived from silicious sandstones of the *Myrtle Creek Sandstone* (RJdm) is associated with sandy soils (*Littabella*) in the Harvey Siding area. An unmapped sodic texture contrast soils (*Peep*) may be assocated.

The alluvial plains of most local creeks occupy broad (up to 1.3 km wide) valley flats often characterised by a sinuous stream channel and very little fall in the landscape. This has resulted in the development of a poorly drained landscape and soils that are saturated during the wet season. Soils are typically grey and mottled with a bleached subsurface in undisturbed situations. Poor soil drainage has allowed a build up of salts above critical levels (EC >0.8 dS/m) in some profiles. Slightly better drained profiles occur only near stream channels. The *Gutchy* soil sometimes occurs on alluvial fans with slightly better drainage.

The soils developed on alluvium of sedimentary rocks (*Timbrell* and *Woober*) have a lower fertility than those derived from andesitic rocks (*Pelion* and *Gutchy*).

Soils overlying moderately weathered sedimentary rocks

Soils in this group have formed from moderately weathered sedimentary rocks. These rocks formed from sediments deposited in the Maryborough Basin during the Triassic and Cretaceous periods. The rocks were subsequently folded and further covered by sediments during the Tertiary period. A long period of deep weathering then occurred followed by the dissection and partial removal of these sediments from the Tertiary landscape exposing the underlying rocks that were not significantly altered. In areas where dissection has subsequently exposed these rocks they are considered only moderately weathered. Because of folding, some of the sedimentary rocks from the Triassic and Cretaceous periods (RJdm, Jdt, Km) were never covered by Tertiary sediments. These rocks occurred on anticlines of folds (ie. the highest parts of the landscape) and were deeply weathered during the Tertiary period. For more detail on geological history and landscape development, refer to Chapter 2.

For the purposes of this study, moderately weathered sediments are defined as those showing clear evidence of bedding and evidence of primary minerals (eg. feldspars) while deeply weathered sediments display little or no bedding and evidence of laterisation. Figure 5 shows the relationships between geological formation, weathered zone and landform for this landscape.

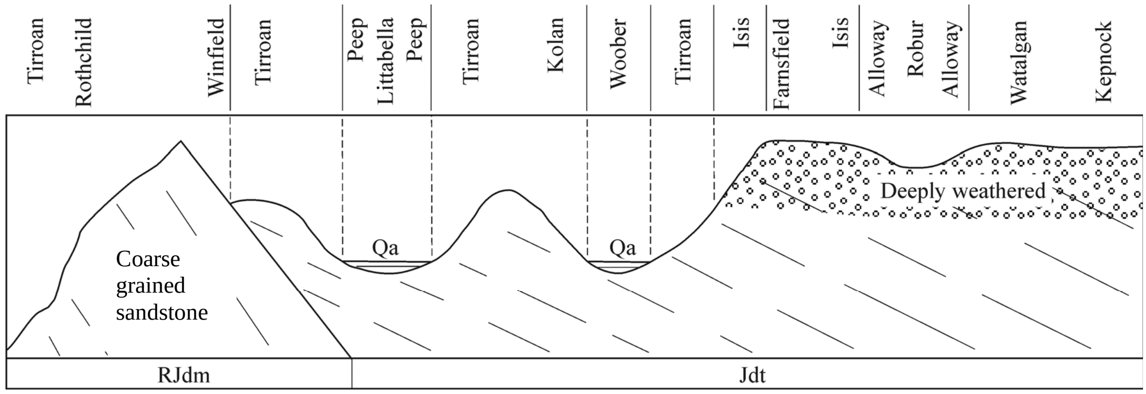


Figure 5. Geology, lithology and associated soils of sedimentary landscapes

Myrtle Creek Sandstone (RJdm) is the oldest sedimentary formation in the study area and dips to the north east. It outcrops as hills in the western part of the study area. Lithology is predominantly consisting of quartzose, coarse grained sandstones dominated by quartz and sodic felspars, some of which have been cemented by silica to form resistant ortho-quartzite bands. The crests of hills are usually rocky (quartzite) with shallow sandy soils. On lower slope positions, either deep sandy surfaced, sodic texture contrast soils (*Tirroan*) or deep sands (*Rothchild* or *Winfield*) have developed, depending on the degree of siliceous or felspar mineral in the parent material. Some of the sands have been strongly leached (podzolised) and iron, aluminium and organic compounds have accumulated as soft pans directly above the more resistant sandstones (*Rothchild podzolic variant*). In lower slope positions, soil drainage is slower and subsoils become more sodic and dispersive.

In areas lying immediately east of the *Myrtle Creek Sandstone* (RJdm), soils are formed from fine grained sandstones, mudstones, and shales of the *Tiaro Coal Measures* (Jdt). This formation is thinly bedded and strongly dipping. As a result, soils change rapidly over short distances. The rocks are dominated by felspars, although the exact mineralogy differs between beds. Loamy surfaced, strongly acid, sodic texture contrast soils (*Kolan*) or strongly acid clays (*Bucca*) have formed from the mudstones and shales; while sandy (*Tirroan*) or loamy (*Givelda*) surfaced, sodic texture contrast soils have formed from the fine grained sandstones.

Soils overlying deeply weathered sedimentary rocks

Soils in this group have formed from deeply weathered sedimentary rocks. These rocks have formed from sediments deposited during or before the Tertiary period and subject to significant deep weathering during the Tertiary coarse grained sedimentary rocks where deeply weathered and a range of sandy, loamy and clay soils have formed. Where the rocks were highly siliceous sandstones, deep sands have formed (*Rothchild* and *Winfield*). Coarse grained rocks high in siliceous and felspar minerals have produced sandy surfaced texture contrast soils (*Alloway, Isis* and *Robur*) or gradational soils (*Farnsfield*), while fine grained sandstones or mudstones dominated by siliceous and felspar minerals have produced loamy surfaced texture contrast and gradational soils (*Kepnock* and *Watalgan*).

The deeply weathered landscapes are usually level to very gently undulating. Soil colour is directly related to soil drainage and position in the landscape. In slightly elevated positions or along margins of the deeply weathered plains, the red *Watalgan* and *Farnsfield* soils occur. In drainage depressions or areas with impeded drainage, grey texture contrast soils (*Alloway* or *Robur*) occur. In some of the drainage depressions, sodic texture contrast soils (*Robur*) have formed due to restricted drainage. Soils with yellow subsoils such as *Isis* and *Kepnock* usually occur in intermediate positions. Ferruginous and ferromanganiferous nodules are common to all soils in this landscape. The nodules have formed as a result of seasonal weathering over a long period of time and are usually found in the lower half of the subsurface horizons. Figure 5 illustrates the relationships between geology, landscape position and soils within the deeply and moderately weathered landscape.

Soils overlying acid to intermediate igneous rocks

Soils in this group have formed from acid to intermediate igneous rocks. These rocks are associated with volcanic activity during the Jurassic and Cretaceous periods and include intermediate lavas (andesite), intermediate intrusives (microdiorite) and acid volcanics (rhyolite, rhyolitic tuff). Similar soils have formed from both intermediate rock types and they are often difficult to distinguish in the field. The intermediate rocks are dominated by sodic and potassic felspars, hornblende, biotite and other dark minerals. Quartz is mostly absent. Because the parent material is high in clay forming felspars, gradational and uniform clay soils have typically formed. The dark minerals in these rocks have contributed to the elevated soil fertility status of these soils.

On crests and upper slopes, soils are often rocky and shallow (*Tiaro rocky phase*) but grade to deeper versions down slope, (*Tiaro*). The soils in this group are well structured and moderately well drained in mid and upper slope positions. A thin sporadically bleached subsurface horizon is sometimes present in mid to lower slope positions (*Netherby*). On older lava flows and exposed intrusions, sodic texture contrast soils (*Owanyilla*) with conspicuously bleached subsurface horizons have developed. These soils are mature, highly weathered, poor in nutrients and have very sodic subsoils. Because microdiorite sills and dykes are often interbedded with sediments of the *Tiaro Coal Measures* (Jdt), abrupt soil changes are common and soil distribution patterns are complex. Such patterns have not always been mappable at the 1:50 000 scale. Figure 6 illustrates the relationships between geology, landscape position and soils for an interbedded sedimentary/microdiorite landscape (left side of figure) and a landscape dominated by andesite (right side of figure).

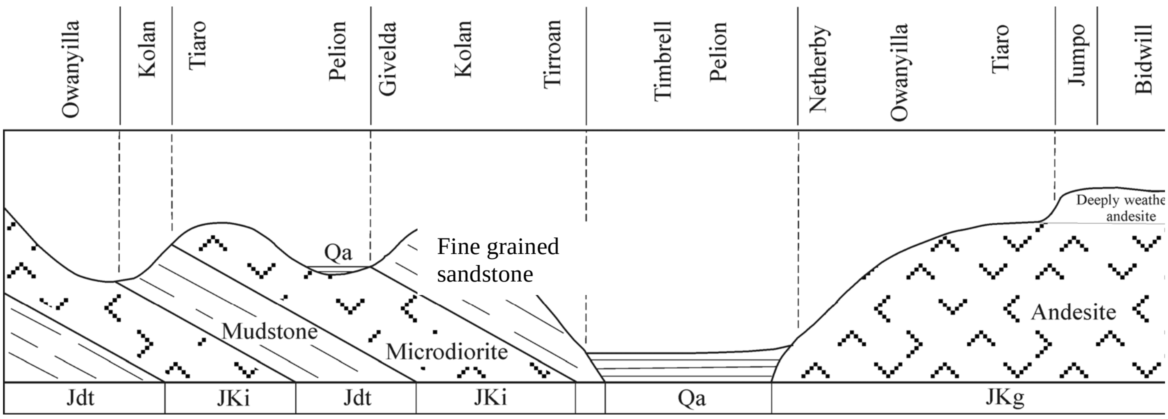


Figure 6. Geology, lithology and associated soils of acid to intermediate igneous landscapes

Rhyolitic flows (ie. acid volcanics) occur in the south eastern part of the study area. Similar soils have formed on the rhyolites to those formed from mudstones *(Kolan)*. They are texture contrast soils with strongly sodic and strongly acid subsoils. Because of their limited occurrence, they have not been mapped separately from the equivalent soils of sedimentary origins.

Soils overlying metamorphosed sedimentary rocks

Soils in this group have formed from phyllite parent material. Phyllite is fine grained sedimentary rock that has been metamorphosed (ie. folded and altered by pressure). Because of the strongly folded nature of these rocks, a steeply undulating landscape has developed. The original sediments were laid down in a quiet marine environment and are high in silt. The soils that have developed are highly weathered but still reflect their marine origins. They are predominantly acid, texture contrast to gradational soils, with loamy surfaces and silty clay loam to clay subsoils (*Beenham* and *Neerdie*). Subsoil colour typically reflects drainage and landscape position. Convex landforms which shed water (ie. crests, upper and mid slope positions) have red to brown subsoils, while concave landforms which accumulate water (usually lower slopes) have developed grey subsoils. Yellow or brown subsoils are often present in intermediate positions. Figure 7 illustrates the relationships between geology, landscape position and soils within the metamorphosed landscapes and adjacent non metamorphic geolgies in the south eastern part of the study area.

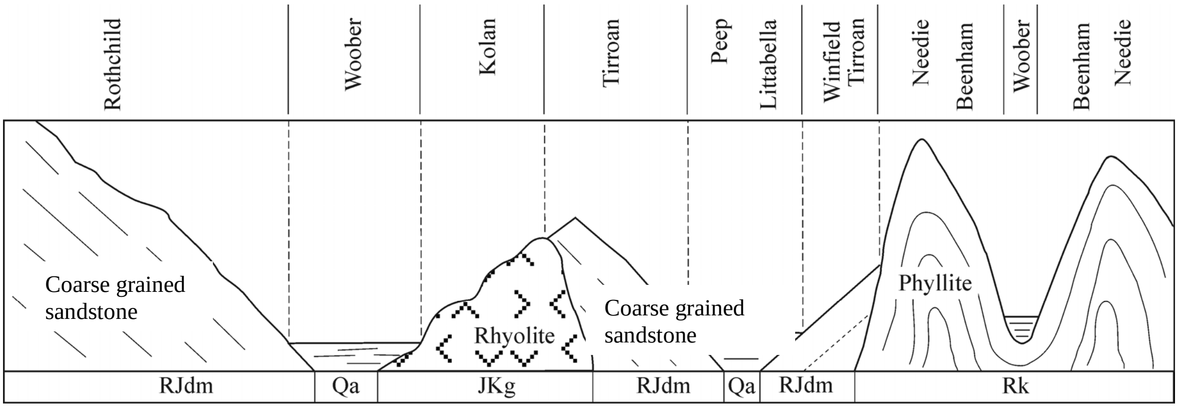


Figure 7. Geology, lithology and associated soils of metamorphosed sedimentary landscapes

Description of Soil Profile Classes

This section summarises the main soil and landscape properties for soils in the study area. Properties may vary slightly from the details SPC descriptions in Appendix ! because the details SPCs represent soils from all survey areas.

Soils are grouped in this section according to the Soil Orders of the Australian Soil Classification (Isbell 1996). The order of presentation is the same as the soil map reference. The resoure follows the ‘soil orders’ listed in the key to the Asutralian Soil Classification and the key in Appendix II.

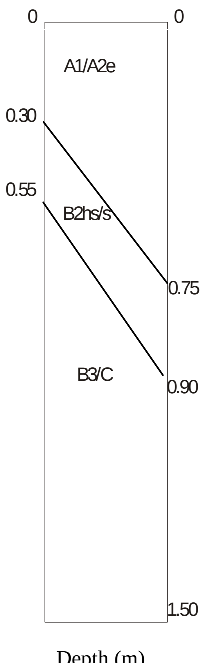
Podosols

Podosols are soils with B horizons dominated by the accumulation of compounds of organic matter, aluminium and/or iron. Only one Podosol *(Rothchild Podosolic Variant* (RtPv)) has been identified. It is associated with the moderately weathered *Myrtle Creek Sandstone* (RJdm) and represents a very minor soil within the study area (38 ha or 0.2%). This soil has similar soil properties to the *Rothchild* soil which occurs on moderately and deeply weathered sandstones.

Rothchild podosolic variant (RtPv)

Concept:	Bleached sand over a brown ortein pan formed on moderately weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Aeric Podosol.
Great Soil Group:	Podzol.
Principal Profile Form:	Uc2.33.

Typical Profile



Soil Description

The surface soil (A1, A2e) is black or grey, sand to loamy sand with single grain structure. Apart from a thin darker surface horizon, most of the surface soil is bleached (white). Surface thickness varies from 0.30 to 0.80 m; pH 4.0 to 6.0.

The ortstein pan (B2hs, B2s) is brown consolidated sand with massive structure. Pan thickness varies from 0.15 to 0.25 m; pH 4.5 to 6.0.

Below the ortstein pan, weathered sandstone is encountered (B3, C).

This soil has similar characteristics to those described for the *Rothchild* soil, except that the transitionary horizon (B3) is dominated by organic – aluminium and sesquioxide – organic complexes and can be loose or cemented in part.

Landform: Gently to moderately inclined (5–15%) upper slopes on hills flanking the Curra Creek valley (Harvey Siding area).

Parent material: Quartzose sandstone of the *Myrtle Creek Sandstone* (RJdm).

Soil associations: This variant is commonly associated with the *Rothchild* and *Winfield* (Tenosol) soils.

Vegetation: Tall open to closed dry sclerophyll forest of pink bloodwood (*Corymbia intermedia*), white stringybark (*Eucalyptus acmenoides*) and grey gum (*E. longirostrata*) with a dense understorey of heath type plants.

Land use: Remnant forest, rural residential, beef cattle grazing.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Low plant available water capacity, low fertility, potential for nutrient leaching.

Soil fertility: All plant nutrients are in low supply with the exception of organic carbon. While levels of organic carbon are moderate, they can be easily lost through cultivation. This is particularly important because organic carbon acts as the main complexing agent retaining certain plant nutrients (P, Cu, Zn) against leaching losses. This is not the case for Base Cations (Ca, Mg, K, Na) which have no capacity to accumulate in the profile because of low CEC and low clay content. When implementing a fertilising program, foliar application of nutrients is recommended in association with soil liming. See *Rothchild* soil (Tenosol) for more information.

Salinity and sodicity: Salt levels are negligible because the *Rothchild podosolic variant* (RtPv) is highly permeable and occupies elevated landscape positions. Profiles are non-sodic because of low clay content.

Physical characteristics: Surface soils are soft or loose. Subsoils are bleached, indicating significant weathering and leaching over a long period. Sometimes the subsoil Bhs horizon is weakly cemented, but appears unlikely to restrict plant roots. Subsoils are highly permeable and well drained to rapidly drained depending on landscape position. Cultivation is not necessary and furrow irrigation is not suitable for this soil.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): A subsoil ortstein or coffee rock pan can occur between 0.3 and 0.8 m and is between 0.15 and 0.25 m thick. This pan is probably discontinuous and not always cemented (hard). ERD is greater than one metre where the ortstein pan is soft or thin but is restricted where the ortstein pan is hard. PAWC is very low (<50 mm) in all cases. Estimates of PAWC are based on data from the *Rothchild* soil.

Subsoil analytical properties: This soil has a strongly acid pH trend, with pH values in the subsoil usually 4.5–6.0. While analytical data is unavailable for the *Rothchild podosolic variant* (RtPv), it is expected to have similar analytical properties to the *Rothchild* soil.

Vertosols

Vertosols are clay soils that swell when wet and shrink when dry. They exhibit strong cracking, and have slickensides and/or lenticular structure at depth. Only one Vertosol (*Pelion* (Pe*)* has been mapped. It is associated with local alluvium derived from intermediate volcanics and represents a minor soil within the study area (899 ha or 4%).

Pelion (Pe) & Pelion dark variant (PeDv)

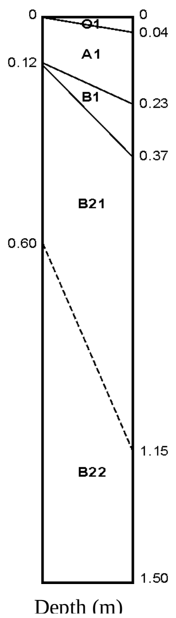
Concept: Cracking, alkaline clay on andesitic alluvium derived from the Grahms Creek Formation (JKg).

Aust. Soil Classification: Black, brown or grey alkaline Aquic Vertosol; Black, Brown or Grey Vertosol.

Great Soil Group: Weisenboden, Brown or Grey Clay.

Principal Profile Form: Ug5.35, Ug5.16.

Typical Profile



Soil Description

The surface soil (O1, A1) is black or grey, light medium to medium clay with granular or sub angular blocky structure. In wet areas a 'root mat' often overlies the soil surface. Surface thickness varies from 0.10 to 0.25 m; pH 6.0 to 8.5.

The upper part of the subsoil (B1, B21) is a black, brown or grey medium clay with lenticular structure. Manganiferous and calcareous nodules may be present. Upper subsoil thickness varies from 0.50 to 0.80 m; pH 7.0 to 9.0.

The lower part of the subsoil (B22) is a mottled, grey, light medium to medium clay with lenticular structure. Manganiferous nodules are normally present. This horizon occurs anywhere below 0.60 to 1.15 m; pH: 9.0 to 9.5.

Pelion dark variant has similar attributes to those described above for the *Pelion* soil but is black throughout and not mottled at depth.

Landform: Level to very gently inclined (0–3%) alluvial plains and swamps draining the hillslopes of Mt Scotchy and the western side of the Gunalda Range.

Parent material: Local alluvium (Qa) derived from intermediate rocks (andesite/microdiorite) of the *Grahams Creek Formation* (JKg) and associated intrusives. (JKi).

Soil associations: The *Pelion* soil is associated with the *Tiaro* and *Netherby* (Dermosols) soils in upslope areas and grades into the *Timbrell* (Hydrosol) soil in low lying areas.

Vegetation: Mostly cleared. Isolated stands of forest red gum (*Eucalyptus tereticornis*) and swamp oak (*Casuarina glauca*) occur along the margins of streams and on road reserves. Sedges and native grass species dominate surface cover in the swamps and on the plains.

Land use: Beef and dairy cattle grazing.

Existing land degradation: Salt scalds and invasive weeds in some cleared areas.

Land and soil limitations: Frost, flooding, soil wetness, narrow moisture range for cultivation and secondary salinity.

Soil fertility: This soil has the highest organic carbon levels of any soil in the study area. Levels of the other soil nutrients are also all moderate to high.

Table 7. Mean surface soil nutrients for the *Pelion* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. alcoholic cations			
water				Acid	Bicarb	K	Cu	Zn		CEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
7.2	4.66	0.31	15	60	38	0.4	1.05	3.3	26	41	13	15	0.5
neutral	high	high		high	med.	med.	med.	med.	high		High	high	med

This table presents the mean surface bulk sample results of two analysed reference sites, MTL 9003 and GCL 9003. General fertility ratings from Bruce and Rayment (1982); med – medium and high - high. For more information. See full profile description in Appendix 3 (GCL 9003).

Salinity and sodicity: Salt levels clearly increase with depth. Electrical conductivity of a 1:5 soil-water solution ($EC_{1:5}$) is a common measure of soil salinity and $EC_{1:5}$ values > 0.8 dS/m can cause reductions in root growth and yields. Figure 8a shows laboratory $EC_{1:5}$ values reach above the critical levels (0.8 ds/m) from about 0.5 m while mean field $EC_{1:5}$ values only reach similar levels at 1.1m. This discrepancy is probably due to inadequate shaking and dispersion of field samples prior to measurement (ie. laboratory measured soil solutions undergo one hour of centrifugal shaking). Figures 8a and 8b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material from about 0.1–0.3 m. In addition, the low lying landscape position of the *Pelion* soil means it is subject to the accumulation of salt from the surrounding landscape.

Physical characteristics: The surface soil has root channel mottling indicating the soil is wet to the surface for prolonged periods. The soil is self-mulching and will crack when dry, but only in better-drained areas. The surface has normal gilgai which are 0.1 to 0.5 m deep and 1.5 to 3.0 m wide. Subsoil horizons become paler, more mottled and alkaline with depth indicating saturated conditions at depth. The *Pelion* soil also has high dispersion and clay activity ratios (see Table 8), which predispose it to gully erosion in areas where surface water concentrates.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is based on physical restrictions to plant roots. Where $EC_{1:5}$ and ESP levels (Figures 8a and 8b) reach a maximum (ie. also known as a salt bulge), root growth is effectively prevented. The salt bulge for the *Pelion* soil normally occurs between 0.6 and 0.9 m. For reference sites MTL 9003 and GCL 9003,ERD is between 0.5 and 0.6 m and estimated PAWC is between 81 and 110 mm.

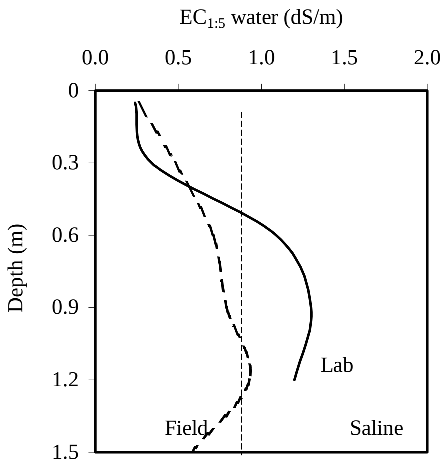


Figure 8a. Mean profile salinity ($EC_{1:5}$) for the *Pelion* soil

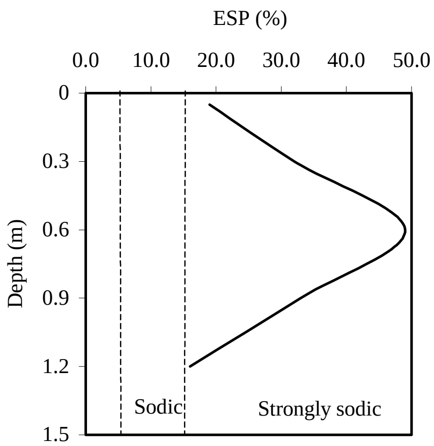


Figure 8b. Mean profile sodicity (ESP) for the *Pelion* soil

Subsoil analytical properties: The soil has an alkaline pH trend, with pH values in the lower subsoil usually 9.0–9.5. Clay content reaches a maximum at depths 0.5–0.9m. Soils have a high capacity to retain nutrients and are particularly high in calcium and magnesium. A weak calcium imbalance (Ca/Mg ratio <1) occurs at depth, and may restrict plant root growth. Exchangeable potassium is low to moderate throughout. Clay activity ratios indicate the clay fraction of this soil is of mixed mineralogy with a high proportion of montmorillonite and significant shrink-swell capacity (see Table 8).

Table 8. Mean soil profile analytical data for the *Pelion* soil

Depth	**pH**	**Sand**	**Silt**	**Clay**	**CEC**	**Base Status**	**Exch. alcoholic cations**				**Ca/Mg**	**Clay activity**
							Ca	**Mg**	**Na**	**K**		
(m)		**(%)**	**(%)**	**(%)**	**(meq/100g)**		**(meq/100g)**					
0–0.1	7.3	21	27	46	42	-	16	15	4.2	0.47	1.1	-
0.2–0.3	7.8	17	24	58	38	66	16	16	6.2	0.16	1.0	0.67
0.5–0.6	8.1	12	18	69	44	73	15	22	13	0.25	0.68	0.64
0.8–0.9	8.5	10	16	72	46	71	15	25	11	0.15	0.60	0.64
1.1–1.2	8.7	27	22	52	35	89	14	21	11	0.25	0.67	0.67

This table presents the mean results of two analysed reference sites, MTL 9003 and GCL 9003. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9003).

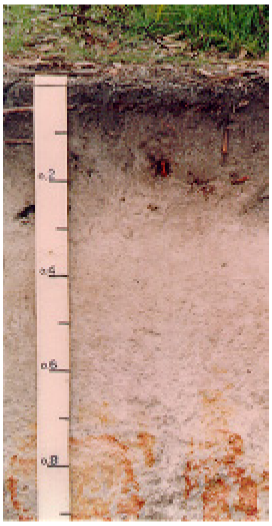
Hydrosols

Hydrosols are soils in which the greater part of the profile is saturated for at least 2–3 months in most years. The soils may or may not experience reducing conditions for all or part of the period of saturation, so that 'gley' colours and ochrous mottles may or may not be present (Podosols and Vertosols are excluded). The order is designed to accommodate a range of seasonally or permanently wet soils.

Saturation by a watertable may not necessarily be caused by low soil permeability and site drainage is particularly important. In artificially drained soils, where drainage has merely lowered the watertable, classification is dependent on the depth and length of saturation under drained conditions, classification of Hydrosols is typically based on: assessments of site drainage, topographic position, climate and soil profile attributes such as colour, mottles, segregations and permeability. It is important to note that soil colours, mottles and segregations can sometimes be relict features and do not necessarily indicate saturation under present conditions. Three Hydrosols (*Robur* (Rb), *Timbrell* (Tb), *Woober* (Wb) have been mapped which occupy 284 ha or 11% of the study area.

Robur (Rb)

Concept:	Sodic texture contrast soil with a thick (0.5 to1.0 m) sandy surface over a mottled grey clay subsoil on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Redoxic Hydrosol; Grey Sodosol.
Great Soil Group:	Soloth, minor solodic soil.
Principal Profile Form:	Dy3.41, Dg2.41, Dg2.42, Dy5.41, Dg4.41.

Typical Profile	Soil Description
	The surface soil (A1, A2e) is a grey, loamy sand to sandy loam with massive structure. The lower two-thirds are bleached (white). Surface thickness varies from 0.50 to 1.00 m; pH 5.5 to 6.0. The subsoil (B21, B22) is a mottled, grey sandy light clay to heavy clay with angular blocky and/or prismatic structure. Ferruginous nodules are frequently present in the lower subsoil. This horizon occurs anywhere below 0.50 to 1.00 m, pH 5.0 to 7.5.

Landform: Drainage depressions and gently inclined (<5%) lower slopes associated with plains and rises on deeply weathered sandstones. Incised stream channels are normally absent.

Parent material: Deeply weathered coarse grained sedimentary rocks of the *Elliot Formation* (Te, Td).

Soil associations: The *Robur* soil is often associated with the *Alloway* and *Isis* soils which occur up slope.

Vegetation: Mostly cleared or disturbed. In undisturbed situations, a mid-high to tall woodland or open forest of broad leaved white mahogany *(Eucalyptus umbra), Melaleuca viridiflora* and brown bloodwood *(E. trachyophloia)* is normally developed. An understorey of *Banksia oblongifolia* and /or broad-leaved banksia (*B. robur*) is characteristic.

Land use: Beef cattle grazing.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost, soil erosion, low plant available water capacity, poor drainage, secondary salinity.

Soil fertility: Table 9 indicates this soil has very low to low levels of all plant nutrients and confirms its deeply weathered origins. The surface soil has very little capacity to retain plant nutrients due to low clay content and low organic matter content. Large additions of organic matter and lime would be required to improve nutrient availability and retention within this soil.

Table 9. Mean surface soil nutrients for the *Robur* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
Water (1:5)	(%)	(%)		Acid (mg/kg)	Bicarb	K (meq/100g)	Cu (mg/kg)	Zn	(mg/kg)	ECEC	Ca (meq/100g)	Mg	K
5.5	0.76	0.06	12	16	2.4	0.07	0.07	0.21	-	1	0.48	0.26	0.03
Acid	low	low	low	low	vlow	vlow	vlow	low			vlow	vlow	vlow

This table presents the mean surface results of up to nine analysed reference sites, CBW S2, S8; Elliott Forestry sites 12 and 13; QCB 178 and 216; MHB 451; BUN 103 and 107. General fertility ratings from Bruce and Rayment (1982) vlow – very low; low.

Salinity and sodicity: Salt levels increase slightly with depth, but remain below the critical threshold (0.8 dS/m). Figures 9a and 9b demonstrate that increased salt concentrations at depth (>0.7 m), are most likely the result of reduced permeability associated with strongly sodic subsoil material, in combination with the influence of shallow watertables. Where watertables rise to within 1.0 m of the soil surface, evaporative conditions and capillary rise lead to the development of surface salting and scalding.

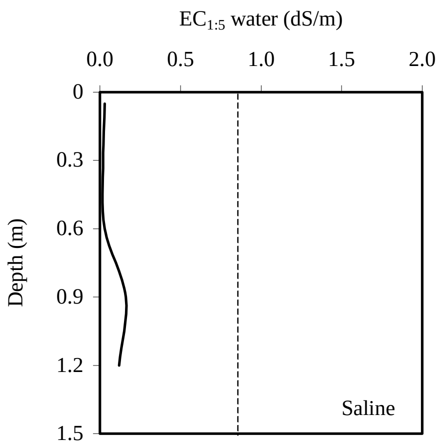


Figure 9a. Mean profile salinity for the *Robur* soil.

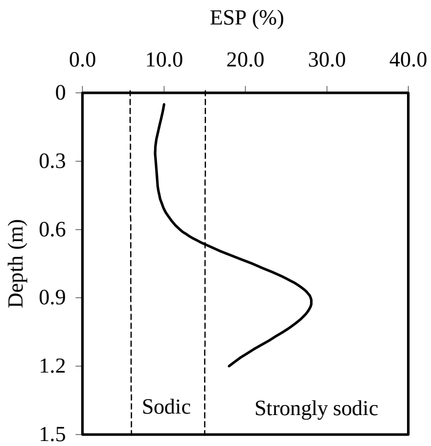


Figure 9b. Mean profile sodicity (ESP) for the *Robur* soil.

Figure 9b indicates subsoils are strongly sodic at depths greater than 0.6 m. Subsoil material below this depth is characterised by poor soil structure, slow permeability and an abrupt change in soil texture. This soil occurs low in the landscape and accumulates water and salt from surrounding areas.

Physical characteristics: Soils have sand to sandy loam surface textures with a predominantly soft or loose surface condition. Clay subsoils disperse readily if exposed or disturbed. Ferruginous nodules in the profile are indicative of a fluctuating watertable.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is between 0.6–0.9 m based on physical restrictions to plant roots associated with fluctuating watertables and strongly sodic subsoil material below 0.6 m. PAWC estimates for the reference sites associated with this soil are between 47 and 66 mm. The prolonged wetness associated with these soils, while potentially contributing to overall crop available water, also reduces root distribution below the watertable due to anaerobic conditions. The presence of significant iron nodules in the profile and the low nutrient status of this soil, (especially calcium) also contributes to reductions in rooting depth and PAWC (Table 10).

Subsoil analytical properties: Analysed profiles are acid throughout (pH <6.5), typically becoming more acidic at depth. Subsoils are subject to leaching because they are dominated by 1:1 clays, have low cation exchange capacity and experience fluctuating watertables (Table 10). Subsoil material is often magnesic (Ca/Mg ratio <0.1) at depth.

Table 10. Mean soil profile analytical data for the *Robur* soil

Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.5	85	11	5	2	-	0.48	0.63	0.20	0.03	0.76	-
0.2–0.3	5.5	79	11	6	2	-	0.18	0.48	0.16	0.02	0.38	-
0.5–0.6	5.7	73	12	15	2	13	0.18	1.37	0.33	0.03	0.13	0.13
0.8–0.9	5.8	50	12	36	6	20	0.25	4.60	2.22	0.05	0.05	0.17
1.1–1.2	5.4	51	14	38	8	14	0.31	3.60	1.50	0.05	0.09	0.22

This table presents the mean results of up to nine analysed reference sites, CBW S2, S8; Elliott Forestry sites 12 and 13; QCB 178 and 216; MHB 451; BUN 103 and 107.

Timbrell (Tb)

Concept: Bleached non-cracking alkaline sodic clay on local alluvial plains
Aust. Soil Classification: Redoxic or Oxyaquic Hydrosol; Brown Dermosol
Great Soil Group: No suitable group, affinities with solodic soils.
Principal Profile Form: Uf6.41, Uf2, Uf3, Gn3.03, Gn3.06, Gn3.93.

Typical Profile

Soil Description

The surface soil (A1, A2ej) is a black or grey, silty clay loam to silty light medium clay with granular or sub angular blocky structure. Occasionally ferruginous or manganiferous nodules are present. The lower half of the surface soil is bleached and mottled. Surface thickness varies from 0.20 to 0.40 m; pH 5.5 to 7.0.

The upper part of the subsoil (B1) is a mottled grey silty light clay to light medium clay with blocky or lenticular structure. Occasionally ferruginous or manganiferous nodules are present. Upper subsoil thickness is typically only 0.10 m; pH 6.5 to 7.5.

The lower part of the subsoil (B2) is a mottled, grey or brown, light medium clay to medium heavy clay with lenticular, prismatic or blocky structure and occasional slickensides. Manganiferous and calcareous nodules are normally present. This horizon occurs anywhere below 0.30 to 0.50 m; pH 7.5 to 9.5.

Landform: Level to very gently inclinded (0–3%) valley flats lying between adjacent rises and low hills. High watertables are associated with a poorly incised drainage and restricted outfall.

Parent material: Local alluvium (Qa) derived from a catchment with mixed lithology. Sediment sources include moderately weathered sedimentary rocks of the Maryborough Basin and relatively fresh andesite (JKg) or microdiorite (JKi).

Vegetation: Mostly cleared. In undisturbed areas a tall open or closed forest of paper barked tea tree (*Melaleuca quinquenervia*), forest red gum, (*Eucalyptus tereticornis*), broad leaf white mahogany (*E. umbra*), gum topped box (*E. moluccana*) and swamp box (*Lophostemon suaveolens*) is usually present. Paper barked tea tree is often restricted to wet areas such as drainage lines, drainage depressions and seepage areas while prickly-leaved paperbark (*Melaleuca nodosa*) is indicative of saline areas. Sedges and native grass species dominate the swamps and plains.

Land use: Beef cattle grazing.

Existing land degradation: Gully and tunnel erosion adjacent to stream channels, invasive weeds in some cleared areas, waterlogging, secondary salinity.

Land and soil limitations: Frost, flooding, soil wetness, soil erosion, hardsetting surface condition, adhesive soil (root crops only), narrow moisture range for cultivation, secondary salinity.

Soil fertility: This soil has moderate levels of most plant nutrients, but is low in available phosphorus and potassium. Moderate amounts of organic carbon help maintain surface structure and fertility (Table 11).

Table 11. Mean surface soil nutrients for the *Timbrell* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Alcoholic Cations			
water				Acid	Bicarb	K	Cu	Zn		CEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
5.8	2.5	0.18	14	3.0	12	0.2	0.8	1.1	22	17	2.6	4.7	0.31
acid	med	med	med	vlow	low	low	med	med	high		med	med	med

This table presents the mean surface results of two analysed reference sites, MTL 299 and GCL 9006. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9006). General fertility ratings from Bruce and Rayment (1982); low, med – medium, high.

Salinity and sodicity: Salt levels clearly increase with depth, but remain just below the critical threshold (0.8 dS/m). Figures 10a and 10b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material, in combination with the influence of shallow watertables and/or saturated subsoil conditions. Subsoil material is strongly sodic from 0.3 m and reaches a maximum at about 0.7 (Figure 10b). The *Timbrell* soil occurs on local, low lying valley flats and alluvial plains which have very little fall (relative to relief) and are subject to salt accumulation from surrounding landscapes.

Physical characteristics: The *Timbrell* soil is characterised by a strong hardsetting surface condition (when dry) due to high levels of silt and clay in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Soils are poorly drained because subsoils are strongly sodic, coarsely structured and very slowly permeable. The presence of a bleached A2 horizon and mottled subsoil are indicative of these processes. Perched and/or fluctuating watertables are common during the wet season.

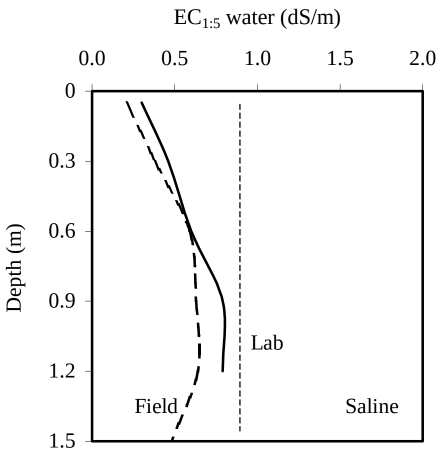


Figure 10a. Mean profile salinity for the *Timbrell* soil

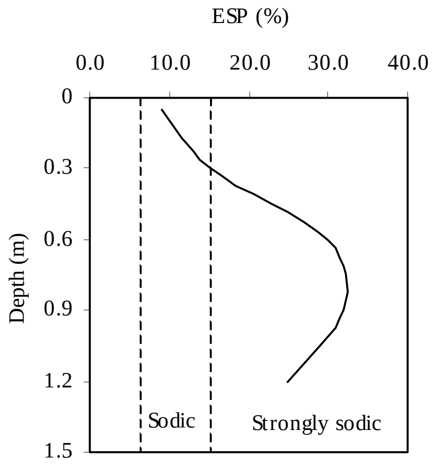


Figure 10b. Mean profile sodicity (ESP) for the *Timbrell* soil

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.9 m and is based on physical restrictions to plant roots. Between 0.2 and 0.4 m, the profile becomes strongly sodic and develops coarse blocky or prismatic structure. In addition, watertable fluctuations and/or permanent wetness capable of restricting root development are normally encountered from 0.6 to 0.9 m.

For reference sites MTL 299 and GCL 9006, ERD is estimated between 0.5 and 0.7 m and PAWC between 83 and 86 mm. The prolonged wetness normally experienced by this soil, while potentially contributing to overall crop available water, also reduces root distribution below the watertable due to anaerobic conditions. The presence of significant iron nodules, in the profile contributes to variations in PAWC.

Subsoil analytical properties: Analysed profiles have an alkaline pH trend, becoming more alkaline at depth (pH 7.5–9.5) as sodicity levels increase. Subsoils are slightly magnesic (Ca/Mg <0.5) and plant growth may be affected by a potential imbalance between calcium and magnesium.

Table 12. Mean soil profile analytical data for the *Timbrell* soil

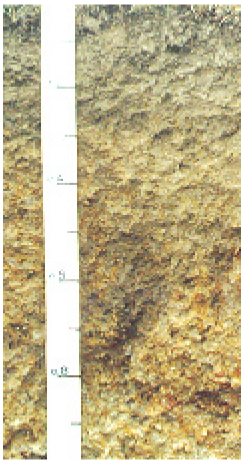
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	CEC (meq/100g)	Base Status	Exch. Alcoholic Cations (meq/100g) Ca	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	5.9	34	33	33	17	29	2.3	5.5	1.5	0.21	0.46	-
0.2–0.3	6.0	26	27	49	20	32	3.4	9	3.0	0.26	0.39	0.41
0.5–0.6	8.1	28	23	50	20	48	4.7	13	5.8	0.12	0.37	0.40
0.8–0.9	8.7	30	21	50	22	56	5.7	15	7.0	0.20	0.39	0.44
1.1–1.2	9.0	35	19	46	20	54	4.5	14	6.3	0.15	0.36	0.44

This table presents the mean results of two analysed reference sites, MTL 299 and GCL 9006. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9006).

Woober (Wb)

Concept:	Bleached non-cracking acid clay on local alluvial plains.
Aust. Soil Classification:	Redoxic Hydrosol.
Great Soil Group:	No suitable group, affinities with soloth.
Principal Profile Form:	Uf2, Uf3, Gn3.04, Gn3.05.

Typical Profile



Soil Description

The surface soil (A1, A2je) is a black or grey, silty loam to light medium clay with massive or weak granular structure. The lower half of the surface soil is bleached and mottled. Surface thickness varies from 0.20 to 0.30 m; pH 5.0 to 6.5.

The upper part of the subsoil (B1) is a mottled, grey, light clay to light medium clay with angular blocky structure. Upper subsoil thickness varies from 0.15 to 0.40 m; pH 5.0 to 6.0.

The lower part of the subsoil (B2) is a mottled, grey or brown, light medium clay to medium heavy clay with angular blocky or prismatic structure and occasional slickensides. This horizon occurs anywhere below 0.35 to 0.70 m; pH 5.5 to 7.0.

Landform: Level to very gently inclined (0–3%) alluvial plains and valley flats lying between adjacent rises and low hills. High watertables are associated with no incised drainage and restricted outfall.

Parent material: Local alluvium (Qa) sourced directly from surrounding moderately weathered sedimentary rocks of the Maryborough Basin.

Vegetation: The *Woober* soil is mostly cleared. In undisturbed areas, a tall open or closed forest of forest red gum, (*Eucalyptus tereticornis*), paper barked tea tree (*Melaleuca quinquenervia*), broad-leaf white mahogany (*E. umbra*), gum-topped box (*E. moluccana*), swamp box (*Lophostemon suaveolens*) and narrow-leaved ironbark (*E. crebra*) is usually present. Paper barked tea tree is often restricted to wet areas such as drainage lines, drainage depressions and seepage areas, while prickly-leaved paperbark (*Melaleuca nodosa*) is indicative of saline areas. Sedges and native grass species dominate the swamps and plains.

Land Use: Beef cattle grazing.

Existing land degradation: Invasive weeds in some cleared areas, waterlogging, secondary salinity.

Land and soil limitations: Frost, flooding, soil wetness, hardsetting surface condition, adhesive soil (root crops only), narrow moisture range for cultivation, secondary salinity.

Soil fertility: This soil has low levels of most plant nutrients, which reflects the inherently infertile nature of the weathered sedimentary rocks from which the parent material was sourced. Acidity in the surface soil will potentially inhibit the availability of macronutrients (P, K, S) and the addition of organic matter and lime is required to improve the productivity of this soil (Table 13).

Table 13. Mean surface soil nutrients for the *Woober* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
Water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
5.6	2.1	0.09	23	8.5	11	0.18	0.44	0.86	10.5	7	1.9	3.6	0.25
acid	med.	low	med	vlow	low	low	med	med	med		low	med	med

This table presents the mean surface results of two analysed reference sites, MHB 450 and GCL 9004. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9004). General fertility ratings Bruce and Rayment (1982) vlow – very low; low; med – medium.

Salinity and sodicity: Salt levels clearly increase with depth and approach the critical threshold (0.8 dS/m). Figures 11a and 11b demonstrate that increased salt concentrations at depths > 0.5 m are most likely the result of reduced permeability associated with strongly sodic subsoil material, in combination with the influence of shallow, saline watertables. Gradually increasing conductivity levels indicate subsoil watertables are saline, while increases near the surface indicate evaporative conditions and capillary rise are occurring (Figure 11a).

Subsoil material is strongly sodic throughout the profile (Figure 11b). The *Woober* soil occurs on local, low lying valley flats and alluvial plains which have very little fall (relative to relief) and are subject to salt accumulation from surrounding landscapes.

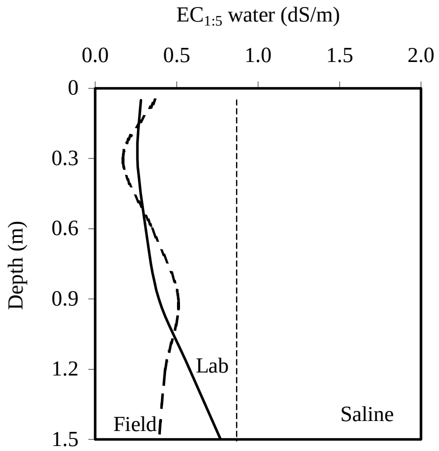


Figure 11a. Mean profile salinity for the *Woober* soil

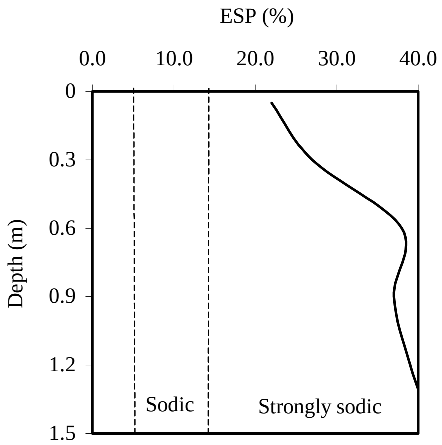


Figure 11b. Mean profile sodicity (ESP) for the *Woober* soil

Physical characteristics: The *Woober* soil is characterised by a strong hardsetting surface condition (when dry) due to high levels of silt and clay in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Profiles are poorly drained because subsoils are strongly sodic, coarsely structured and very slowly permeable. The presence of a bleached A2 horizon and mottled subsoil are indicative of these processes. Perched and/or fluctuating watertables are common during the wet season.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.8 m and is based on physical restrictions to plant roots, associated with subsoil sodicity and poor physical structure. Figure 11b shows sodicity increases rapidly from about 0.4–0.5 m, while field data suggest the B2 horizon is dominated by tough prismatic structure, for 0.4–0.8 m. For reference sites MHB 450 and GCL 9004, PAWC estimates range from 45 to 70 mm. The prolonged wetness normally experienced by this soil, while potentially contributing to overall crop available water, also reduces root distribution below the watertable due to anaerobic conditions.

Subsoil analytical properties: Analysed profiles have an acid pH trend, with pH values in the subsoil typically 5.0–6.5. Plant root growth will be restricted by the magnesic (Ca/Mg <0.1) nature of the subsoil at depths greater than 0.3 m (Table 14).

Table 14. Mean soil profile analytical data for the *Woober* soil

Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.4	39	38	22	8	-	2.1	4.0	1.1	0.24	0.53	-
0.2–0.3	5.7	40	38	24	7	-	1.1	4.4	1.7	0.09	0.25	-
0.5–0.6	5.4	33	31	39	16	42	0.56	8.0	7.7	0.16	0.07	0.41
0.8–0.9	5.2	30	31	39	23	59	0.72	12.3	10.0	0.20	0.08	0.59
1.1–1.2	5.3	33	30	36	26	70	0.87	13.5	10.8	0.20	0.06	0.72

This table presents the mean results of two analysed reference sites, MHB 450 and GCL 9004. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9004).

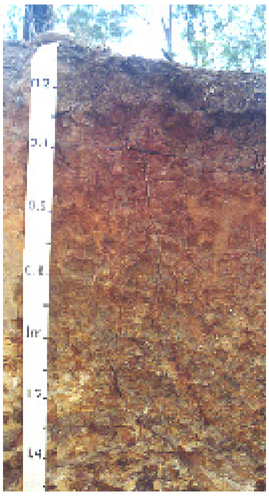
Kurosols

Kurosols are soils with strong texture contrast between A horizons and strongly acid (pH <5.5) upper B horizons. Only the *Kolan* (Ko) soil type and its *red variant* (KoRv) consistently key out as Kurosols. The *Owanyilla* and *Tirroan* soils occasionally qualify but more typically key out as Sodosols. The *Kolan* soil occupies 6 209 ha or 30% of the study area.

Kolan (Ko), Kolan rocky phase (KoRp), Kolan red variant (KoRv)

Concept:	Sodic texture contrast soil with a thin (0.15–0.30 m) bleached loamy surface over a (red) mottled, grey or brown acid clay subsoil on moderately weathered fine grained sedimentary rocks.
Aust. Soil Classification:	Grey, Brown (or occ. Red) Kurosol; Grey or Brown Sodosol.
Great Soil Group:	Soloth.
Principal Profile Form:	Dy3.41, Dy3.31.

Kolan Red variant



Soil Description

The surface soil (A1, A2ej) is a black, brown, or grey, fine sandy clay loam to clay loam fine sandy with granular, blocky or massive structure. The lower half of the surface soil is bleached. Surface thickness varies from 0.15 to 0.30 m; pH 5.5 to 6.5.

The upper part of the subsoil (B21, B22) is a (red) mottled, grey or brown, medium clay to heavy clay with prismatic or blocky structure. Ferruginous nodules are often present. Subsoil thickness varies from 0.35 to 1.05 m; pH 4.5 to 6.0.

The lower part of the subsoil (B3) is a mottled, grey, medium clay to heavy clay with angular blocky or lenticular structure. Typically fragments of rock are present. This horizon occurs anywhere below 0.50 to 1.35 m; pH 4.5 to 6.0.

Kolan red variant (KoRv) is characterised by a red subsoil (B2) with grey mottles. All other attributes are similar to those described above for the *Kolan* soil. *Kolan rocky phase (KoRp)* occurs either as a rocky version with > 20% coarse fragments in the surface soil or a shallow version with weathered rock before 0.3 m.

Landform: Gently to moderately inclined (3–15%) slopes on rises and low hills.

Parent material: Moderately weathered mudstones and siltstones of the *Elliott Formation* (Te), *Maryborough Formation* (Km) and *Tiaro Coal Measures* (Jdt); or rhyolites of the *Graha's Creek Formation* (JKg).

Soil associations: The *Kolan* soil occurs in association with the *Bucca* soil (clayey surfaced Dermosol), the *Owanyilla* or *Givelda* soils (loamy surfaced Sodosols) and the *Tirroan* soil (sandy surfaced Sodosols).

Vegetation: Tall to very tall (18–25 m) open dry sclerophyll forest of lemon-scented gum (*Corymbia citrodora*), ironbark (*Eucalyptus siderophloia*, *E. fibrosa)*, white mahogany (*E. acmenoides*), Queensland peppermint (*E. exserta*) and gum-topped box (*E. moluccana*) with a very sparse understorey. In some areas, tall open gum-topped box (*E. moluccana*) forests occur without the other species. Brush box *(Lophostemon confertus*) may occur locally in association with the other species.

Land use: Remnant forest, native pasture beef cattle grazing, forestry, rural residential.

Existing land degradation: Extensive areas of gully, tunnel and sheet erosion, invasive weeds in some cleared areas, secondary salinity scalds on some lower slopes.

Land and soil limitations: Frost on lower slopes, soil erosion, low plant available water capacity, soil wetness on lower slopes, hardsetting surface condition, secondary salinity on lower slopes.

Soil fertility: Moderate levels of most plant nutrients are present in the surface soil with the exception of nitrogen, phosphorus and copper which are deficient. Surface soil fertility is expected to decline with cultivation because of sediment loss and declining organic matter levels. Soil acidity will restrict the availability of the macronutrients (P, K, Ca, Mg, K) in this soil and liming and the maintenance of soil organic matter levels is essential (Table 15).

Table 15. Mean surface soil nutrients for the *Kolan* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)	(meq/100g)			
5.5	2.3	0.14	16	9.0	4.0	0.25	0.23	1.10	-	11	2.80	3.2	0.41
acid	med.	low		vlow	vlow	med	low	med			med	med	med

This table presents the mean surface results of six analysed reference sites, CBW 918, BSS 38, ATB 14, MON CB10, BUN C3, and MBS 52. General fertility ratings from Bruce and Rayment (982) vlow – very low; low; med – medium.

Salinity and Sodicity: Salt levels clearly increase with depth, but remain below the critical threshold (0.8 dS/m). Figures 12a and 12b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material and the presence of weathered substrate. Subsoil material is strongly sodic from about 0.5 m (Figure 12b). The occurrence of profile salinity within the *Kolan* soil is more common in lower landscape positions.

Physical characteristics: The *Kolan* soil is characterised by a strong hardsetting surface condition

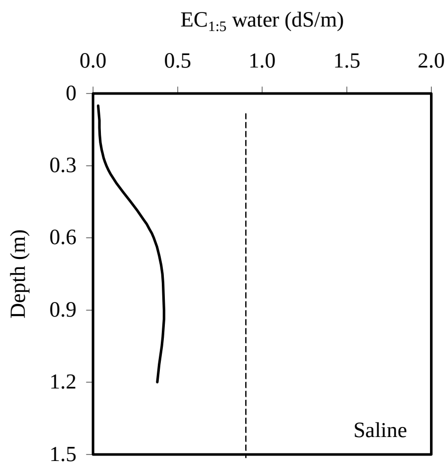


Figure 12a. Mean profile salinity for the *Kolan* soil.

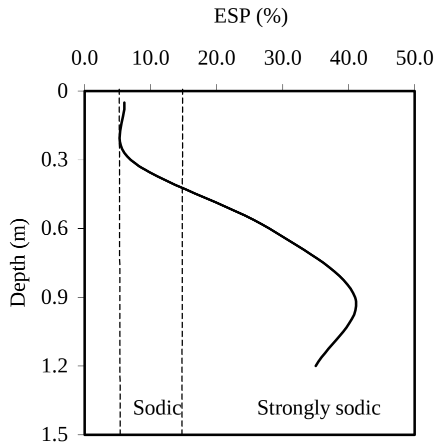


Figure 12b. Mean profile sodicity (ESP) for the *Kolan* soil.

(when dry) due to high levels of fine sand and clay in the surface soil. Hardsetting behaviour restricts water entry into the profile during rewetting. Subsoils are acidic, strongly sodic and have high clay contents, which restrict drainage and plant root growth. On lower slopes, fluctuating watertables during the wet season are common while on mid to upper slopes drainage is slightly better due to lateral water flow. Surface soils are shallow, fine textured and easily disturbed because of weak structure. The combination of erodible surface soils, imperfect drainage, moderate slopes and sodic subsoils suggests a significant erosion risk exists with this soil.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.3–0.6 m and is based on physical restrictions to plant roots and associated with subsoil sodicity poor physical structure and low pH. The low nutrient status, particularly very low calcium, in the subsoil also impacts on rooting depth and PAWC. Estimates from the reference sites for this soil suggest PAWC levels range from 45 to 75 mm.

Subsoil analytical properties: This soil is strongly acid throughout, with pH values in the subsoil usually 4.5–6.0. The subsoil is characterised by significant cation imbalances, which inhibit the uptake of calcium and potassium (Baker and Eldershaw 1993). In addition, the profile is magnesic (Ca/Mg ratio <0.1) with greater than 50% of cation exchange in the subsoil dominated by magnesium ions. Clay activity ratios indicate the subsoil is dominated by clay material of mixed mineralogy with a high proportion of illite (Table 16).

Table 16. Mean soil profile analytical data for the *Kolan* soil

Depth	**PH**	**Sand**	**Silt**	**Clay**	**ECEC**	**Base Status**	**Exch. Aqueous Cations**				**Ca/Mg**	**Clay activity**
							Ca	**Mg**	**Na**	**K**		
(m)		**(%)**	**(%)**	**(%)**	**(meq/100g)**		**(meq/100g)**					
0–0.1	5.5	55	22	18	11	-	2.80	3.20	0.55	0.41	0.88	-
0.2–0.3	5.1	40	18	42	15	-	0.41	6.90	2.16	0.28	0.06	-
0.5–0.6	5.1	36	16	48	19	34	0.47	10.3	5.30	0.20	0.05	0.40
0.8–0.9	4.9	36	17	46	20	43	0.15	11.3	7.88	0.23	0.01	0.44
1.1–1.2	4.9	33	16	47	23	41	0.24	11.5	7.40	0.29	0.02	0.49

This table presents the mean results for up to six analysed reference sites, CBW 918, BSS 38, ATB 14, MON CB10, BUN C3, and MBS 52.

Sodosols

Sodosols are soils with strong texture contrast between A horizons and sodic (ESP >6) upper B horizons that are not strongly acid (pH >5.5).

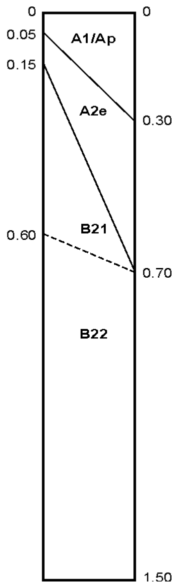
The presence of a sodic B horizon may be indicated in the field by the presence of one or more of the following: a bleached A2 horizon abruptly changing to a clay B2 horizon with columnar or coarse angular blocky or prismatic structure; a high pH (>8.5); the 'soapy' or slippery nature of the clay when wet; and/or dispersion of the clay fraction.

Nine Sodosols including one variant and three phases have been mapped. These include soils developed on granite (*Gigoon* (Gn), *Doongul* (Do), andesite (*Owanyilla* (Ow), *Owanyilla rocky phase* (OwRp), moderately weathered sedimentary rocks (*Tirroan* (Tr,) *Givelda* (Gv), and alluvium (*Peep* (Pp), *Butcher*(Bt), *Butcher sandy variant* (BtSv). They occur extensively and occupy 4173 ha or 20% of the study area.

Butcher (Bt), Butcher sandy variant (BtSv), Butcher roky phase (BtRp)

Concept:	Fine loamy surfaced sodic texture contrast soil on alluvial plains of the Mary River.
Aust. Soil Classification:	Brown or Grey Sodosol; minor Redoxic Hydrosol.
Great Soil Group:	Soloth, solodic soil.
Principal Profile Form:	Dy3.41, Dy3.42, Dy3.43.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, Ap, A2e) is a black or grey, fine sandy clay loam to silty clay loam with weak cast or massive structure. The lower half of the surface soil is bleached, mottled and frequently has manganiferous nodules. Surface thickness varies from 0.15 to 0.70 m; pH 5.5 to 6.5.

The subsoil (B21, B22) is a mottled, grey or brown, light medium clay to heavy clay with angular blocky or prismatic structure. Manganiferous nodules are frequently present. Subsoil horizons occur anywhere below 0.15 to 0.70 m; pH 5.5 to 8.5.

Butcher sandy variant occurs on sandy levees associated with prior streams and has a sandy loam surface soil. All other attributes are similar to those described above for the *Butcher* soil.

Butcher rocky phase is characterised by the presence of a relict, water deposited cobble layer on the surface. The underlying soil horizons are similar to those described above for the *Butcher* soil.

Landform: Elevated margins of the highest and/or oldest river terraces along the Mary River. Often associated with prior levees of the river that are now relict and form high points within the alluvial plain.

Parent material: Older alluvium (Qpa) within the contemporary Mary River system that was deposited during the Pleistocene period.

Soil associations: The *Butcher* soil grades into the *Granville* or *Mungar* soils (Dermosol) on backplains where parent material is finer (more clayey). It also adjoins the *Aldershot* soil (Dermosol) on prior levees. In areas where the soil is sandier and A horizons are deeper, it has been mapped as *Butcher sandy variant*.

Vegetation: Mostly cleared. Forest red gum (*Eucalyptus tereticornis*) may have dominated this soil prior to clearing.

Land use: Sugarcane, improved pastures for dairy and beef cattle grazing.

Existing land degradation: Giant Rats Tail grass in some areas.

Land and soil limitations: Frost, occasional flooding, low plant available water capacity, hardsetting surface condition.

Soil fertility: The soil is deficient in nitrogen and phosphorus while all other plant nutrients are in moderate supply. Maintenance of soil organic matter is essential to maintain the productivity of this soil (Table 17).

Table 17. Mean surface soil nutrients for the *Butcher* soil

PH	O.C.	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
Water (1:5)	(%)	(%)		Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
				(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.0	1.3	0.09	14	3.0	10.0	0.22	0.82	0.97	12.0	9	1.8	2.7	0.28
Acid	low.	low		vlow	vlow	med	med	med	med		low	med	med

This table presents the mean surface results of two analysed reference sites, BUN 113 and MTL 315. General fertility ratings Bruce and Rayment (1982) vlow – very low; low; med – medium.

Salinity and sodicity: Salt levels clearly increase with depth, but remain below the critical threshold (0.8 dS/m). Figures 13a and 13b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material from about 0.6 m (ie. B22 horizon).

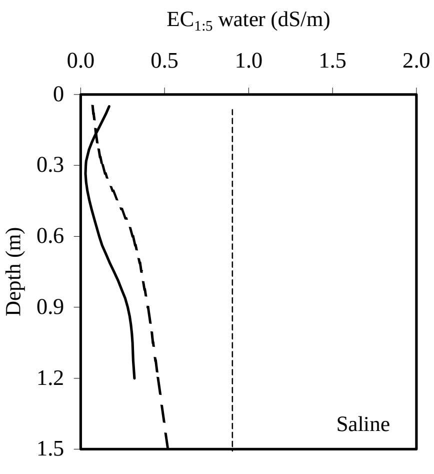


Figure 13a. Mean profile salinity for the *Butcher* soil

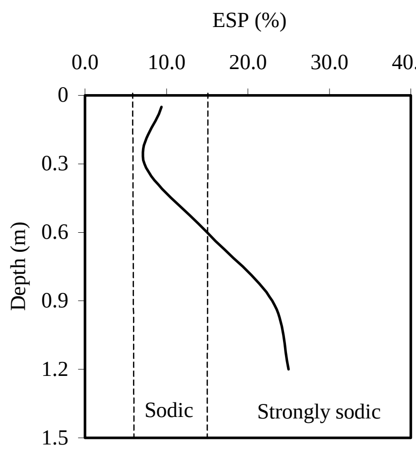


Figure 13b. Mean profile sodicity (ESP) for the *Butcher* soil

Physical characteristics: The *Butcher* soil is characterised by a hardsetting surface condition (when dry) due to high levels of fine sand and massive structure (i.e. structureless) in the surface soil. Hardsetting behaviour restricts water entry into the profile during rewetting. A bleached A2 horizon and mottling in the upper part of the profile indicate seasonal saturation is occurring and the possibility of a perched and/or fluctuating watertable. The subsoil has a high clay content (medium to heavy clay) and is sodic to strongly sodic.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.8 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. The shape of the salt bulge in Figure 13a is also indicative. For reference sites BUN113 and MTL315, ERD estimates are between 0.6 and 0.8 m and PAWC between 62 to 80 mm.

Subsoil analytical properties: This soil typically has an alkaline pH trend (increasing pH with depth) associated with strong sodicity in the subsoil. The pH values in the lower subsoil are usually 7.0–8.5. Silt content is high throughout the profile and contributes to hardsetting surface horizons and slow drainage. The strongly sodic nature of the subsoil and the relative dominance of magnesium on the exchange complex (Ca/Mg ratio <0.5) suggest subsoil material is dispersive and highly erodible (Table 18).

Table 18. Mean soil profile analytical data for the *Butcher* soil

Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.0	64	20	17	7	23	3.0	3.2	0.6	0.21	0.94	-
0.2–0.3	6.2	62	18	21	9	16	2.3	3.1	0.5	0.05	0.74	-
0.5–0.6	6.7	39	19	41	16	22	4.1	8.9	2.5	0.13	0.47	0.39
0.8–0.9	7.3	48	20	39	16	29	4.1	10.9	3.6	0.16	0.36	0.41
1.1–1.2	7.4	43	20	39	18	43	2.0	23.0	4.3	0.11	0.22	0.46

This table presents the mean results of two analysed reference sites, BUN 113 and MTL 315.

Gigoon (Gn)

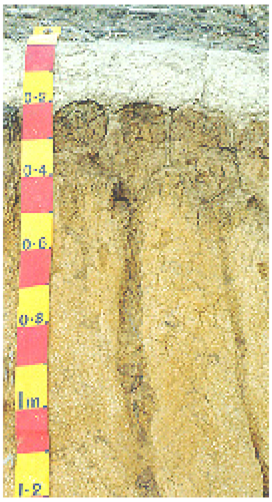
Concept: Sodic texture contrast soil with a thick (0.20–0.6m) bleached coarse sandy surface over a mottled, brown or grey clay subsoil on or granite.

Aust. Soil Classification: Brown or Grey Sodosol.

Great Soil Group: Soloth, solodized solonetz, solodic soil.

Principal Profile Form: Dy5.41, Dy3.42, Dy3.41, Dy3.43, Dg4.41.

Typical Profile



Soil Description

The surface soil (A1, A2e) is a black or grey, loamy sand to sandy loam with massive structure. The lower half of the surface soil is bleached. Surface thickness varies from 0.20 to 0.60 m; pH 5.5 to 6.0.

The subsoil (B2) is a mottled, brown or grey, sandy light clay to sandy medium heavy clay with columnar, prismatic or angular blocky structure. Subsoil thickness varies from 0.30 to 0.60 m; pH 5.5 to 9.5.

The transition zone between the subsoil and parent material (B3) consists of a mottled, brown or grey, sandy clay to sandy light medium clay with angular or prismatic structure and/or weathered rock; pH 5.5 to 9.0. This transition layer occurs anywhere below 0.5 to 1.20 m.

Landform: Gently to moderately inclined (5–15%) slopes on rises, low hills and hills.

Parent material: In this study area, the parent material is microdiorite of unnamed intrusives (JKi).

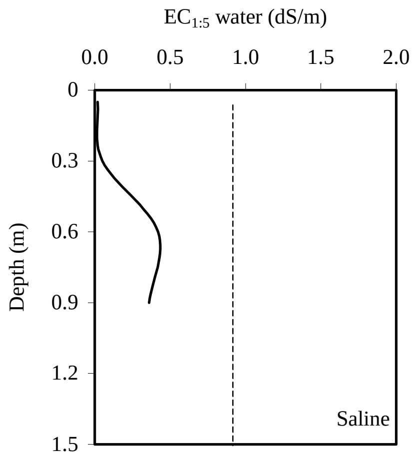


Figure 14a. Profile salinity for the *Gigoon* soil

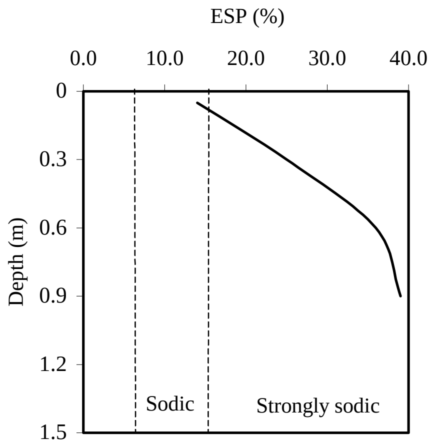


Figure 14b. Profile sodicity (ESP) for the *Gigoon* soil

Soil associations: The *Gigoon* soil occurs in association with the *Doongul* (Sodosol) soil on microdiorite. The two soils differ mainly in the texture of surface horizons. The *Gigoon* soil has a moderately thick (0.2 to 0.6 m) sandy surface while the *Doongul* has a thin (0.1 to 0.25 m) loamy surface.

Vegetation: Tall to very tall (15–25 m) open forest of narrow leaved ironbark (*Eucalyptus crebra*), lemon-scented gum (*Corymbia citrodora*), forest red gum (*E. tereticornis*) and/or pink bloodwood (*C. intermedia*), Queensland peppermint (*E. exserta*) and grey ironbark (*E. siderophloia*).

Land use: Beef cattle grazing.

Land and soil limitations: Rockiness, shallow rooting depth, low plant available water capacity, soil erosion.

Soil fertility: This soil is low in nitrogen, phosphorus and calcium. All other plant nutrients are in moderate supply. Maintenance of soil organic matter and liming in conjunction with fertilising is essential to maintain the productivity of this soil.

Table 19. Surface soil nutrients for the *Gigoon* soil

pH	O.C.	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.0	1.3	0.09	14	3.0	10.0	0.22	0.82	0.97	12.0	9	1.8	2.7	0.28
acid	low	low		vlow	vlow	med	med	med	med		low	med	med

This table presents surface results from analysed reference site, CBW S13. General fertility ratings from Bruce and Rayment (1982) vlow – very low; low; med –medium.

Salinity and sodicity: Salt levels clearly increase with depth, but remain below the critical threshold (0.8 dS/m). Electrical conductivity of a 1:5 soil-water solution ($EC_{1:5}$) is a common measure of soil salinity and $EC_{1:5}$ values >0.8 dS/m can cause reductions in root growth and plant yields. Figures 14a and 14b demonstrate that increased salt concentrations at depth are most likely the result of reduced permieability associated with strongly sodic subsoil material and the presence of weathered substrate. Subsoil material is strongly sodic from about 0.2–0.6 m (Figure 14b).

Physical characteristics: The combination of strongly sodic material (Figure 14b) and strong, coarse columnar or prismatic structure makes the subsoil of the *Gigoon* soil dense, impermeable and impenetrable to root growth. Surface horizons are massive and sandy with a soft or firm surface condition. Erosion risk is significant where these soils occur on moderate slopes.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is effectively restricted to surface horizons because of physical restrictions to plant roots associated with subsoil sodicity, poor physical structure and the magnesic nature of the subsoil material. ERD is between 0.3 and 0.7 m depending on surface soil depth. Estimates for reference site CBW S13, suggest ERD is 0.5 m and PAWC is 48 mm.

Subsoil analytical properties: This soil typically has an alkaline pH trend (increasing pH with depth) although significant variability exists in the subsoil (pH 5.5–9). Subsoils are characteristically magnesic (Ca/Mg ratio <0.1), strongly sodic (Figure 14b) and highly dispersive. These properties correlate well with field descriptions where strong, coarse columnar structure is recorded.

Table 20. Soil profile analytical data for the *Gigoon* soil

Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.8	88	9	5	1	-	0.64	0.46	0.14	0.11	1.39	-
0.2–0.3	5.7	88	9	5	1	-	0.13	0.4	0.25	0.05	0.33	-
0.5–0.6	6.9	58	10	33	15	45	0.1	9.1	5.4	0.08	0.01	0.45
0.8–0.9	7.0	62	0	38	17	44	0.1	10	6.6	0.11	0.01	0.45

This table presents results from analysed reference site, CBW S13.

Givelda (Gv)

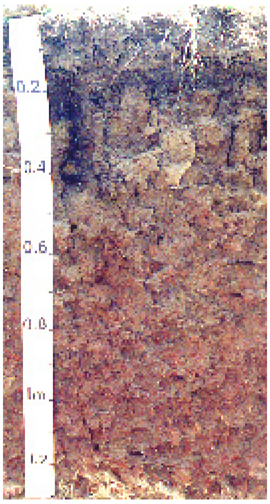
Concept: Sodic texture contrast soil with a thin (0.15–0.30 m) bleached loamy surface over a mottled, brown or yellow clay subsoil on moderately weathered fine grained sedimentary rocks.

Aust. Soil Classification: Brown or Yellow Sodosol.

Great Soil Group: Soloth, solodic soil.

Principal Profile Form: Dy3.41, Dy3.42.

Typical Profile



Soil Description

The surface soil (A1, A2e) is a black or grey, fine sandy clay loam to clay loam fine sandy with massive or weak cast structure. The lower two-thirds of the surface soil is bleached, mottled and frequently has manganiferous nodules. Surface thickness varies from 0.15 to 0.30 m; pH 5.5 to 6.5.

The subsoil (B2) is a mottled, brown or yellow, medium clay to heavy clay with prismatic structure parting to angular blocky. Manganiferous nodules are frequently present. Subsoil thickness varies from 0.3 to 1.0 m; pH 6.0 to 8.0.

The transition zone between the subsoil and substrate (B3) consists of clay and weathered fine grained sandstone. It occurs anywhere below 0.45 to 1.30 m.

Landform: Gently to moderately inclined (5–15%) slopes on rises and low hills.

Parent material: Sub-labile fine grained sandstones and siltstones of the *Tiaro Coal Measures* (Jdt).

Soil associations: The *Givelda* soil is associated with the *Kolan* (Kurosols) or *Tirroan* (Sodosol) soils on hillslopes, and the *Woober* or *Timbrell* (Hydrosols) soils on adjacent local alluvium.

Vegetation: Tall (18 to 20 m) open dry sclerophyll forest of gum-topped box (*Eucalyptus* *moluccana*), narrow-leaved ironbark (*E. crebra*), spotted gum (*Corymbia citriodora* ssp *varigata*) and forest red gum (*E. tereticornis*).

Land use: Beef cattle grazing.

Existing land degradation: Gully, tunnel and sheet erosion.

Land and soil limitations: Frost on lower slopes low plant available water capacity, hardsetting surface condition soil erosion.

Soil fertility: This soil is low in nitrogen, phosphorous and sulfur. All other nutrients are in moderate to high supply (Table 21).

Table 21. Mean surface soil nutrients for the *Givelda* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC (meq/100g)	Ca	Mg	K
6.4	2.0	0.13	15	15.0	8.0	0.60	0.35	2.70	7	7	6.00	2.60	0.35
neutral	med.	low		low	vlow	high	med	med	low		high	med	med

This table presents the mean surface results of two analysed reference sites, BAB 9012 and CBW 911. General fertility ratings from Bruce and Rayment (1982) vlow – very low; low; med – medium; high.

Salinity and sodicity: Salt levels clearly increase with depth but remain below the critical threshold (0.8 dS/m). Electrical conductivity of a 1:5 soil-water solution ($EC_{1:5}$) is a common measure of soil salinity and $EC_{1:5}$ values >0.8 dS/m can cause reductions in root growth and plant yields. Figures 15a and 15b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material and the presence of weathered sbustrate. Subsoil material is strongly sodic from about 0.3 m (Figure 15b).

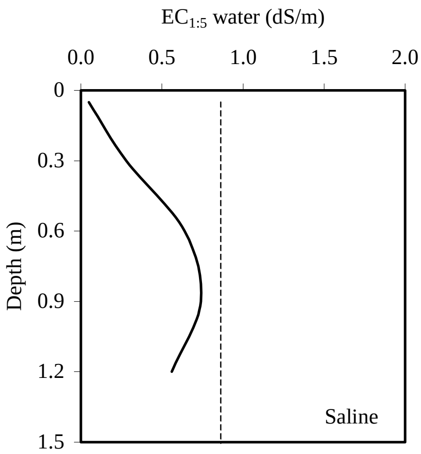


Figure 15a. Mean profile salinity for the *Givelda* soil

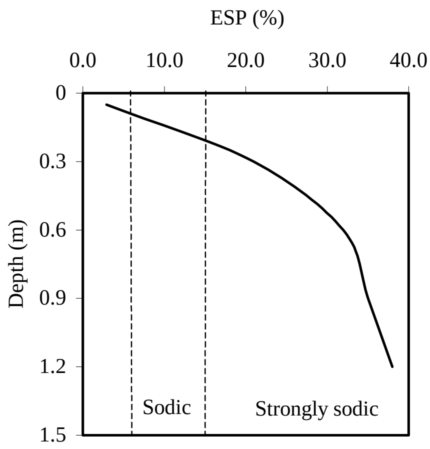


Figure 15b. Mean profile sodicity (ESP) for the *Givelda* soil

Physical caracteristics: The *Givelda* soil is characterised by a hardsetting surface condition (when dry) due to high levels of fine sand and massive structure (ie. structureless) in the surface soil. ardsetting behaviour restricts water entry into the profile during rewetting. A bleached A2 horizon and mottling in the upper part of the profile indicates that seasonal saturation is occurring and the possibility of a perched and/or fluctuating watertable on lower slopes. Mid to upper slopes are better drained due to the lateral flow. The subsoil has a high clay content (medium to heavy clay) and is strongly sodic, with coarse prismatic structure.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.35–0.5 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. For reference sites CBW 911 and BAB 9012, ERD estimates are between 0.4 and 0.6 m and PAWC between 43 and 87 mm.

Subsoil analytical properties: This soil typically has an alkaline pH trend (increasing pH with depth) associated with strong sodicity in the subsoil. The pH values in the lower subsoil are usually 7.0–8.0. Fine sand levels are high in the surface soil and contribute to hardsetting behaviour. The strongly sodic nature of the subsoil and the relative dominance of magnesium on the exchange complex suggest subsoil material is dispersive and highly erodible (Table 22).

Table 22. Mean soil profile analytical data for the *Givelda* soil.

Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.4	68	15	14	6	-	3.2	2.6	0.2	0.35	1.23	-
0.2–0.3	6.3	45	12	45	20	44	2.6	13	4.1	0.25	0.20	0.44
0.5–0.6	5.8	32	19	43	27	62	2.3	16	8.2	0.22	0.14	0.63
0.8–0.9	7.3	32	30	40	27	63	1.9	14	9.2	0.26	0.14	0.68

This table presents the mean results of two analysed reference sites, BAB 9012 and CBW 911.

Owanyilla (Ow), Owanyilla rocky phase (OwRp)

Concept: Sodic texture contrast soil loamy surface over a mottled, brown or grey clay subsoil on moderately weathered intermediate igneous rocks.

Aust. Soil Classification: Brown or Grey Sodosol.

Great Soil Group: Solodic soil, soloth.

Principal Profile Form: Dy3.32, Dy3.33, Dy3.43, Dy3.42, Dy341.

Typical Profile

Soil Description

The surface soil (A1, A2ej) is a black or grey, fine sandy loam to clay loam with massive or weak granular structure. The lower half of the surface soil is bleached. Surface thickness varies from 0.05 to 0.30 m; pH 5.5 to 6.5.

The upper part of the subsoil (B21, B22) is a mottled, brown or occasionally grey, light medium clay to heavy clay with prismatic structure parting to blocky or lenticular. Ferromanganiferous nodules are frequently present. Upper subsoil thickness varies from 0.25 to 0.60 m; pH 0.0 to 7.0.

The lower part of the subsoil (B3) is a mottled, brown, grey or yellow, medium clay to heavy clay with blocky structure and fragments of rock present. This horizon occurs anywhere below 0.30 to 0.90 m; pH 6.5 to 9.0.

Owanyilla rocky phase is a shallow version of this soil with weathered substrate normally encountered from about 0.20 m. All other attributes are similar to those described above for the *Owanyilla* soil.

Landform: Gently to moderately inclined (3–15%) slopes on rises and low hills.

Parent material: Andesite of the *Grahams Creek Formation* (Jkg) and microdiorite of unnamed intrusives (JKi).

Soil associations: The *Owanyilla* soil often occurs in association with the *Kolan* (Kurosol) soil formed on rhyolite, tuffs and sediments, and the *Jumpo* and *Tiaro* (Dermosol) soils formed on andesite or microdiorite. Because the rhyolite and tuffs are inter-bedded with the andesite flows and the whole sequence has been folded and tilted, changes between the *Owanyilla* and the *Kolan*, *Tiaro* and *Jumpo* soils can be abrupt. These changes are often difficult to predict within the landscape and result in complex soil distribution patterns that have not always been mappable at the scale of this survey. The

Owanyilla soil usually grades to the *Timbrell* soil on local alluvium at the base of these slopes.

Vegetation: Tall (12–20 m) open dry sclerophyll forest of spotted gum (*Corymbia citriodora* ssp. *varigata*), gum-topped box (*Eucalyptus moluccana*), narrow-leaved ironbark (*E. crebra*), forest red gum (*E. tereticornis*), Moreton Bay Ash (*C. tessellaris*), grey ironbark (*E. siderophloia)* and Queensland peppermint (*E. exserta*).

Land use: Remnant forest, native pasture beef cattle grazing, rural residential.

Existing land degradation: Extensive areas of gully, tunnel and sheet erosion, invasive weeds in some cleared areas, secondary salinity scalds on some lower slopes.

Land and soil limitations: Frost on lower slopes, soil erosion, low plant available water capacity, soil wetness on lower slopes, hardsetting surface condition, secondary salinity on lower slopes.

Soil fertility: This soil is low in phosphorus, copper and sulfur. All other nutrients are in moderate supply. Surface soil fertility is expected to decline with long term cultivation due to the gradual loss of organic matter (Table 23).

Table 23. Mean surface soil nutrients for the *Owanyilla* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.1	2.3	0.16	14	10	12	0.3	0.23	1.90	8	8	3.0	3.9	0.32
neutral	med.	med		low	low	med	low	med	low		med	med	med

This table presents the mean surface results of three analysed reference sites, MBS 10, MTL 282 and GCL 9002. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9002). General fertility ratings from Bruce and Rayment (1982) low; med – medium.

Salinity and sodicity: Salt levels clearly increase with depth but remain below the critical threshold (0.8 dS/m). Figures 16a and 16b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material and the presence of weathered substrate. Subsoil material is strongly sodic from about 0.4 m (Figure 16b).

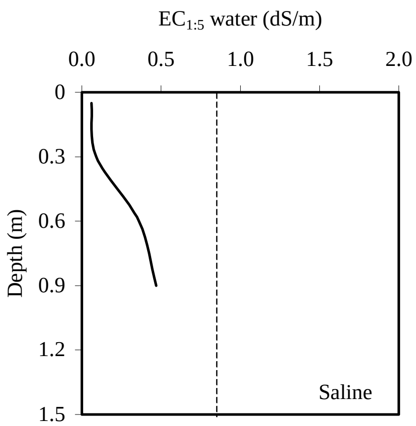


Figure 16a. Mean profile salinity for the *Owanyilla* soil

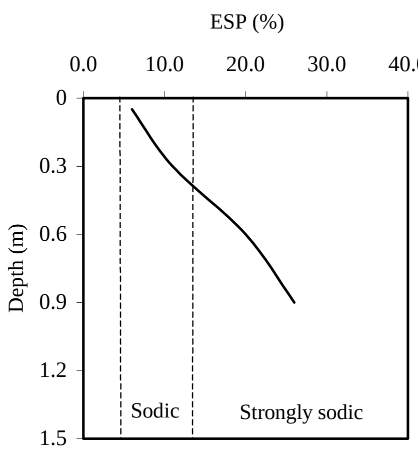


Figure 16b. Mean profile sodicity (ESP) for the *Owanyilla* soil

Physical Characteristics: The *Owanyilla* soil is characterised by a hard setting surface condition (when dry) due to high levels of silt and fine sand in the surface soil. Hardsetting behaviour restricts water entry into the profile and causes moderate soil adhesion problems for root crops. A bleached A2 horizon and mottled subsoil horizons indicate periods of soil wetness and seasonal saturation commonly occur. Restricted soil permeability and drainage associated with strongly sodic subsoil material is probably responsible.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.3–0.5 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. For reference sites MTL 282 and GCL 9002, ERD estimates are between 0.3 and 0.4 m and PAWC between 35 and 56 mm.

Subsoil analytical properties: This soil typically has an alkaline pH trend (increasing pH with depth), although the reference sites are neutral to acid. Subsoils are magnesic, (Ca/Mg ratio close to 0.1) and strongly sodic and subsoil material is dispersive and highly erodible. The calcium/magnesium imbalance in the subsoil also inhibits root growth and limits ERD (Table 24). High levels of silt and clay in the surface soil contribute to hard setting behaviour.

Table 24. Mean soil profile analytical data for the *Owanyilla* soil

Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.6	64	18	25	10	-	2.7	4.0	0.37	0.35	0.39	-
0.2–0.3	5.9	54	12	52	15	20	1.6	7.4	1.3	0.17	0.22	0.29
0.5–0.6	5.6	45	12	43	22	39	1.4	9.8	4.0	0.13	0.14	0.51
0.8–0.9	5.5	47	14	39	25	49	1.4	12	5.7	0.15	0.12	0.64

This table presents the mean results of three analysed reference sites, MBS 10, MTL 282 and GCL 9002. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9002).

Tirroan (Tr), Tirroan rocky phase (TrRp)

Concept: Sodic texture contrast soil with a thick (0.25–0.50 m) bleached sandy surface over a mottled, grey or brown sandy clay subsoil on moderately weathered sandstone.

Aust. Soil Classification: Grey Sodosol; Brown Kurosol.

Great Soil Group: Soloth, rarely solodic soil

Principal Profile Form: Dy3.41, Dy3.42.

Typical Profile

Soil Description

The surface soil (A1, Ap, A2e) is a black or grey, loamy sand to sandy loam with massive structure. The lower two-thirds of the surface soil is bleached and mottled. Surface thickness varies from 0.25 to 0.50 m; pH 5.5 to 6.0.

The subsoil (B2) is a mottled grey or brown, sandy light medium clay to sandy medium heavy clay with prismatic or angular blocky structure. Subsoil thickness varies from 0.20 to 0.75 m; pH 5.5 to 8.0.

The transition zone between the subsoil and substrate consists of a mottled, grey or brown, sandy light medium clay to medium clay with angular blocky structure and sandstone fragments. Lower parts of this horizon grade into weathered rock. The transition layer occurs anywhere below 0.45 to 1.25 m.

Tirroan rocky phase (TrRp): has similar surface horizons to those described above but profiles are much shallower with rock from 0.3 m.

Landform: Gently to moderately inclined (3–16%) slopes on rises and low hills.

Parent material: Moderately weathered sub-labile sandstones of the *Elliot Formation* (Te), *Tiaro Coal Measures* (Jdt) and *Myrtle Creek Sandstone* (RJdm).

Soil associations: The *Tirroan* soil typically occurs upslope of the *Kolan* (Kurosol) soil, in situations where sandy material from deeply weathered coarse grained sediments has moved downslope over moderately weathered sediments. he *Kolan* and *Tirroan* soils are differentiated by surface texture and thickness. The *Kolan* soil has a thin (0.15 to 0.3 m) loamy surface while *Tirroan* soil has a relatively thick (0.25 to 0.5 m) sandy surface. The *Tirroan* soil grades to the *Woober* (Hydrosol) soil on nearby alluvial plains.

Vegetation: Tall to very tall (18 to 22 m) open dry sclerophyll forest of white mahogany (*Eucalyptus acmenoides*), brown bloodwood (*Corymbia trachyphloia*), broad leaved white mahogany, (*Eucalyptus umbra*), Queensland peppermint (*E. exserta*), pink bloodwood (*C. intermedia*), spotted gum (*C. citriodora* ssp. *varigata*) and smooth bark apple (*Angophora leiocarpa*).

Land ue: Native pasture beef and dairy cattle grazing, minor cropping.

Existing land degradation: Gully and tunnel erosion.

Land and soil limitations: Frost, low plant available water capacity, soil erosion.

Soil fertility: Most plant nutrients are in low supply, with the exception of potassium, sulfur and zinc which are moderate (Table 25).

Table 25. Mean surface soil nutrients for the *Tirroan* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water (1:5)	(%)	(%)		Acid (mg/kg)	Bicarb	K (meq/100g)	Cu (mg/kg)	Zn	(mg/kg)	ECEC	Ca (meq/100g)	Mg	K
5.7	1.1	0.05	22	27	11	0.40	0.20	2.3	22	3	0.85	1.2	0.27
acid	low	low		med	low	med	low	med	high		vlow	low	med

This table presents the mean surface results of two analysed reference sites, BSS 16 and GCL 9009. For depth intervals, 0.8–0.9 and 1.1–1.2 m, data is only derived from reference site BSS 16. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9009). Fertility ratings from Bruce and Rayment (1982).

Salinity and Sodicity: Salt levels are negligible (Figure 17a) because the *Tirroan* soil is shallow with sandy surface horizons and occupies elevated landscape positions.

Subsoils are strongly sodic from about 0.3–0.5 m (Figure 17b) and are typically stiff and coarsely structured with slow permeability.

Physical Characteristics: Surface soils are weakly hardsetting to loose while subsoils are strongly sodic and coarsely structured. Surface soils are erosion prone because slopes are >3%, drainage is imperfect and surface material is loose and erodible. Subsoils are dispersive and prone to gully erosion following disturbance.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.3–0.7 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. For reference site GCL 9009, ERD is 0.3 m and PAWC is 37 mm.

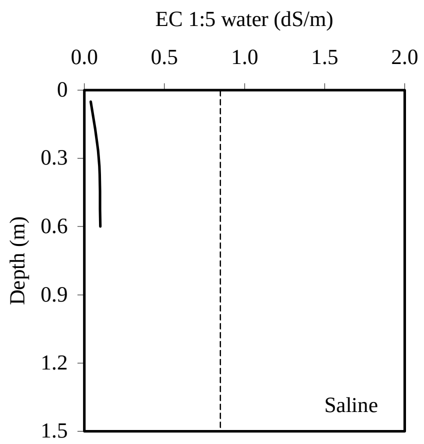


Figure 17a. Mean profile salinity for the *Tirroan* soil

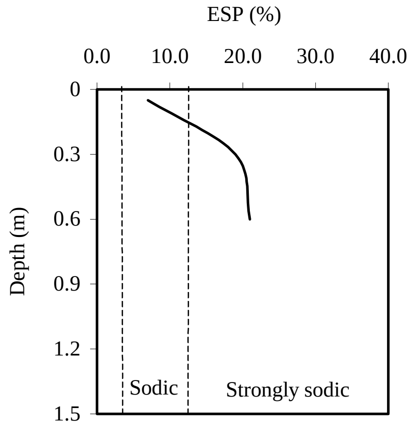


Figure 17b. Mean profile sodicity (ESP) for the *Tirroan* soil

Subsoil analytical properties: This soil typically has an acid pH trend (increasing acidity with depth), with pH values in the lower subsoil usually 5.5–6.5. These compare with the *Kolan* soil. Cation exchange capacity is very low and nutrient retention very poor. Subsoils are strongly sodic (Figure 17b), magnesic (Ca/Mg <0.1) and highly dispersive (Table 26).

Table 26. Mean soil profile analytical data for the *Tirroan* soil

Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations Ca (meq/100g)	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	5.8	88	6	9	3	-	0.59	1.8	0.14	0.20	0.33	0.33
0.2–0.3	5.7	78	8	15	5	-	0.15	3.3	0.75	0.15	0.05	0.33
0.5–0.6	6.1	85	7	8	6	-	0.12	4.3	1.2	0.09	0.03	0.75

This table presents the mean results of two analysed reference sites, BSS 16 and GCL 9009. For more information, a full profile description is present in Appendix 3 for this soil (GCL 9009).

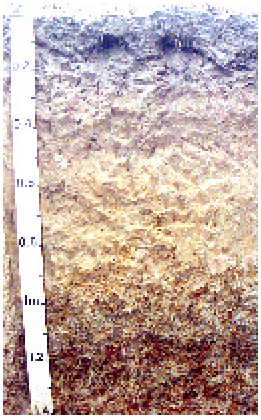
Chromosols

Chromosols are soils with strong texture contrast between the A and B horizons. By definition, the B horizon is neither strongly acid (pH >5.5) nor sodic (ESP <6). Four chromosols including one phase have been mapped *(Alloway* (Al*), Beenham* (Bh), *Isis* (Is). *Isis rocky phase* (IsRp)) occupies 830 ha or 4% of the study area. Although the *Isis* soil keys out dominantly as a chromosol, there is also a high proportion of Dermosol and Tenosol profiles recorded.

Alloway (Al)

Concept:	Bleached sandy surface over a mottled, non sodic, structured gleyed subsoil on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Grey Chromosol (locally dominant), Redoxic Hydrosol.
Great Soil Group:	Gleyed podzolic soil.
Principal Profile Form:	Dg2.41, Dg4.41, Dy3.41, Dy5.42, Gn3.04

Typical Profile



Soil Description

The surface soil (A1, Ap, A2e) is a grey, loamy sand to sandy loam with massive structure. The lower two-thirds of the surface soil is bleached. Surface thickness varies from 0.50 to 0.80 m;, pH 5.0 to 6.0.

The upper part of the subsoil (A3, B1) is a mottled grey or pale yellow, sandy clay loam to sandy light clay with massive to weak polyhedral or subangular blocky structure. Ferruginous nodules are frequently present. Subsoil thickness varies from 0.25 to 0.40 m; pH 5.5 to 6.5.

The lower part of the subsoil (B2) is a mottled, grey, light clay to medium clay with polyhedral or subangular blocky structure. Ferruginous nodules are frequently present. This horizon occurs anywhere below 0.75 to 1.20 m; pH 5.5 to 6.5.

Landform: Level plains (0–1%) to very gently inclined (1–3%) slopes within the deeply weathered land surface.

Parent material: Deeply weathered coarse grained sedimentary rocks (sandstones) of the *Elliott Formation* (Te).

Soil associations: Occurs in association with the *Isis* and *Isis rocky phase* soils.

Vegetation: Tall (15–18 m) dry sclerophyll woodland or open forest of broad leaved white mahogany (*Eucalyptus umbra*), broad-leaved paperbark (*Melaleuca viridiflora*) and occasionally brown bloodwood (*Corymbia trachyphloia*), pink bloodwood (*C. intermedia*) and white mahogany (*E. acmenoides*).

Land use: Native pasture beef cattle grazing, rural residential.

Existing land degradation: Sheet erosion.

Land and soil limitations: Low plant available water capacity, soil wetness.

Soil fertility: All plant nutrients are in low to very low supply because of the highly weathered, leached nature of this soil.

Table 27. Mean surface soil nutrients for the *Alloway* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC (meq/100g)	Ca	Mg	K
5.1	0.8	0.04	20	4.5	4	0.10	0.36	0.26	-	1	0.3	0.3	0.09
acid	low	vlow		vlow	vlow	low	med	low			vlow	vlow	vlow

This table presents the mean results of six analysed reference sites, BSS 30 and 35, CBW 6 and 18, BAB 9004 and BUN 121. General fertilityr ating from Bruce and Rayment (1982). vlow– very lowl l – low; med – medium

Salinity and sodicity: Salt levels are negligible (Figure 18a) because the *Alloway* soil is moderately permeable and occupies elevated landscape positions within the deeply weathered landscape.

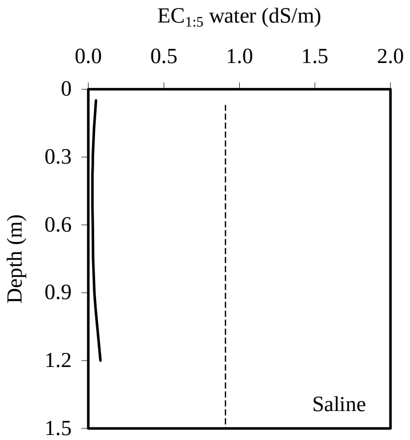


Figure 18a. Mean profile salinity for the *Alloway* soil

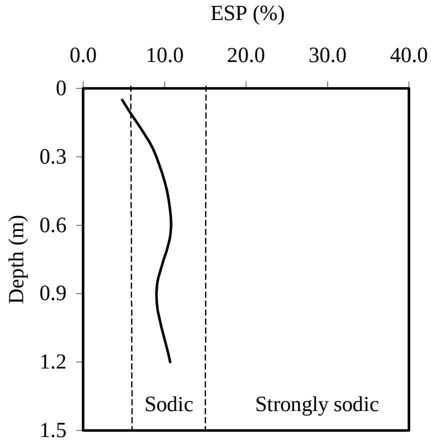


Figure 18b. Mean profiles sodicity (ESP) for the *Alloway* soil

Profiles are typically non-sodic to slightly sodic (Figure 18b) but lack the physical characteristics normally associated with sodic soils. Low pH (<6.0), low ECEC, (<5 meq/100g), low clay activity ratios (<0.2) and low dispersion values associated with kaolinitic clays limit the physical expression of any dispersive effects.

Physical characteristics: The sandy soil surface is typically loose to firm and structureless (massive) and is susceptible to sheet erosion even on gentle slopes (<3%). Soil wetness and very low plant nutrient status in the subsoil (particularly calcium) restrict root development.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and physical restrictions to plant roots are not apparent in the upper profile. Predicted PAWC for the reference sites associated with this soil is between 59 to 65 mm. The thick sandy surface soil (>0.5 m) significantly restricts the PAWC levels.

Subsoil analytical properties: This soil typically has an acid pH trend, with pH values in the subsoil usually 5.5–6.5. The soil is very sandy (even in the clayey subsoil) and has a very low cation exchange capacity. The profile is very low in all exchangeable cations and is magnesic (Ca/Mg ratio <0.2) in the lower subsoil.

Table 28. Mean soil profile analytical data for the *Alloway* soil

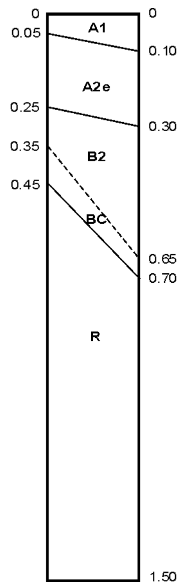
Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.1	84	10	7	1	-	0.3	0.3	0.1	0.09	1.0	0.15
0.2–0.3	5.2	83	11	8	1	-	0.1	0.2	0.1	0.04	0.50	0.13
0.5–0.6	5.4	77	9	17	1	-	0.2	0.3	0.2	0.03	0.67	0.06
0.8–0.9	5.6	69	9	22	3	10	0.3	1.6	0.3	0.03	0.19	0.14
1.1–1.2	5.8	55	8	29	4	14	0.2	3.2	0.5	0.02	0.06	0.14

This table presents the mean results of six analysed reference sites, BSS 30 and 35, CBW 6 and 18, BAB 9004 and BUN 121.

Beenham (Bh)

Concept: Loamy surfaced texture contrast soil with brown or grey loamy surface over red or brown clay subsoil on moderately pyllite.
Aust. Soil Classification: Yellow or Grey Chromosol;
Great Soil Group: Soloth, grey or yellow podzolic soil.
Principal Profile Form: Dy3.41, Dy2.41.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2e) is a black, loam to clay loam with moderate granular structure. The lower two-thirds of the surface soil is bleached and massive. Surface thickness varies from 0.25 to 0.30 m; pH 6.0 to 7.0.

The subsoil (B2) is a mottled, yellow or grey medium clay with subangular blocky structure. Up to 10% rock fragments (phyllite) are normally present in both the surface soil and subsoil. Subsoil thickness varies from 0.10 to 0.35 m; pH 5.5 to 6.0.

The transition zone between the subsoil and substrate consists of a mottled, grey, light medium clay to medium clay with weak blocky structure. Rock fragments of phyllite typically form 50–>90% of the soil matrix. This horizon occurs anywhere below 0.35 to 0.65 m; pH 5.0 to 5.5.

Landform: Moderately inclined (10–25%) slopes on rises and low hills.

Parent material: Phyllite of the *Kin Kin Beds* (Rk).

Soil associations: The *Beenham* soil is associated with *Neerdie* soil, in sloping areas and grades to the *Woober* soil on adjacent alluvial flats.

Vegetation: Mostly cleared. In undisturbed areas, a tall to very tall (18–25 m) open forest of grey gum (*Eucalyptus major),* Crows ash *(Flindersia Australis),* pink bloodwood *(Corymbia intermedia),* giron bark *(E. fibrosa)* and forest red gum *(E. tereticornis*).

Land use: Remnant forest, native pasture beef cattle grazing, rural residential.

Existing land degradation: Sheet erosion, invasive weeds in some cleared areas.

Land and soil limitation: Frost on lower slopes, soil erosion, low plant available water capacity, soil wetness on lower slopes, hardsetting surface condition.

Salinity and sodicity: Profile salinity is generally not apparent in the *Beenham* soil. However on lower slopes and adjacent alluvium some accumulation of salt in the profile can be expected. Subsoils are typically sodic and have prismatic or blocky structure that restricts root growth and reduces soil permeability.

Physical characteristics: The *Beenham* soil is characterised by a hardsetting surface condition (when dry) due to high levels of silt from the phyllite parent material. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. A bleached A2 horizon and mottling in the upper part of the profile indicate seasonal saturation commonly occurs (due to restricted permeability associated with subsoil sodicity).

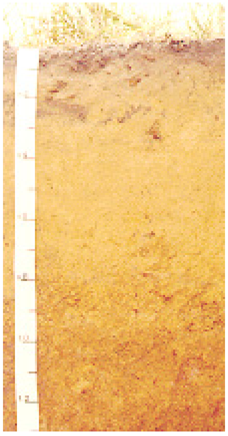
Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.5 m and based on physical restrictions to plant roots associated with subsoil sodicity, poor physical structure and weathering substrate while analytical data is not available for this soil, PAWC is estimated at less than 75 mm.

Subsoil analytical properties: This soil has an acid pH trend, with pH values in the subsoil usually 5.5–6.5. Further analytical data is unavailable for this soil.

Isis (Is) and Isis rocky phase (IsRp)

Concept:	Thick (0.30–0.70 m) bleached sandy surface over a mottled, yellow structured clay subsoil on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Yellow Chromosol; Yellow Dermosol.
Great Soil Group:	Yellow podzolic soil.
Principal Profile Form:	Dy3.41, Gn3.84.

Typical Profile



Soil Description

The surface soil (Ap, A1, A2e) is a grey, sandy loam to fine sandy loam with massive structure. The lower two-thirds of the surface soil is bleached. Surface thickness varies from 0.30 to 0.70 m; pH 5.5 to 6.5.

The upper part of the subsoil (A3, B1) is a yellow sandy clay loam to sandy light clay with massive or weak polyhedral structure. Ferruginous nodules are frequently present. Subsoil thickness varies from 0.20 to 0.40 m; pH 5.5 to 6.5.

The lower part of the subsoil (B2) is a mottled, yellow, light clay to medium clay with polyhedral or subangular blocky structure. Ferruginous nodules are frequently present. This horizon occurs anywhere below 0.50 to 1.10 m; pH 5.5 to 6.5.

Isis rocky phase occurs either as a shallow version with substrate from 0.6 m; or as a rocky version with greater than 10% surface cobbles >0.06 m.

Landform: Mid to upper slopes or level to gently undulating plains and rises.

Parent material: Deeply weathered coarse grained sedimentary rocks (sandstones) of the *Elliot Formation* (Te) and other deeply weathered sedimentary formations.

Soil associations: The *Isis* soil grades into the *Isis Rocky phase* soil in areas dominated by conglomerate and the *Tirroan* soil on lower slopes.

Vegetation: Mostly cleared. In undisturbed areas a tall (12–20 m) open dry sclerophyll forest of pink bloodwood (*Corymbia intermedia*) and brown bloodwood (*C. trachyphloia*) is usually present.

Land use: Remnant forest, native pasture beef cattle grazing, minor small crops, rural residential.

Existing land degradation: Sheet erosion, invasive weeds in some cleared areas.

Land and soil limitations: Soil erosion, low plant available water capacity, rockiness.

Soil fertility: All plant nutrients are in very low to low supply due to the deeply weathered nature of the sedimentary parent material (Table 29). Subsoils are magnesic at depth and calcium uptake and root growth are severely affected.

Table 29. Mean surface soil nutrients for the *Isis* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)	(meq/100g)			
5.3	1.4	0.17	8	9.8	5	0.16	1.1	0.20	-	4	1.1	0.3	0.06
acid	low	med		vlow	vlow	vlow	med	low			vlow	vlow	vlow

This table presents the mean results of five analysed reference sites, QCB 137 and 142, MBS 31, 50 and 62. General fertility rating from Bruce and Rayment (1982). vlow – very low; low; med – medium

Salinity and sodicity: Salt levels are negligible (Figure 19a) because the *Isis* soil is freely drained and occupies elevated landscape positions within the deeply weathered landscape.

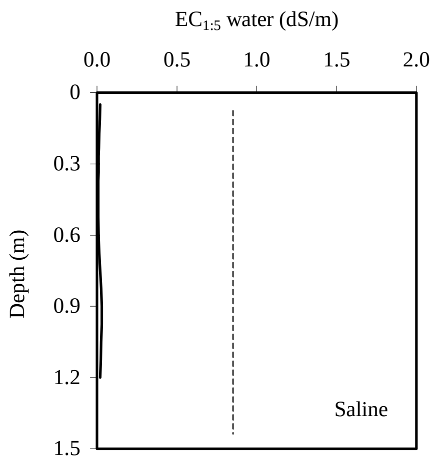


Figure 19a. Mean profile salinity for the *Isis* soil

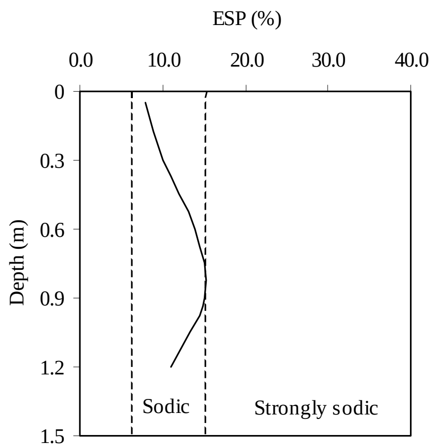


Figure 19b. Mean profile sodicity (ESP) for the *Isis* soil

Profiles are typically sodic (ESP 6–15), particularly between about 0.5–1.1 m) but lack the physical characteristics normally associated with sodic soils. Low pH (<6.0), low ECEC (<5 meq/100g), low clay activity ratios (<0.2), and low dispersion values associated with kaolinitic clays limit the physical expression of any dispersive effects.

Physical characteristics: The surface soil is loose to firm and is susceptible to sheet erosion even on gentle slopes because of its sandy nature and massive structure. There are no physical restrictions to rooting depth and the soil is imperfectly drained.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. Predicted PAWC for the reference sites associated with this soil is between 59 and 65 mm. Lower water holding capacity in the thick sandy surface soil significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid pH trend, and is typical of soils developed on deeply weathered sediments. The pH values throughout the profile are 5.5–6.5. The soil matrix is dominated by the sand fraction (>70%) and is highly weathered and leached with a very low cation exchange capacity. Levels of exchangeable cations are extremely low and the profile is magnesic at depth.

Table 30. Mean soil profile analytical data for the *Isis* soil

Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations (meq/100g)				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
0–0.1	5.3	83	11	7	3	-	1.1	0.5	0.2	0.06	2.2	0.43
0.2–0.3	5.4	84	9	7	3	-	0.4	0.3	0.3	0.03	1.3	0.43
0.5–0.6	5.4	78	11	11	2	-	0.4	0.7	0.3	0.02	0.57	0.18
0.8–0.9	5.7	63	6	25	3	15	0.3	2.8	0.5	0.05	0.11	0.12
1.1–1.2	5.8	67	6	30	3	10	0.4	2.2	0.3	0.02	0.18	0.10

This table presents the mean results of five analysed reference sites, QCB 137 and 142, MBS 31, 50 and 62.

Ferrosols

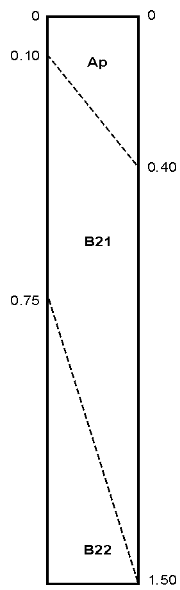
Ferrosols are soils with B2 horizons which are high in free iron oxide, lack vertic properties and typically have strong polyhedral structure. Profiles lack strong texture contrast between the A and B horizons. These soils are formed almost entirely on either basic or ultra basic igneous rocks, their metamorphic equivalents or alluvium derived from there.

Only one Ferrosol *(Bidwill* (Bd)) has been mapped. It is of limited extent and is restricted to areas developed on deeply weathered (lateritised) andesite east of the Mary River, at Scotchy Pocket. Because Ferrosols are highly productive and extensively used for cultivation, their surface characteristics have often been modified or lost. Because of this, the *Watalgan* (Wt) soil (Dermosol) can have a similar appearance. Ferrosols occupy only 120 ha or less than 0.6% of the study area. Whilst of limited extent the *Bidwill* (Bd) soil represents one of the most productive soils in the area.

Bidwill (Bd)

Concept: Red structured clay on deeply weathered andesite of the *Grahams Creek Formation.*
Aust. Soil Classification: Red Ferrosol.
Great Soil Group: Krasnozem, Euchrozem.
Principal Profile Form: Uf5.21, Uf5.22, Uf6.31.

Typical Profile



Depth (m)

Soil Description

The surface soil (Ap) is a red, light clay to light medium clay with granular structure. Surface thickness varies from 0.10 to 0.40 m; pH 5.5 to 6.5.

The subsoil (B21, B22) is a red, light clay to medium clay with polyhedral structure and manganiferous nodules. This horizon occurs anywhere below 0.10 to 0.40 m; pH 5.5 to 7.0.

Landform: Level to gently inclined (0–4%) crests on rises and low hills (or occasionally on slightly elevated crests within gently undulating plains).

Parent material: Deeply weathered andesite of the *Grahams Creek Formation* (JKg).

Soil associations: The *Bidwill* soil grades into the *Jumpo* soil (Dermosol) on lower slopes. Where the deeply weathered parent material changes from andesite to sedimentary rocks, the *Kepnock* and *Watalgan* soils (Dermosols) are typically associated.

Vegetation: Mostly cleared, with minor vine scrub remnants along road reserves.

Land use: Tree crops, sugar cane, improved pastures.

Existing land degradation: Minor soil compaction may occur in heavily cultivated fields.

Land and soil limitations: Deep drainage contributing to wetness and secondary salinity on lower slopes.

Soil fertility: Most plant nutrients are in moderate to high supply with the exception of available phosphorus which is low. Soils high in iron and aluminium oxides (Ferrosols) are subject to significant phosphorus sorption which converts available phosphorus into unavailable forms. The cation exchange capacity is significantly higher in the surface soil due to high organic carbon/organic matter content. Surface soil fertility will decline with long term cultivation if organic matter levels are not maintained (Table 31).

Table 31. Mean surface soil nutrients for the *Bidwill* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)	(meq/100g)			
6.4	3.1	0.28	11	5	13	1.3	2.9	3.4	-	11	6.5	3.6	1.35
neutral	high	high		vlow	low	high	med	med			high	mod	vhigh

This table presents the mean results of two analysed reference sites, BUN 111 and MTL 246. General fertility rating from Bruce and Rayment (1982). vlow - very low; low; med – medium, high, vhigh – very high

Salinity and sodicity: Salt and sodicity levels are negligible (Figures 20a and 20b) because the *Bidwill* soil is strongly structured, well drained and occurs in elevated landscape positions.

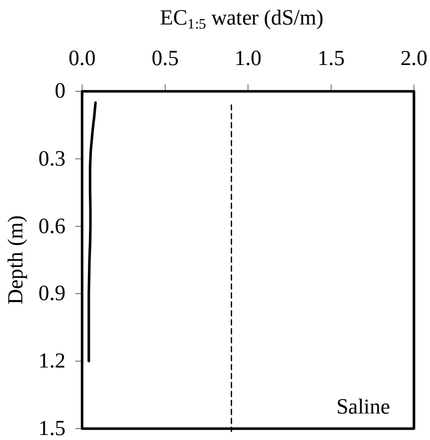


Figure 20a. Mean profile salinity for the *Bidwill* soil

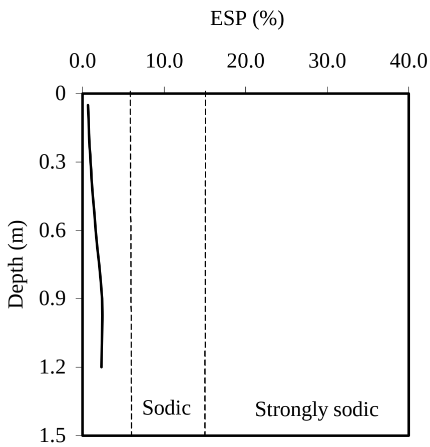


Figure 20b. Mean profile sodicity (ESP) for the *Bidwill* soil

Physical characteristics: In undisturbed situations, the *Bidwill* soil has dark (brown or black) hardsetting surface horizons that grade to red clay subsoils. In cultivated fields, the original surface horizons have often been altered due to erosion and loss of organic matter and surface layers are now red clays. The presence of very fine (<0.02 m) manganiferous nodules throughout the profile is a useful feature that helps distinguish this soil from the *Watalgan* (Dermosol) soil in cultivated situations. The *Bidwill* soil has strong fine polyhedral structure throughout and is usually very well drained. Soil compaction is an issue with regular cultivation because subsoils are dominated by 1:1 kaolinite clays that do not exhibit shrink swell behaviour and have limited capacity for self repair.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots, except where subsoils have been compacted. For BUN111 and MTL246 reference sites, PAWC is estimated at between 124 to 152 mm. High clay content, fine structure and significant surface organic matter are responsible for elevated PAWC levels.

Subsoil analytical properties: This soil has an acid pH trend, and is typical of soils developed on deeply weathered substrates. The pH values throughout the profile are 5.5–7.0. Field data suggest subsoil clay contents are 35–55%, while laboratory data confirm actual clay contents are >70%. The combination of very strongly structured, sub-plastic clay material and high levels of iron and aluminium oxides are responsible for this discrepancy. Cation exchange capacity is low throughout the profile and reflects the highly weathered leached nature and age of this soil. Its excellent drainage and subsoil chemistry suggest nutrient retention is an issue and applied fertilisers are easily leached.

Table 32. Mean soil profile analytical data for the *Bidwill* soil

Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.3	32	23	45	10	-	5.9	3.2	0.2	1.04	1.8	0.22
0.2–0.3	6.5	24	18	60	6	-	4.0	2.2	0.2	0.58	1.8	0.10
0.5–0.6	5.9	16	13	73	5	7	2.6	2.2	0.2	0.26	1.2	0.07
0.8–0.9	6.0	16	15	72	5	7	1.6	2.9	0.2	0.04	0.55	0.07
1.1–1.2	5.7	14	13	73	4	6	1.0	3.1	0.2	0.03	0.32	0.05

This table presents the mean results of two analysed reference sites, BUN 111 and MTL 246.

Dermosols

Dermosols are soils (other than Vertosols, Hydrosols and Ferrosols) that lack strong texture contrast between the A and structured B horizons. Sixteen Dermosols including two variants and one phase have been mapped. These include soils formed on andesite *(Netherby* (Nb), *Tiaro* (Ta), *Tiaro rocky phase* (TaRp), *Tiaro red variant* (TaRv)), deeply weathered sedimentary rocks *(Jumpo* (Jp), *Watalgan (Wt))*, moderately weathered sedimentary rocks *(Bucca* (Bc)) and alluvium *(Aldershot* (Ad), *Copenhagen* (Co), *Granville* (Gr), *Gutchy* (Gy), *Mary (My), Mary dark variant* (MyDv), *Miva* (Mv), *Mungar* (Mg), *Walker* (Wk)). Dermosols are widespread and occupy 3 946 ha or 19% of the study area. They represent the main group of soils under cultivation for sugar cane and horticulture.

Aldershot (Ad)

Concept:	Thin (0.10–0.35 m) massive loamy surface over a red or brown structured non-sodic clay subsoil on alluvium of the Mary River.
Aust. Soil Classification:	Red or Brown Dermosol.
Great Soil Group:	Red brown earth.
Principal Profile Form:	Dr2.21, Gn3.22, Gn3.72.

Typical Profile

Soil Description

The surface soil (Ap, A2) is a grey, black or brown, fine sandy loam to silty clay loam with massive structure. The lower half of the horizon can have a paler colour. Surface thickness varies from 0.10 to 0.35 m; pH 5.5 to 6.5.

The subsoil (B21, B22) is a red or brown, clay loam sandy to light medium clay with blocky structure. Manganiferous nodules are normally present. Subsoil thickness varies from 0.80 to 1.15 m; pH 6.5 to 7.5.

A buried horizon (D) often occurs below the subsoil. Typically, it is a brown, clay loam sandy with massive structure. This horizon occurs anywhere below 0.9 to >1.5 m; pH 7.0 to 7.5.

Landform: Elevated margins of relict levees and river terraces associated with former flood plains of the Mary River.

Parent material: Quaternary Pleistocene alluvium (predominantly sandy) (Qpa).

Soil associations: The *Aldershot* soil occurs in association with the *Butcher* soil on terrace margins and grades into the *Mungar* and *Granville* soils on backplains.

Vegetation: Mostly cleared.

Land use: Sugar cane, small crops, improved dairy pastures.

Existing land degradation: Steam bank erosion.

Land and soil limitations: Frost, occasional localised flooding.

Soil fertility: Most plant nutrients are in moderate supply apart from sulfur, which is very low. Levels are moderate rather than high because of the age of the alluvial sediments on which this soil develops.

Table 33. Surface soil nutrients for the *Aldershot* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC (meq/100g)	Ca	Mg	K
6.4	2.1	0.17	12	27	37	0.5	1.3	4.2	1.3	10	4.7	4.3	0.63
neutral	med	med		med	med	med	med	med	vlow		med	med	high

This table presents surface results from analysed reference site, GCL 9000. See appendix 3 for a full description. General fertility ratings from Bruce and Rayment (1982). vlow – very low; med – medium, high.

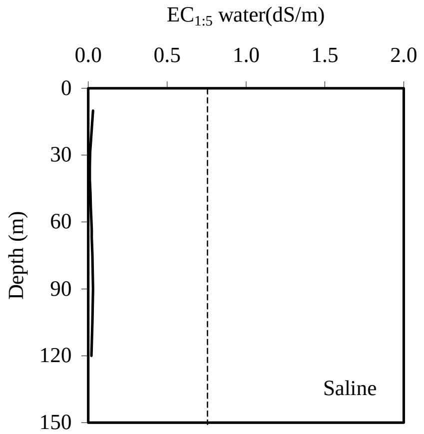


Figure 21a. Profile salinity for the *Aldershot* soil

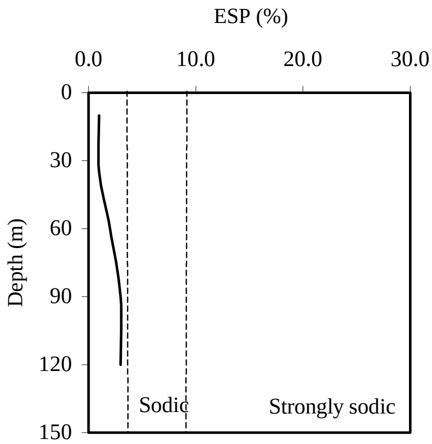


Figure 21b. Profile sodicity (ESP) for the *Aldershot* soil

Salinity and sodicity: Salt and sodicity levels are negligible (Figures 21a and 21b) because the *Aldershot* soil is well structured, permeable and occurs in elevated landscape positions.

Physical characteristics: Surface soils have loamy textures, massive structure and set hard when dry. Subsoils are well structured and well drained and present no restrictions to rooting depth. The well drained nature of this soil reduces runoff and lessens surface soil erodibility.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. Clay content and clay mineralogy however, strongly influence final PAWC levels. For reference site GCL 9000, PAWC is estimated at 81 mm.

Subsoil analytical properties: This soil has a neutral pH trend with pH values in the subsoil usually 6.5–7.5. The profile is high in sand and silt and reflects the soil's alluvial origins. Subsoils are non-sodic with balanced levels of exchangeable Ca and Mg while clay activity ratios indicate the clay fraction is of mixed mineralogy.

Table 34. Soil profile analytical data for the *Aldershot* soil

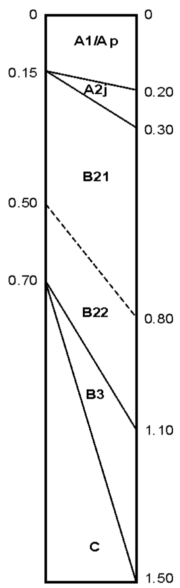
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations Ca (meq/100g)	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	6.0	55	23	21	11	-	5.3	4.7	0.11	0.44	1.12	0.52
0.2–0.3	6.5	55	22	23	11	-	5.6	5.4	0.13	0.10	1.04	0.48
0.5–0.6	7.3	55	16	32	12	39	5.1	7.0	0.24	0.08	0.73	0.38
0.8–0.9	7.6	59	9	28	11	40	4.2	6.5	0.34	0.08	0.65	0.39
1.1–1.2	7.8	68	8	23	10	44	3.7	6.0	0.30	0.08	0.62	0.44

This table presents results from analysed reference site, GCL 9000. See appendix 3 for a full description.

Bucca (Bc)

Concept:	Sporadically bleached, mottled, grey or brown acid sodic clay on moderately weathered fine grained sedimentary rocks.
Aust. Soil Classification:	Grey or Brown Dermosol; Grey or Brown Vertosol.
Great Soil Group:	No suitable group, affinities with grey or brown clay.
Principal Profile Form:	Uf3, Uf6.41, Ug5.24, Ug5.35

Typical Profile



Depth (m)

Soil Description

The surface soil (Ap, A1, A2j) is a grey or brown, light clay to medium clay with cast, granular or blocky structure. The lower third of the horizon may be sporadically bleached in undisturbed situations. Surface thickness varies from 0.15 to 0.3 m; pH 4.5 to 5.5.

The subsoil (B21, B22) is a mottled, grey or brown medium clay to heavy clay with lenticular or subangular blocky structure. Ferruginous nodules are frequently present. The lower part of the subsoil (B3) often has up to 50% rock fragments. Subsoil thickness varies from 0.55 to 1.2 m; pH 4.0 to 5.5.

A transitional horizon (B3) occurs between the subsoil and the parent material. This horizon occurs anywhere below 0.7 to 1.5 m.

Landform: Gently to moderately inclined (3–12%) slopes on rises and low hills.

Parent material: Mudstone (or occasionally rhyolite and tuff) of the *Grahams Creek Formation* (JKg), *Tiaro Coal Measures* (Jdt) and *Maryborough Formation* (Km).

Soil associations: The *Bucca* soil is most commonly associated with the *Kolan* (Kurosol) soil. It also occurs in a complex with the *Tiaro* (Dermosol) soil due to microdiorite sills and dykes interbedded with the mudstones.

Vegetation: Tall to very tall (18 to 25 m) open or closed forest (scrub) with emergent hoop pine (*Araucaria cunninghamii*) and swamp box (*Lophostemon suaveolens*), grey ironbark (*Eucalyptus siderophloia*), gum-topped box (*E. moluccana*), spotted gum (*Corymbia citriodora* ssp. *varigata*) and occasional forest red gum (*E. tereticornis*).

Land use: Native and improved pasture beef cattle grazing.

Existing land degradation: Sheet and gully erosion.

Land and soil limitations: Soil erosion, acid subsoils, adhesive soil (root crops only), hardsetting surfaces condition, narrow moisture range for cultivation, secondary salinity on lower slopes.

Soil fertility: Most plant nutrients are in moderate supply and reflect the nutrient status of the labile sedimentary rocks from which this soil has developed. The acid pH of the soil may restrict the availability of calcium, magnesium, and phosphorus however.

Table 35. Mean surface soil nutrients for the *Bucca* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
5.0 acid	2.3 med	0.19 med	12	15 low	23 med	0.3 med	0.45 med	0.70 med	51 high	12	3.6 med	3.5 med	0.31 med

This table presents the mean results of three analysed reference sites, BSS 37, BAB 9007 and MTL 9002. General fertility rating from Bruce and Rayment (1982). med – medium, high.

Salinity and sodicity: Salt levels clearly increase in the lower subsoil and are most probably associated with weathered parent material at depth and impermeable strongly sodic subsoils. Figure 22a shows mean $EC_{1:5}$ values are largely negligible above 1.2 m indicating significant profile drainage is occurring even though strongly sodic, subsoil material is present from about 0.7 m.

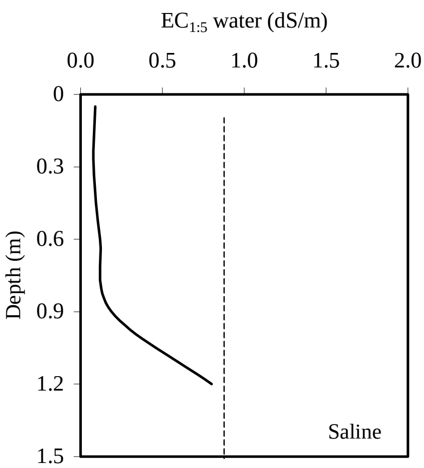


Figure 22a. Mean profile salinity for the *Bucca* soil

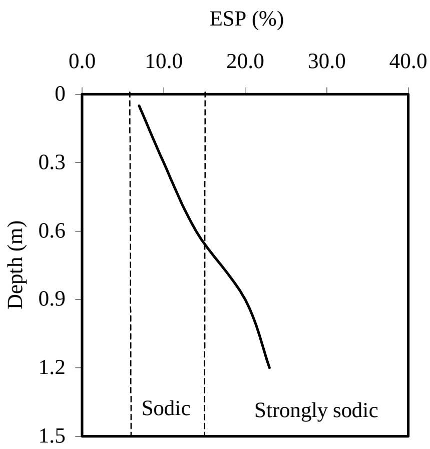


Figure 22b. Mean profile sodicity (ESP) for the *Bucca* soil

Physical characteristics: The *Bucca* soil is characterised by a hardsetting surface condition (when dry) due to high levels of silt and clay in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Subsoils are acid, sodic, medium to heavy clays that restrict rooting depth, permeability and drainage.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.6–0.8 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. Very low calcium levels and strongly acid subsoils may further reduce rooting depth to as little as 0.3 m. For reference sites, BSS 37, BAB 9007 and MTL 9002, ERD is between 0.4 to 0.6 m and estimated PAWC is between 78 and 86 mm.

Subsoil analytical properties: This soil is strongly acid throughout (pH <5.5). Subsoils have significant cation exchange capacity but are strongly sodic, and magnesic (deficient in calcium). Where pH is <5.5 in the profile, aluminium toxicity may also be a problem.

Table 36. Mean soil profile analytical data for the *Bucca* soil

Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations (meq/100g) Ca	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	5.1	24	19	53	11	-	3.3	3.5	0.80	0.32	0.94	0.21
0.2–0.3	5.0	23	20	54	10	8	1.0	2.1	0.91	0.16	0.48	0.19
0.5–0.6	5.0	19	20	60	12	8	0.63	2.7	1.32	0.12	0.23	0.20
0.8–0.9	4.9	17	14	66	20	15	0.56	6.2	3.08	0.23	0.09	0.30
1.1–1.2	5.0	17	12	72	26	22	0.76	9.5	5.21	0.32	0.08	0.36

This table presents the mean results of three analysed reference sites, BSS 37, BAB 9007 and MTL 9002.

Copenhagen (Co)

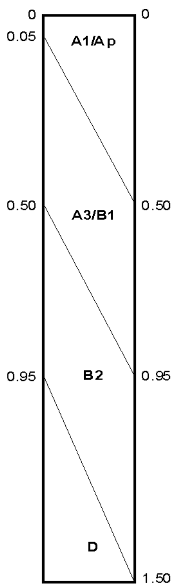
Concept: Layered alluvial soil with a loamy surface over a sandy clay loam to sandy clay subsoil on terraces of the Mary River.

Aust. Soil Classification: Black or Brown Dermosol.

Great Soil Group: Prairie soil, Alluvial soil.

Principal Profile Form: Gn3.22, Um5.52, Um6.31, Um6.32, Uf6.31

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, Ap, A3, B1) is a brown or black loam to clay loam with massive to strong subangular blocky structure. The lower half is normally more weakly structured. Surface thickness varies from 0.50 to 0.95 m; pH 6.0 to 7.5.

The subsoil (B2) is a black or brown sandy clay loam to fine sandy light clay with subangular blocky structure. Subsoil thickness varies from 0.45 to 0.55 m; pH 6.5 to 7.5.

A buried horizon (D) often occurs below the subsoil. Typically, it is a brown, fine sand to fine loamy sand that lacks structure. This horizon occurs anywhere below 0.95 to 1.5 m; pH 6.5 to 7.5.

Landform: Channel benches, levees and scrolls on terrace flats of the Mary River.

Parent material: Quaternary Holocene alluvium (Qha1).

Soil associations: The *Copenhagen* soil occurs in association with the *Baddow* (Rudosol) and the *Mary* (Dermosol) soils.

Vegetation*:* Mostly cleared.

Land use: Sugar cane, improved pastures for beef and dairy cattle.

Existing land degradation: Stream bank slumping, riparian weeds.

Land and soil limitations: Frost, flooding.

Soil fertility: Most plant nutrients are in moderate to very high supply. (Note – Reference site GCL 9008 is located on area used for improved pastures and has probably been fertilised).

Table 37. Surface soil nutrients for the *Copenhagen* soil

PH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.4	1.5	0.15	10	160	150	1.9	1.5	3.1	17	11	4.6	3.9	2.3
neutral	low	low		vhigh	vhigh	vhigh	med	med	med		med	med	vhigh

This table presents surface results from analysed reference site GCL 9008. See appendix 3 for a full description. General fertility ratings from Bruce and Rayment (1982), low, med-medium, vhigh- very high.

Salinity and Sodicity: The *Copenhagen* soil is well drained and has salt concentrations that are negligible throughout (Figure 23a). Profiles are typically friable and non sodic. (Figure 23b).

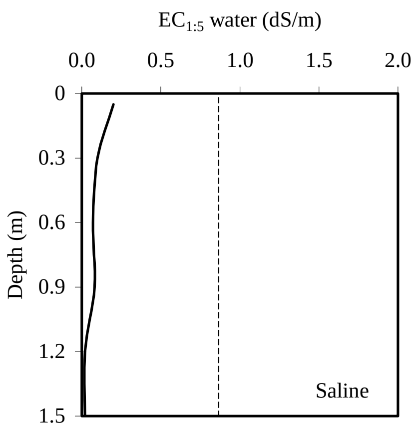


Figure 23a. Typical profile salinity for the *Copenhagen* soil

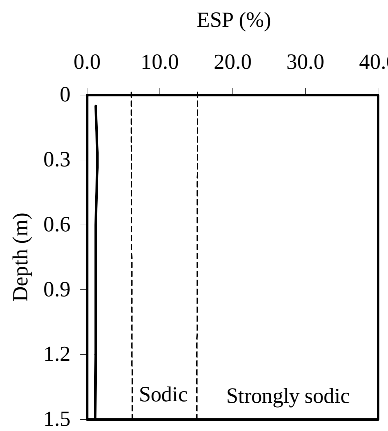


Figure 23b. Profile sodicity (ESP) for the *Copenhagen* soil

Physical characteristics: Surface soils are soft or firm and subsoils are well structured with few if any restrictions to root development. Profiles are permeable and moderately well to well drained.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. Clay content and clay mineralogy however, strongly influence final PAWC levels. For reference site GCL 9008, estimated PAWC is 66 mm.

Subsoil analytical properties: This soil has a neutral pH trend with pH values in the subsoil usually 6.5–7.5. Clay and silt contents gradually increase with depth (Table 38) although the profile is dominated by the sand fraction throughout. Cation exchange capacity is moderate and is dominated by calcium and magnesium which are largely in balance. Total potassium (soluble and insoluble forms) is high throughout the profile, and reflects the origins of the alluvium in the Mary River catchment from which this soil is derived. Clay activity ratio indicates the soil is dominated by montmorillonitic clays (Baker and Eldershaw 1993).

Table 38. Soil profile analytical data for the *Copenhagen* soil

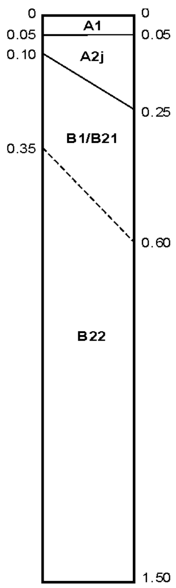
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations (meq/100g) Ca	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	6.2	73	12	14	12	-	5.0	4.1	0.14	2.5	1.21	-
0.3–0.4	6.3				11	-	6.0	4.5	0.16	0.79	1.33	-
0.5–0.6	6.7	67	15	19	14	73	7.8	5.3	0.16	0.60	1.47	0.74
0.8–0.9	6.7	58	20	23	17	78	11	6.3	0.21	0.37	1.75	0.74
1.1–1.2	7.3	62	19	21	17	82	11	5.9	0.20	0.18	1.86	0.81
1.4–1.5	7.4				15		8.9	5.4	0.16	0.16	1.65	

This table presents results from analysed reference site GCL 9008. See appendix 3 for a full description.

Granville (Gr)

Concept: Sporadically bleached acid, grey clay on alluvium of the Mary River.
Aust. Soil Classification: Grey or Brown Dermosol, Brown Vertosol.
Great Soil Group: No suitable group.
Principal Profile Form: Uf3, Ug3.2.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2j) is a grey, light clay to light medium clay with granular or subangular blocky structure. The lower two-thirds is sporadically bleached and mottled, with manganiferous segregations normally present. Surface thickness varies from 0.10 to 0.25 m; pH 5.5 to 6.0.

The subsoil (B21, B22) is a mottled, grey or brown, light medium clay to heavy clay with subangular blocky structure. Typically, the lower subsoil is characterised by the development of lenticular structure and the presence of manganiferous segregations. Subsoil horizons occur anywhere below 0.10 to 0.25m; pH 5.0 to 6.5.

Landform: Elevated, relict alluvial plains or older terrace flats of the Mary River.

Parent material: Quaternary Pleistocene alluvium (Qpa) – predominantly clay sediments.

Soil associations: Occurs in association with the *Butcher* (Sodosol) and *Aldershot* (Dermosol) soil, on margins of the relict alluvial plain and sometimes *Mungar* (Dermosol) soils.

Vegetation: Mostly cleared.

Land use: Sugar cane, improved pastures for beef and dairy cattle.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost, flooding during very large events, soil wetness (in backplain depressions) hardsetting surface condition, adhesive soil (root crops only), narrow moisture range for cultivation.

Soil fertility: Most plant nutrients are in moderate supply, with the exception of available phosphorus which is very low. Moderate organic matter levels (ie. organic carbon) in the surface soil assists in the accumulation of nutrients.

Table 39. Mean surface soil nutrients for the *Granville* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.0	2.3	0.15	15	5	6.5	0.26	1.2	1.0	15	11	3.8	4.9	0.26
neutral	med	low		vlow	vlow	med	med	med	med		med	med	med

This table presents the mean results of three analysed reference sites, BUN 109, MBS 17, and MHB 448. General fertility ratings from Bruce and Rayment (1982). vlow- very low, low, med – medium.

Salinity and sodicity: Salt levels clearly increase with depth. Figure 24a indicates mean $EC_{1:5}$ values are critical from about 0.9 m.

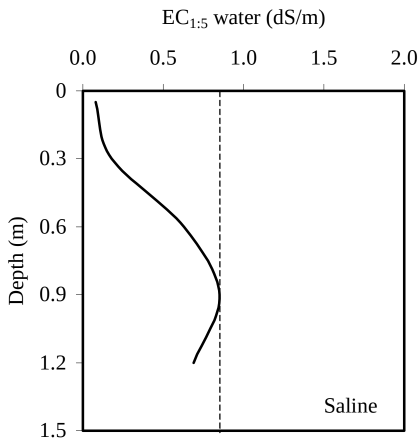


Figure 24a. Mean profile salinity for the *Granville* soil

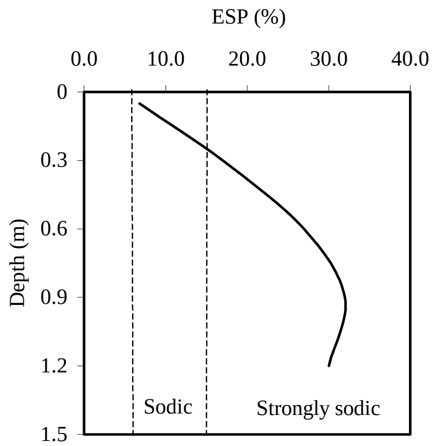


Figure 24b. Mean profile sodicity (ESP) for the *Granville* soil

Figure 24b indicates surface soils are sodic, while subsoils are strongly sodic below about 0.3 m. Subsoils are also magnesic (high in magnesium ions), highly dispersive (high dispersion ratio) and only slowly permeable. Comparison of Figures 24a and 24b illustrates that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material.

Physical characteristics: The *Granville* soil is characterised by a hardsetting surface condition (when dry) due to high levels of fine sand and silt in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Profiles are poorly drained because subsoils are strongly sodic, coarsely structured and very slowly permeable. The upper subsoil has reasonable blocky structure, while the lower subsoil is dominated by shrink-swell clays with lenticular structure.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.6 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure. For reference sites BUN 108, MBS 17 and MHB 448, ERD estimates are between 0.4 and 0.6 m and PAWC between 73 and 101 mm.

Subsoil analytical properties: This soil has an acid to neutral pH trend, with pH values in the subsoil usually 5.0–6.5. Silt and clay contents are high throughout the profile and reflect the soil's alluvial origins. Cation exchange capacity is typically high in the subsoil, a strong calcium – magnesium imbalance restricts root growth below 0.3 m. The lower subsoil is dominated by illite clays which help explain the presence of lenticular structure and high base status.

Table 40. Mean soil profile analytical data for the *Granville* soil

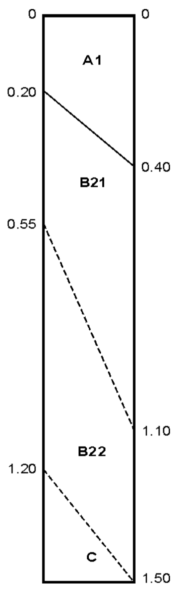
Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.9	36	39	24	11	-	3.3	4.9	0.70	0.30	0.67	0.46
0.2–0.3	6.1	27	29	45	14	-	2.0	6.0	1.89	0.12	0.33	0.31
0.5–0.6	6.5	19	25	56	21	39	1.3	15	5.44	0.16	0.09	0.38
0.8–0.9	6.7	18	27	54	26	51	1.1	18	8.23	0.20	0.06	0.48
1.1–1.2	6.9	11	29	60	33	56	0.38	23	9.60	0.29	0.02	0.55

This table presents the mean results of three analysed reference sites, BUN 109, MBS 17, and MHB 448.

Gutchy (Gy)

Concept: Black clayey soil on alluvial fans.
Aust. Soil Classification: Black or grey Dermosol; Redoxic or Oxyaquic Hydrosol.
Great Soil Group: No suitable group, affinities with Prairie soil.
Principal Profile Form: Uf6.32, Uf6.33.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1) is a black or grey, light medium clay with granular or subangular blocky structure. Surface thickness varies from 0.20 to 0.40 m; pH 6.0 to 7.0.

The subsoil (B21, B22) is a black or grey, medium clay to medium heavy clay with lenticular or angular blocky structure in its upper part and lenticular structure at depth. The lower part has only lenticular structure. Ferruginous and calcareous nodules are normally present in the lower subsoil. Subsoil thickness varies from 1.0 to 1.1 m; pH 8.0 to 8.5.

A transitional horizon (C) occurs between the subsoil and the parent material anywhere below 1.2 and 1.5 m. This horizon is a grey, medium heavy clay and is characterised by with weak structure, calcareous nodules and significant rock fragments; pH 9.0.

Landform: Level to very gently inclined (0–3%), broad alluvial fans draining hills and mountains associated with intermediate to basic rocks (eg. Mt Bauple).

Parent material: Quaternary alluvium (Qa) – predominantly clay sediments, derived from hills of intermediate rocks (microdiorite and andesite).

Soil associations: The *Gutchy* soil occurs in association with the *Tiaro* soil (Dermosol) upslope and

Pelion soil downslope (Vertosol) on valley flats.

Vegetation: Mostly cleared, with isolated forest red gum (*Eucalyptus tereticornis*), grey ironbark *(E. siderophloia)*, Moreton bay ash (*Corymbia tessellaris*) and rough-barked apple (*Angophora floribunda*).

Land use: Improved pastures for beef cattle grazing.

Existing land degradation: Gully erosion.

Land and soil limitations: Frost, soil erosion, soil wetness, narrow moisture range for cultivation, secondary salinity.

Soil fertility: Fertility data is unavailable for this soil, but it is expected to have moderate to high levels of organic matter and most plant nutrients, with the exception of available phosphorus.

Salinity and sodicity: Mean profile salinity field data (Figure 25) indicates that while $EC_{1:5}$ values never reach critical levels, there is a gradual build up of salt with depth. No laboratory measured EC or ESP data is available for this soil and it is possible that field EC measurements have underestimated salt concentrations at depth (ie. because of inadequate shaking). Subsoils are likely to be strongly sodic because pH is alkaline, textures are clayey and the soil bolus has a soapy feel.

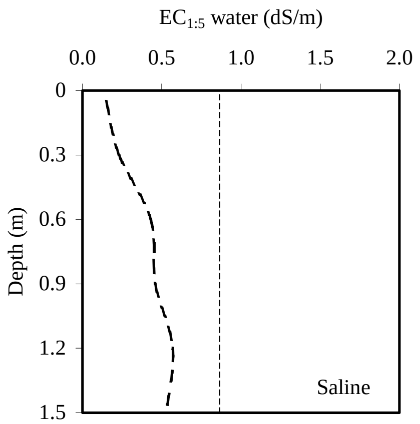


Figure 25. Mean profile salinity for the *Gutchy* soil

Physical characteristics: The soil is clayey throughout with a firm or occasionally self mulching structured surface. Subsoils are quite heavy and are characterised by lenticular structure and the presence of calcareous segregations. The clay surface may restrict the tillage window associated with this soil.

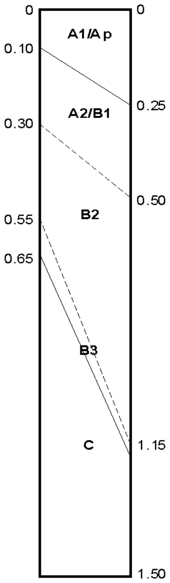
Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.5–1.0 m and is based on physical restrictions to plant roots associated with the presence of sodic, calcareous, lenticular, strongly alkaline subsoil material. Laboratory data is unavailable for this soil and PAWC estimates are based on data from similar soils. Estimates PAWC is between 80 and 135 mm.

Subsoil analytical properties: The soil has an alkaline pH trend with surface pH values 6.0–7.0 and subsoil values 8.0 and 9.0. Further analytical data is unavailable for this soil.

Jumpo (Jp)

Concept:	Loamy or clayey surface on acid to neutral mottled, brown structured clay subsoil with manganiferous nodules throughout on deeply weathered andesite.
Aust. Soil Classification:	Brown Dermosol.
Great Soil Group:	No suitable group, affinities with Xanthozem.
Principal Profile Form:	Uf6.41, Uf4.42, Uf4.43, Gn3.72.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, Ap, A2, B1) is a grey or brown, clay loam to silty light medium clay with granular or subangular blocky structure. Manganiferous nodules are normally present. Surface thickness varies from 0.3 to 0.5 m; pH 6.0 to 7.0.

The subsoil (B2, B3) is a mottled, brown light clay to medium clay with blocky or polyhedral structure. The lower subsoil (B3) is heavier with lenticular structure, while significant manganiferous nodules are normally present throughout. Subsoil thickness varies from 0.35 to 0.65m; pH 6.0–7.0, often dropping below 6.0 in the B3.

At depth, the subsoil grades into weathered andesite (C) anywhere below 0.65 to 1.15 m.

Landform: Gently inclined (3–8%) slopes on rises and low hills.

Parent material: Deeply weathered andesite of the *Grahams Creek Formation* (JKg).

Soil associations: The *Jumpo* soil occurs down slope of the *Bidwill* (Ferrosol) soil.

Vegetation: Tall to very tall (18 to 25 m) open dry sclerophyll forest of white stringybark (*Eucalyptus acmenoides*), Queensland peppermint (*Eucalyptus exserta*), broad-leaved red ironbark (*E. fibrosa*), swamp box (*Lophostemon suaveolens),* pink bloodwood (*Corymbia intermedia*), forest red gum (*E. tereticornis*) and Moreton bay ash (*C. tessellaris).*

Land use: Sugar cane.

Existing land degradation: Minor sheet erosion.

Land and soil limitations: Frost on lower slopes, soil erosion, hardsetting surface condition.

Soil fertility: Most plant nutrients are in moderate to high supply, with the exception of available phosphorus and potassium. Total K, exchangeable K and extractable K are all very low to low.

Table 41. Surface soil nutrients for the *Jumpo* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)	(meq/100g)			
6.4	2.6	0.17	15	2	4	BQ	0.72	1.1	14	12	6.6	5.0	0.15
neutral	high	med		vlow	vlow	vlow	med	med	med		high	high	low

This table presents surface results from analysed reference site MTL 9000. General fertility ratings from Bruce and Rayment (1982), vlow - very low, low, med – medium, high.

Salinity and sodicity: Salt levels increase in the lower subsoil and are most probably associated with weathered parent material at depth**.** Figure 26a shows mean $EC_{1:5}$ values are largely negligible above 1.2 m, but increase significantly below this depth due to the presence of weathered andesitic material.

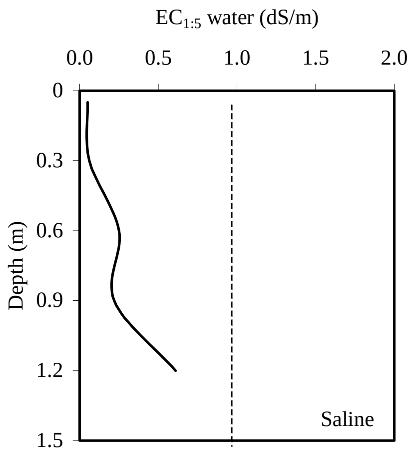


Figure 26a. Profile salinity for the *Jumpo* soil

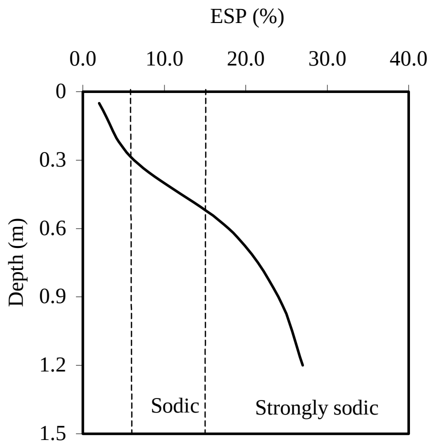


Figure 26b. Profile sodicity (ESP) for the *Jumpo* soil

Low salt concentrations in the upper profile indicate significant profile drainage is occurring even though strongly sodic subsoil material is present from about 0.5 m (Figure 26b).

Physical Characteristics: The *Jumpo* soil is characterised by a firm to hardsetting surface condition (when dry) due to high levels of fine sand, silt and clay in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Manganiferous segregations are common within the profile and indicate seasonal saturation occurs regularly. Where the soil is cultivated, surface and subsoil material is often mixed increasing the clay content of the surface. Both surface horizons and the upper subsoil (B2) are well structured and possibly colluvial in origin. The deeper subsoil however, has formed in stitu and is typically a tough clay with lenticular structure.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.5–1.1 m and is based on physical restrictions to plant roots associated with lenticular or blocky structure at depth. For reference site MTL 9000, ERD is 0.8 m and estimated PAWC is 108 mm.

Subsoil analytical properties: This soil has an acid pH trend, with pH values in the subsoil usually 5.0–6.5. Cation exchange capacity increases significantly with depth, and subsoils are severely magnesic, (Ca/Mg ratio <0.1). Calcium is extremely deficient in the subsoil due to the leached and highly weathered nature of this soil and a strong imbalance exists between these two ions. All forms of potassium are also at very low levels. The upper surface and subsoil typically have fine granular structure while the lower subsoil has coarser lenticular structure. At depth the profile is strongly sodic and strongly acid with significant exchangeable aluminium (not presented here) on the clay exchange. Clay activity ratios indicate the upper profile is predominantly kaolinitic with some illite with the lower profile dominated by illite clays.

Table 42. Soil profile analytical data for the *Jumpo* soil

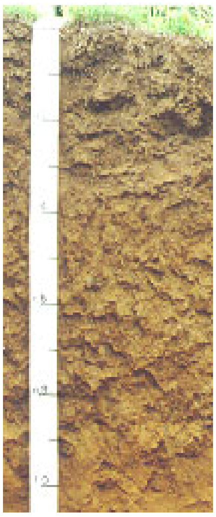
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	ECEC (meq/100g)	Base Status	Exch. Aqueous Cations Ca (meq/100g)	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	6.3	47	28	25	9	-	4.1	4.9	0.18	0.21	0.84	0.36
0.2–0.3	6.1	48	21	33	7	-	0.60	5.7	0.44	0.05	0.11	0.21
0.5–0.6	5.2	19	15	67	14	19	BQ	10	2.5	0.05	0.01	0.21
0.8–0.9	5.1	31	19	52	21	36	0.19	14	4.6	0.11	0.01	0.40
1.1–1.2	5.0	26	18	57	26	44	0.51	17	7.1	0.17	0.03	0.46

This table presents results from analysed reference site MTL 9000.

Mary (My), Mary dark variant (MyDv)

Concept: Brown structured non-cracking clay on alluvium of the Mary River.
Aust. Soil Classification: Brown (or occasionally Black) Dermosol.
Great Soil Group: Prairie soil.
Principal Profile Form: Gn3.21, Uf6.31.

Typical Profile



Soil Description

The surface soil (Ap) is a black or brown, silty clay loam to silty light clay with granular structure. Surface thickness varies from 0.1 to 0.25 m; pH 5.5 to 7.0.

The subsoil (B21, B22) is a brown, light clay to heavy clay with strong blocky structure. Manganiferous segregations are normally present at depth. Subsoil thickness varies from 0.9 to 1.25 m; pH 5.5–7.5.

A buried horizon (D) sometimes occurs below the subsoil. Typically, it is a brown, loamy fine sand to fine sandy light clay with massive or weak subangular blocky structure. This horizon occurs anywhere below 1.0 to > 1.5 m; pH 7.0–8.0.

Mary dark variant (MyDv) has similar attributes to those described above for the *Mary* soil but is black throughout.

Landform: Level to gently inclined (0–5%) scrolls, swales and levees on alluvial terraces of the Mary River.

Parent material: Quaternary alluvium (Qa) associated with the Mary River.

Soil associations: The *Mary* soil is typically associated with the *Copenhagen* (Dermosol) and *Baddow* soils (Rudosol). It sometimes grades into the *Walker* soil (Hydrosols) on terrace backplains.

Vegetation: Mostly cleared, with isolated forest red gum (*Eucalyptus tereticornis*).

Land use: Sugar cane, improved pastures for dairy and beef cattle grazing, small crops.

Existing land degradation: Stream bank collapse along the river, invasive weeds in some cleared areas.

Land and soil limitations: Frost, flooding.

Soil fertility: Most plant nutrients are in moderate to high supply, with the exception of sulfur. Supply of organic nutrients is restricted by low organic matter levels (ie. low organic carbon).

Table 43. Mean surface soil nutrients for the *Mary* soil

PH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC	Ca	Mg	K (meq/100g)
6.5	1.5	0.16	9	69	72	0.83	2.4	2.5	5.3	13	7.2	5.4	0.87
neutral	low	med		high	high	high	med	med	low		high	med	high

This table presents the mean results of three analysed reference sites, BUN 120, MTL 350 and GCL 9007. See appendix 3 for a full description of site GCL 9007. General fertility ratings based on Bruce and Rayment (1982), low, med – medium, high.

Salinity and sodicity: This soil is well drained and has salt concentrations that are negligible throughout (Figure 27a). Profiles are typically friable and non sodic (Figure 27b).

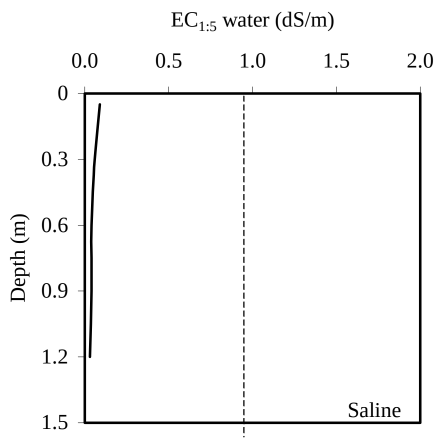


Figure 27a. Mean profile salinity for the *Mary* soil

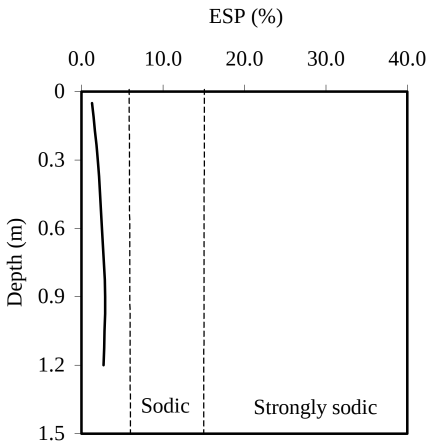


Figure 27b. Mean profile sodicity (ESP) for the *Mary* soil

Physical characteristics: The *Mary* soil is characterised by a firm to hardsetting surface condition (when dry) due to high levels of fine sand and silt. It is also influenced by the degree of structure with strongly structured surface soils mostly and moderate to massive structured profiles mostly hardsetting. Subsoils are typically well structured with no physical restrictions to root development.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. Clay mineralogy, clay content and organic matter levels however, strongly influence final PAWC values. For reference sites BUN 120, MTL 350 and GCL 9007, estimated PAWC is between 73 and 84 mm.

Subsoil analytical properties: This soil has a neutral pH trend, with pH values in the subsoil usually 6.5–8.0. Clay content is relatively uniform throughout the profile and soil textures are strongly influenced by high silt levels. Cation exchange capacity is high and calcium and magnesium dominate the clay exchange. Ca/Mg ratios indicate calcium and magnesium are well balanced. Total potassium (not presented) is high throughout the profile and reflects the origins of the alluvium from which this soil is derived. Clay activity ratios and Total K indicate the soil is dominated by mixed mineralogy clays with significant montmorillonite (Baker and Eldershaw 1993).

Table 44. Mean soil profile analytical data for the *Mary* soil

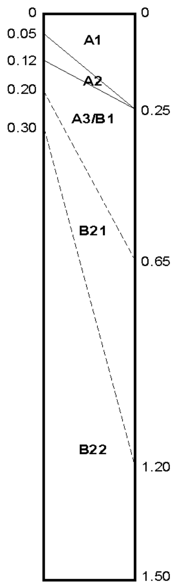
Depth	pH	Sand	Silt	Clay	ECEC	Base Status	Exch. Aqueous Cations				Ca/ Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.3	54	24	23	14	-	7.6	5.3	0.19	0.75	1.43	0.61
0.2–0.3	6.8	52	26	25	15	-	9.0	5.8	0.30	0.20	1.55	0.60
0.5–0.6	7.1	52	20	27	16	60	9.2	6.5	0.39	0.17	1.41	0.59
0.8–0.9	7.4	47	25	28	19	69	10.6	7.9	0.52	0.18	1.34	0.68
1.1–1.2	7.4	49	24	26	19	72	9.5	8.5	0.46	0.19	1.12	0.73

This table presents the mean results of three analysed reference sites, BUN 120, MTL 350 and GCL 9007. See appendix 3 for a full description of site GCL 9007.

Miva (Mv)

Concept: Sporadically bleached alkaline black silty clay on alluvium of the Mary River.
Aust. Soil Classification: Black Dermosol; Black Sodosol.
Great Soil Group: No suitable group, solodic.
Principal Profile Form: Uf3, Uf6.32, Dd1.13.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2j) is a black or grey, clay loam to light clay with granular or subangular blocky structure. The lower quarter is sporadically bleached in undisturbed situations and typically has significant manganiferous segregations. Surface thickness varies from 0.12 to 0.25 m; pH 6.5 to 7.0.

Typically, a transitional horizon (A3, B1) is developed between the surface soil and subsoil. It occurs as a grey or brown, light medium clay to medium clay with subangular blocky structure and significant manganiferous segregations. Horizon thickness varies from 0.08 to 0.4 m; pH 7.0 to 8.0.

The subsoil (B21, B22)) is a black (or sometimes brown in the lower subsoil), medium clay to medium heavy clay with prismatic structure parting to blocky or lenticular. Manganiferous and calcareous nodules are normally present. This horizon occurs anywhere below 0.20 to 0.65 m; pH 7.5 to 9.5.

Landform: Elevated alluvial plains or relict terraces of the Mary River.

Parent material: Quaternary Pleistocene alluvium (Qpa) – predominantly clay sediments.

Soil associations: The *Miva* soil is associated with the *Mungar* soil (Dermosol) and grades into the *Butcher* (Sodosol) and *Aldershot* (Dermosol) soils on the margins of the elevated alluvial plain.

Vegetation: Mostly cleared, with isolated narrow-leaved ironbark (*Eucalyptus crebra*), gum-topped box (*E. moluccana*) and forest red gum (*E. tereticornis*).

Land Use: Improved and native pasture beef cattle grazing, sugar cane.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost, minor flooding, soil wetness in depressions, hardsetting surface condition, adhesive soils (relevant for root crops), and narrow moisture range for machinery operation.

Soil fertility: Most plant nutrients are in moderate supply, except for phosphorus and sulfur.

Table 45. Surface soil nutrients for the *Miva* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.4	2.2	0.21	11	6	16	0.50	2.1	1.6	5.1	21	4.5	9.0	0.72
neutral	med	med		vlow	low	med	med	med	low		med	high	high

This table presents surface results from analysed reference site GCL 9001. General fertility ratings from Bruce and Rayment (1982), vlow-very low, low, med-medium, high.

Salinity and sodicity: Salt levels clearly increase with depth but remain below the critical threshold (0.8 dS/m). Electrical conductivity of a 1:5 soil-water solution ($EC_{1:5}$) is a common measure of soil salinity and $EC_{1:5}$ values >0.8 dS/m can cause reductions in root growth and plant yields. Figures 28a and 28b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material from about 0.7–0.8 m.

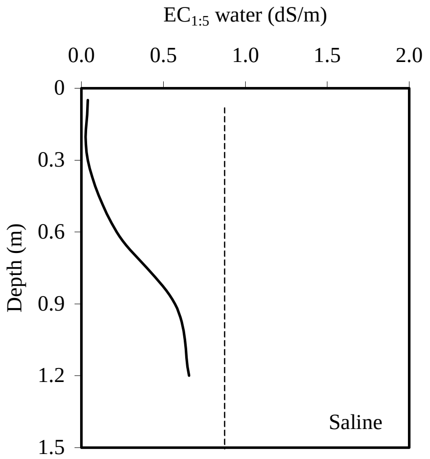


Figure 28a. Profile salinity for the *Miva* soil

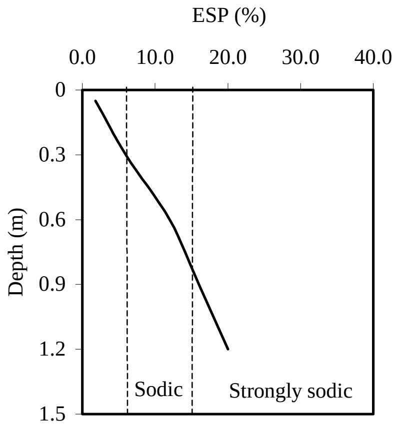


Figure 28b. Profile sodicity (ESP) for the *Miva* soil

Physical characteristics: The *Miva* soil is characterised by a hardsetting surface condition (when dry) despite strong granular or blocky structure, due to very high levels of silt in the surface soil. Subsoils are sodic, very slowly permeable, imperfectly drained and exhibit vertic properties. Profiles do not seasonally crack, however in uncultivated areas, normal gilgai sometimes form.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.25–0.7 m and is based on physical restrictions to plant roots associated with subsoil sodicity and coarse, tough prismatic structure. For reference site GCL 9001, ERD is 0.7 m and estimated PAWC is 95 mm.

Subsoil analytical properties: This soil has an alkaline pH trend with pH values in the subsoil 7.5–9.5. The profile is high in silt and clay because of its alluvial origins. Cation exchange capacity is high and the subsoil is strongly sodic and magnesium dominant (Ca/Mg ratios 0.2–0.5). Typically, the subsoil is unstable, dispersive and prone to gully erosion following disturbance.

Table 46. Soil profile analytical data for the *Miva* soil

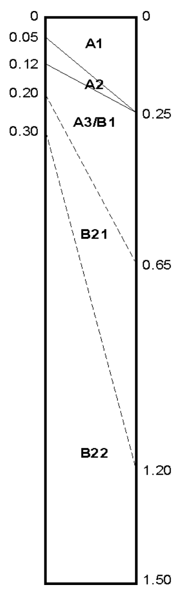
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	CEC (meq/100g)	Base Status	Exch. Alcoholic Cations (meq/100g) Ca	Mg	Na	K	Ca/Mg	Clay activity
0–0.1	6.3	19	39	31	11	-	4.5	8.0	0.39	0.53	0.56	0.36
0.2–0.3	7.3	23	33	48	14	-	6.4	15	1.50	0.15	0.43	0.29
0.5–0.6	8.2	16	30	56	21	39	5.6	19	3.10	0.10	0.30	0.38
0.8–0.9	9.0	20	30	55	26	51	5.3	19	4.00	0.09	0.28	0.47
1.1–1.2	9.1	19	31	53	33	56	5.2	20	5.20	0.12	0.26	0.62

This table presents results from analysed reference site GCL 9001. See Appendix 3 for a full description for site GCL9001.

Mungar (Mg)

Concept: Sporadically bleached alkaline grey non cracking clay on alluvium of the Mary River.
Aust. Soil Classification: Grey or Brown Dermosol; Redoxic Hydrosol.
Great Soil Group: No suitable group, affinities with grey clay.
Principal Profile Form: Uf3, Uf6.41.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2j) is a black or grey, silty light clay to silty light medium clay with granular or subangular blocky structure. The lower quarter is sporadically bleached in undisturbed situations and has significant manganiferous segregations. Surface thickness varies from 0.12 to 0.25 m; pH 6.5 to 7.0.

Typically, a transitional horizon (A3, B1) is developed between the surface soil and subsoil. It occurs as a grey or brown, light medium clay to medium clay with subangular blocky structure. Manganiferous segregations are normally present. Horizon thickness varies from 0.08 to 0.40 m; pH 7.0 to 8.0.

The subsoil (B21, B22) is a grey or brown, medium clay to medium heavy clay with prismatic structure parting to subangular blocky or lenticular. Manganiferous and calcareous nodules are normally present. This horizon occurs anywhere below 0.20 to 0.65 m; pH 7.5 to 9.5.

Landform: Backplains and swamps within elevated, relict alluvial plains (older terraces) of the Mary River.

Parent material: Quaternary Pleistocene alluvium (Qpa) – predominantly clay sediments.

Soil associations: The *Mungar* soil is associated with the *Miva* (Dermosol) soil on the backplains and the *Butcher* (Sodosol) and *Aldershot* (Dermosol) soils close to terrace margins.

Vegetation: Mostly cleared, with isolated forest red gum (*Eucalyptus tereticornis*) and narrow-leaved ironbark (*E. crebra*).

Land use: Improved and native pasture beef cattle grazing, sugar cane.

Existing land degradation: Gully erosion, invasive weeds in some cleared areas.

Land and soil limitations: Frost, soil wetness, hardsetting surface conditions, minor flooding, adhesive soil (root crops only), narrow moisture range for cultivation, gully erosion.

Soil fertility: Most plant nutrients are in moderate supply with the exception of phosphorus which is low.

Table 47. Surface soil nutrients for the *Mungar* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC	Exch. Aqueous Cations Ca (meq/100g)	Exch. Aqueous Cations Mg (meq/100g)	Exch. Aqueous Cations K (meq/100g)
5.9	2.8	0.18	16	7	18	0.40	1.3	1.7	13	8	2.6	4.6	0.35
acid	high	med		vlow	low	med	med	med	med		med	med	med

This table presents results from analysed reference site MTL 9006. General fertility ratings based on Bruce and Rayment (1982).

Salinity and sodicity: Salt levels clearly increase with depth but remain below the critical threshold (0.8 dS/m). Figures 29a and 29b demonstrate that increased salt concentrations at depth are most likely the result of reduced permeability associated with strongly sodic subsoil material. Subsoil material is strongly sodic from about 0.5 m (Figure 29b) and the presence of lenticular structure is often indicative. Subsoils are very slowly permeable and manganiferous segregations throughout the profile suggest saturated conditions and/or fluctuating seasonal watertables are a common occurrence.

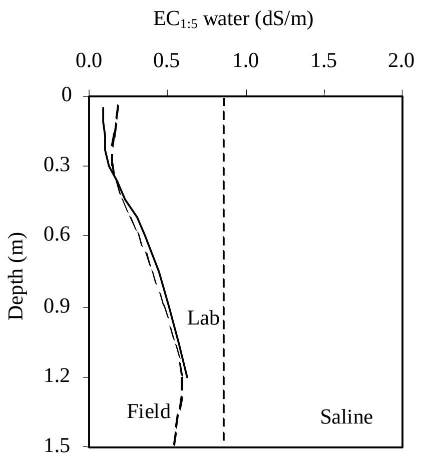


Figure 29a. Profile salinity for the *Mungar* soil

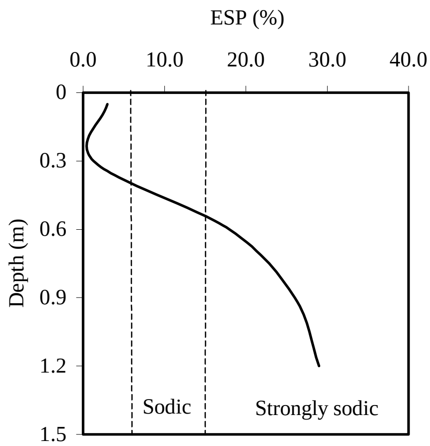


Figure 29b. Profile sodicity (ESP) for the *Mungar* soil

Physical characteristics: The *Mungar* soil is characterised by a hardsetting surface condition (when dry), despite strong granular or blocky structure, due to high levels of silt in the surface soil. Subsoils are sodic, very slowly permeable, imperfectly drained and exhibit vertic properties. Profiles do not seasonally crack, however, in uncultivated areas, normal gilgai sometimes form.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.25–0.65 m and is based on physical restrictions to plant roots associated with subsoil sodicity and poor physical structure (ie. coarse prismatic). For reference site MTL 9006, ERD is 0.65 m and estimated PAWC is 72 mm.

Subsoil analytical properties: This soil has a neutral to alkaline pH trend, with pH values in the subsoil 7.5–9.5. Profiles have approximately equal proportions of fine sand, silt and clay, and cation exchange capacity is high throughout. Exchangeable calcium and potassium levels decline markedly at depth as the subsoil becomes strongly magnesic. Lower potassium values are also indicative of the age of the soil and the greater weathering and leaching that has occurred on the older terraces/plains of the river. Because this soil is strongly sodic and magnesic, there is significant potential for gully erosion and slumping in areas adjacent to river banks.

Table 48. Soil profile analytical data for the *Mungar* soil

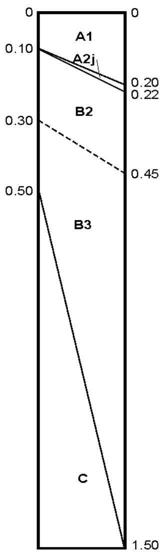
Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.0	53	30	13	17	-	9.0	6.4	0.51	0.63	1.40	1.31
0.2–0.3	6.2	40	26	36	14	-	4.7	7.8	1.40	0.15	0.60	0.39
0.5–0.6	5.4	31	24	46	17	36	2.3	11	3.10	0.11	0.21	0.37
0.8–0.9	6.4	33	25	43	23	53	1.6	15	5.90	0.13	0.11	0.56
1.1–1.2	7.6	29	26	46	26	57	1.5	17	7.60	0.16	0.09	0.57

This table presents results from analysed reference site MTL 9006.

Netherby (Nb)

Concept: Black or grey structured clayey surface, frequently with a sporadically bleached horizon, overlying a brown or grey structured clay developed from andesite.
Aust. Soil Classification: Brown or Grey Dermosol.
Great Soil Group: No suitable group, affinities with Prairie soil.
Principal Profile Form: Gn3.63, Gn3.83.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2j) is a black or grey, clay loam to light medium clay with granular or subangular blocky structure. Andesite coarse fragments are often present. The lower quarter of the surface soil is normally sporadically bleached and has significant manganiferous segregations. Surface thickness varies from 0.10 to 0.22 m; pH 6.0 to 7.5.

The subsoil (B2) is a brown or grey, light medium clay to medium clay with subangular blocky structure. Manganiferous nodules are normally present. Subsoil thickness varies from 0.20 to 0.25 m; pH 7.0 to 8.0.

A transitional horizon (B3) occurs between the subsoil and parent material. Typically, it is a mottled, brown or grey, light medium clay to medium clay with prismatic structure. Manganiferous segregations and andesite fragments are normally present. This layer grades to weathered andesite at depth. This transitional horizon occurs anywhere below 0.3 to 0.45 m and varies in thickness from 0.2 m to >1.0 m; pH 8.0 to 9.5.

Landform: Gently to moderately inclined (4–20%) slopes on rises and low hills.

Parent material: Andesite of the *Grahams Creek Formation (JKg).*

Soil associations: The *Netherby* soil is associated with *Tiaro* (Dermosol) soil on hillslopes and grades to the *Pelion* (Vertosol) soil on alluvial plains.

Vegetation: Mostly cleared.

Land Use: Improved and native pasture beef cattle grazing.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost on lower slopes, adhesive soil (root crops only), narrow moisture range for cultivation.

Soil fertility: While analytical data is not available for this soil it is expected to have similar fertility to *Tiaro* (Dermosol) soil.

Salinity and Sodicity: Salt levels are typically very low throughout the profile. The upper subsoil is non-sodic and well structured, but overlies sodic, coarsely structured clay from 0.5 to 1.5m.

Physical characteristics: Profiles on mid to lower slopes often have a sporadically bleached subsurface indicating some degree of seasonal wetness in these landscape positions. Surface soils have a clayey texture, strong fine granular or blocky structure and a firm surface condition. The relatively high clay content in surface layers provides only a narrow moisture range for effective cultivation. Manganiferous segregations occur throughout the profile and are indicative of periods of soil wetness as well as parent material influences (ie. basic rocks). Sodicity in the lower subsoil restricts root development and slows permeability.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–0.6 m and is based on physical restrictions to plant roots associated with subsoil sodicity in the B3 horizon and the presence of weathered substrate at relatively shallow depths in many profiles. PAWC estimates are unavailable for the *Netherby* soil but are assumed similar to the *Tiaro* (Dermosol) soil.

Subsoil analytical properties: This soil has a neutral to alkaline pH trend often with free carbonate nodules at depth. The pH values in the subsoil are 7.0–9.5, and usually increase in the lower profile. While analytical data is unavailable for the *Netherby* soil, it is expected to have similar analytical properties to the *Tiaro* (Dermosol) soil.

Tiaro (Ta), Tiaro rocky phase (TaRp), Tiaro red variant (TaRv)

Concept:	Structured black or brown clayey soil overlying weathering andesite or microdiorite rocks.
Aust. Soil Classification:	Black, Brown (or occasionally red) Dermosol.
Great Soil Group:	Prairie soil.
Principal Profile Form:	Uf6.32, Gn3.92, Gn3.22.

Typical Profile

Soil Description

The surface soil (A11, A12, A3) is a black or brown, clay loam to light medium clay with strong granular, subangular blocky or polyhedral structure. Manganiferous or ferromanganiferous nodules are normally present. Surface thickness varies from 0.05 to 0.35 m; pH 6.0 to 7.0.

The subsoil (B2) is a black or brown, light medium clay to medium clay with strong subangular blocky structure. Manganiferous segregations and weathered rock fragments are normally present. Subsoil thickness varies from 0.20 to 0.30 m; pH 7.0 to 8.0.

A transitional horizon (B3) occurs between the subsoil and the parent material. Typically it is a brown or grey light clay to medium heavy clay with subangular blocky structure and significant weathered rock fragments. This layer grades to weathered andesite from 0.55 to 0.85 m and varies in thickness from 0.2 to 0.35 m.

Tiaro rocky phase (TaRp) is a shallow version where only A horizons are developed and weathered rock is present from 0.3 m.

Tiaro red variant (TaRv) has similar attributes to the *Tiaro* soil except the B2 horizon is red and the B3 horizon is brown.

Landform: Very gently to moderately inclined (2–15%) slopes on rises and low hills.

Parent material: Andesite or microdiorite of the *Grahams Creek Formation* (JKg) and associated unnamed intrusives (JKi).

Soil associations: The *Tiaro* soil is associated with the *Netherby* (Dermosol) soil on mid to lower slopes and grades to the *Pelion* (Vertosol) soil on adjacent alluvial plains.

Vegetation: Mostly cleared, with occasional vine scrub remnants.

Land use: Improved and native pasture beef cattle grazing.

Existing land degradation: Minor sheet erosion, invasive weeds in some cleared areas.

Land and soil limitations: Frost on lower slopes, rockiness (*Tiaro rocky phase* only).

Soil fertility: Most plant nutrients are in moderate to high supply with the exception of phosphorus which is low.

Table 49. Mean surface soil nutrients for the *Tiaro* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
wter (1:5)	(%)	(%)		Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
				(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)	(meq/100g)			
6.0	2.4	0.24	10	16	12	0.52	0.48	1.1	-	17	8.0	5.9	0.36
neutral	med	med		low	low	high	med	med	-		high	med	med

This table presents the mean surface results of two analysed reference sites MBS 89 and BUN C2.

Salinity and Sodicity: Salt levels are negligible because the *Tiaro* soil is moderately well drained to well drained and only slightly sodic at depth (Figures 30a and 30b). Increased sodicity levels in the lower subsoil (ESP >6) appear related to the presence of weathered andesitic substrate from about 0.5–0.6 m.

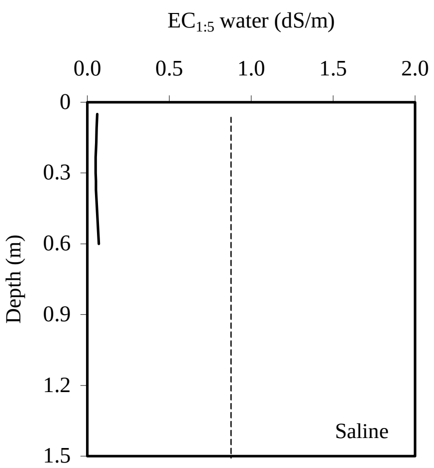


Figure 30a. Mean profile salinity for the *Tiaro* soil

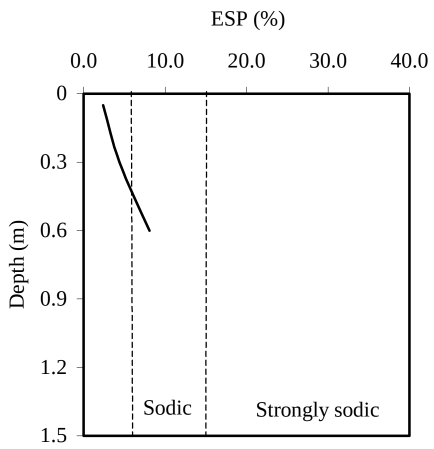


Figure 30b. Mean profile sodicity (ESP) for the *Tiaro* soil

Physical Characteristics: The *Tiaro* soil has a clayey surface soil with strong fine granular or blocky structure and a soft to firm surface condition. The relatively high clay content in surface layers provides only a moderate moisture range for effective cultivation. Manganiferous segregations occur throughout the profile and are indicative of periods of soil wetness as well as parent material influences (i.e. basic rocks). Soils become shallower and more strongly structured in upslope positions.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.55–0.85 m and is based on physical restrictions to plant roots associated with the presence of substrate material. For reference sites MBS 89 and BUN C2, ERD is 1.1 m and estimated PAWC is 115 mm.

Subsoil analytical properties*:* This soil has a neutral pH trend, with pH values in the subsoil usually 7.0–8.0. Some profiles have free carbonate nodules in the lower subsoil. Clay content increases with depth and cation exchange capacity is high throughout. Clay activity ratios suggest the clay fraction within the profile is predominantly of mixed mineralogy, while weathered substrate at depth is largely montmorillonitic (2:1 shrink swell clay material) with a much higher base status.

Table 50. Mean soil profile analytical data for the *Tiaro* soil

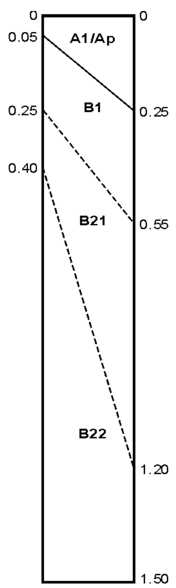
Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.0	53	25	23	17	-	8.0	5.9	0.39	0.36	1.36	0.74
0.2–0.3	6.1	39	20	43	17	-	7.5	7.8	0.79	0.11	0.96	0.40
0.5–0.6	7.2	36	17	48	24	56	10.0	14.5	1.94	0.29	0.69	0.50
0.8–0.9	7.6	33	19	50	23	46	10.0	12	0.63	0.31	0.83	0.46
1.1-1.2	7.4	68	12	20	18	89	8.3	8.7	0.55	0.15	0.95	0.90

This table presents the mean results of two analysed reference sites, MBS 89 and BUN C2. Results for depths 0.8–0.9 and 1.1–1.2, are from one site only.

Walker (Wk)

Concept: Dark clay loam to clay surface over a mottled grey clay subsoil on alluvium of the Mary River.
Aust. Soil Classification: Grey Dermosol; Redoxic Hydrosol.
Great Soil Group: Humic gley.
Principal Profile Form: Gn3.91, Gn3.92, Uf6.41, Uf6.22

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, Ap) is a black, silty clay loam to light medium clay with granular or subangular blocky structure. Surface thickness varies from 0.05 to 0.25 m; pH 6.0 to 6.5.

A transitional horizon (B1) is developed between the surface soil and subsoil. It occurs as a mottled, black, light medium clay to medium clay with subangular blocky structure. Horizon thickness varies from 0.2 to 0.3 m; pH 5.5 to 7.0.

The subsoil (B22, B22) is a mottled, grey, light medium clay to heavy clay with subangular blocky structure. The lower subsoil often has lenticular structure and manganiferous nodules developed. Subsoil horizons occur anywhere below 0.25 to 0.55 m; pH 5.5 to 7.0.

Landform: Channel benches, scrolls and floodplains of the Mary River.

Parent material: Quaternary Pleistocene alluvium (Qpa) – predominantly clay sediments.

Soil associations: The *Walker* soil is associated with the *Mary* and *Copenhagen* (Dermosol) soils and also the *Baddow* (Rudosol) soil.

Vegetation: Mostly cleared.

Land use: Improved and native pasture beef and dairy cattle grazing, sugar cane.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost, flooding, soil wetness, hardsetting surface condition, narrow moisture range for cultivation, adhesive soil (root crops only).

Soil fertility: Most plant nutrients are in moderate to high supply with the exception of phosphorus and nitrogen. Levels of total P and iron in the surface are high.

Table 51. **S**urface soil nutrients for the *Walker* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
water				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
6.1	1.7	0.13	13	-	3.0	0.58	1.6	2.3	-	9	3.9	3.9	0.54
neutral	med	low			vlow	high	med	med	-		med	med	high

This table presents surface results from analysed reference site BUN 108. General fertility ratings from Bruce and Rayment (1982), vlow – very low; low, med – medium, high.

Salinity and sodicity: Salt levels are negligible throughout the profile and indicate the *Walker* soil has reasonable permeability (Figure 31a). Profiles become sodic (ESP 10%) in the lower subsoil and suffer reduced permeability (Figure 31b). The presence of lenticular structure is often indicative.

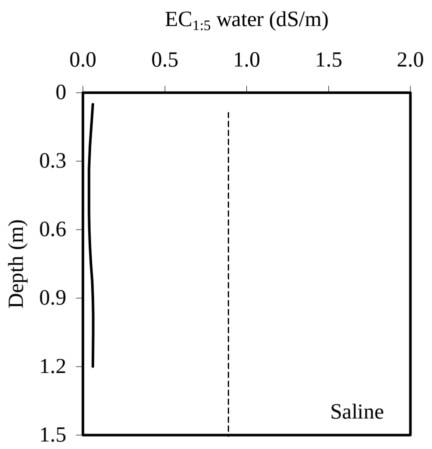


Figure 31a. Mean profile salinity for the *Walker* soil

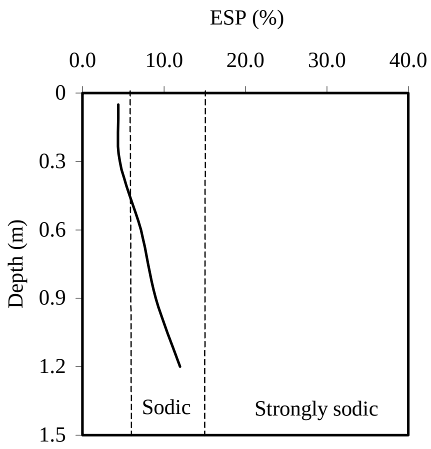


Figure 31b. Mean profile sodicity (ESP) for the *Walker* soil

Physical characteristics: The *Walker* soil is characterised by a hardsetting surface condition (when dry) due to high levels of silt and fine sand in the surface soil. Hardsetting behaviour restricts water entry into the profile, causes excessive soil adhesion (to root crops) and results in a narrow tillage window. Manganiferous nodules, subsoil mottling and grey soil colours indicate seasonal saturation is a common occurrence.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is 0.4–1.2 m and is based on physical restrictions to plant roots associated with subsoil wetness and the presence of lenticular structure. For reference site BUN 108, ERD is 0.6 m and estimated PAWC is 75 mm.

Subsoil analytical properties: This soil has a acid to neutral pH trend, with pH values in the subsoil 5.5–7.0. Cation exchange capacity is moderate and cations are balanced and in adequate supply, with the exception of potassium. Clay activity ratios indicate the clay fraction is predominantly of mixed mineralogy.

Table 52. Soil profile analytical data for the *Walker* soil

Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.1	61	21	18	9	-	3.9	3.9	0.40	0.54	1.00	0.50
0.2–0.3	5.8	62	19	20	7	-	2.8	3.6	0.46	0.10	0.78	0.35
0.5–0.6	5.8	58	14	26	9	39	2.7	5.3	0.65	0.14	0.51	0.35
0.8–0.9	6.7	52	18	32	13	41	4.0	7.8	1.20	0.18	0.51	0.41
1.1–1.2	7.9	51	20	29	15	52	4.4	8.7	1.80	0.11	0.51	0.52

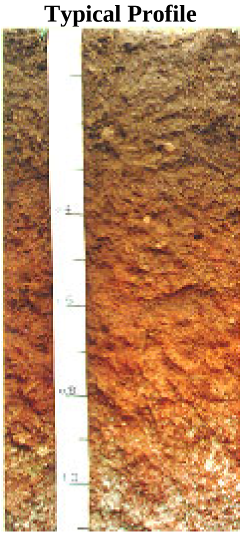
This table presents results from analysed reference site BUN 108.

Watalgan (Wt), Watalgan mottled variant (WtMv)

Concept: Black or brown clay loam surface over a pale A2 horizon over a red structured clay subsoil on deeply weathered fine grained sedimentary rocks.

Aust. Soil Classification: Red Dermosol; Red Ferrosol.
Great Soil Group: Red podzolic soil.
Principal Profile Form: Gn3.14, Dr2.21, Gn3.11, Uf6.31.

Typical Profile



Soil Description

The surface soil (A1, Ap, A2) is a black or brown, clay loam with granular, cast or subangular blocky structure. Ferruginous nodules are normally present. Surface thickness varies from 0.15 to 0.3 m;, pH 5.0 to 6.0.

A transitional horizon (B1) is developed between the surface soil and the subsoil. It occurs as a red light clay with subangular blocky or polyhedral structure. Ferruginous nodules are normally present. This horizon is typically 0.1 m thick; pH 5.5 to 6.0.

The subsoil (B2) is a red, light clay to medium clay with strong polyhedral structure. Ferruginous nodules are normally present. Subsoil horizons occur anywhere below 0.25 to 0.4 m; pH 5.5 to 6.5.

Watalgan mottled variant (WtMv) has similar attributes to the *Watalgan* soil except the B2 horizon is mottled.

Landform: Very gently to gently inclined (1–4%) upper slopes and crests on rises and low hills; or slightly elevated, local crests within gently undulating plains.

Parent material: Deeply weathered mudstones, siltstones and fine grained sandstone of the *Elliott Formation* (Te).

Soil associations: The *Watalgan* soil is associated with the *Kepnock* (Dermosol) soil and may also adjoin the *Bidwill* (Ferrosol) soil where the *Elliott Formation* overlies the *Grahams Creek Formation.*

Vegetation: Mostly cleared. In undisturbed areas, a tall to very tall (18 to 25 m) open dry sclerophyll forest of spotted gum (*Corymbia citriodora*), white mahogany (*Eucalyptus acmenoides*), grey ironbark (*E. siderophloia*) and narrow-leaved ironbark (*E. crebra*) is usually present.

Land use: Sugar cane, tree crops, small crops, improved pastures for beef cattle grazing.

Existing land degradation: Not apparent.

Land and soil limitations: Soil erosion, hardsetting surface condition.

Soil fertility: Most plant nutrients are in moderate supply with the exception of phosphorus which is very low. Levels of total P and iron are moderate to high in the surface soil, which suggests phosphorus sorption may be occurring (Baker and Eldershaw 1993). Phosphorus sorption will reduce existing and applied P availability to plants.

Table 53. Mean surface soil nutrients for the *Watalgan* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid	Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu	Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC	Ca	Mg	K (meq/100g)
6.0 neutral	2.4 med	0.18 med	13	5 vlow	5 vlow	-	0.62 med	1.5 med	-	8	3.7 med	2.8 med	0.33 med

This table presents the mean surface results of twelve analysed reference sites, BSS 13, MBS 4, 5, 28, MTL 9001, BUN 3, 112, 115, 123, MON CB8, QCB 209 and 210. General fertility ratings from Bruce and Rayment (1982), vlow – very low; low; med – medium.

Salinity and sodicity: Salt and sodicity levels are negligible (Figures 32a and 32b) because the *Watalgan* soil is highly permeable and occupies elevated landscape positions. The presence of non sodic subsoil material (Figure 32b) is typical for soils in well drained positions on deeply weathered sediments.

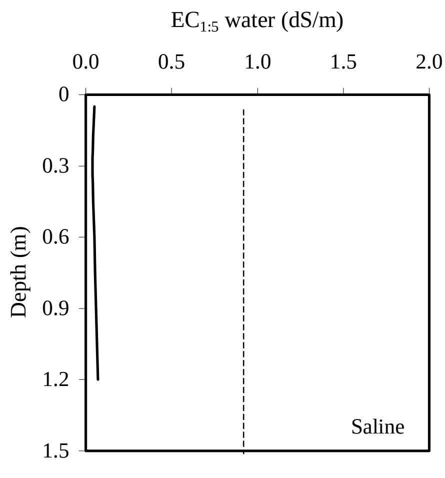


Figure 32a. Mean profile salinity for the *Watalgan* soil.

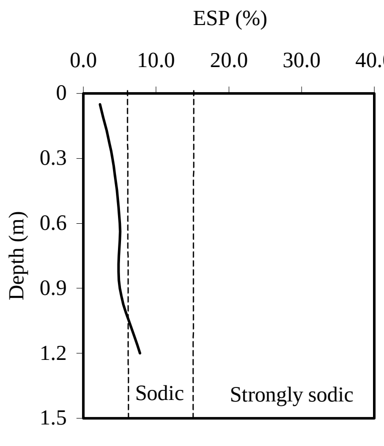


Figure 32b. Mean profile sodicity (ESP) for the *Watalgan* soil.

Physical characteristics: The *Watalgan* soil is characterised by a hardsetting surface condition (when dry) due to high levels of fine sand and silt and loamy textures. Ferruginous nodules are common in the surface soil and subsoils are deep, red and well structured.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. For the reference site associated with this soil, estimated PAWC is between 117 and 148 mm.

Subsoil analytical properties: This soil has a acid pH trend, with pH values in the subsoil 5.5–6.5. Cation exchange capacity is low and subsoils are magnesic, with Ca/Mg ratios 0.03–0.3. Low levels of exchangeable calcium and potassium in the subsoil may restrict root development.

Table 54. Mean soil profile analytical data for the *Watalgan* soil

Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	6.0	50	21	29	8	-	3.7	2.8	0.19	0.33	1.32	0.28
0.2–0.3		47	16	38	6	-	1.8	2.1	0.24	0.16	0.86	0.16
0.5–0.6		26	15	59	6	7	0.7	3.2	0.30	0.04	0.22	0.10
0.8–0.9		24	14	62	6	6	0.8	2.7	0.30	0.06	0.30	0.10
1.1–1.2		19	16	64	4	6	0.1	3.4	0.31	0.07	0.03	0.06

This table presents the mean results of twelve analysed reference sites, BSS 13, MBS 4, 5, 28, MTL 9001, BUN 3, 112, 115, 123, MON CB8, QCB 209 and 210.

Kandosols

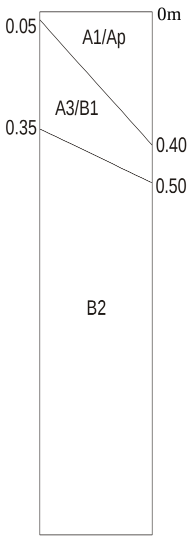
Kandosols are soils which lack strong texture contrast, have massive or only weakly structured B horizon, and are not calcareous throughout.

Only two Kandosols *(Farnsfield* (Ff), *Littabella* (Lt)) have been mapped. They are of limited extent and occupy only 62 ha or 0.3% of the study area.

Farnsfield (Ff)

Concept:	Sandy surface over a red massive subsoil on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Red Kandosol.
Great Soil Group:	Red earth.
Principal Profile Form:	Gn2.11, Gn2.12, Um5.52.

Typical Profile | **Soil Description**



The surface soil (A1, Ap) is a red, brown or black, loamy sand to sandy loam with massive structure. Surface thickness varies from 0.05 to 0.4 m; pH 5.5 to 6.5.

A transitional horizon (A3, B1) is developed between the surface soil and the subsoil. It occurs as a red or brown, sandy clay loam to clay loam sandy with massive structure. This horizon is typically 0.1–0.3 m thick; pH 5.5 to 7.0.

The subsoil (B2) is a red, sandy clay loam to light clay with massive to weak subangular blocky or polyhedral structure. Subsoil horizons occur anywhere below 0.35 to 0.5 m; pH 5.5 to 7.0.

Landform: Gently inclined (4–8%) crests and slopes on plains and rises within the deeply weathered land surface. (Occasionally on crests and upper slopes of low hills.)

Parent material: Deeply weathered sandstones of the *Elliott Formation* (Te).

Soil associations: The *Farnsfield* soil is associated with the *Isis* (Chromosol) soil**.**

Vegetation: Mostly cleared. In undisturbed areas, the vegetation is dominated by pink bloodwood (*Corymbia intermedia*) and grey ironbark (*Eucalyptus siderophloia*).

Land use: Sugar cane, tree crops, small crops.

Land and soil limitations: Soil erosion, low plant available water capacity.

Soil fertility: Most plant nutrients are in low supply with the exception of potassium, copper, zinc and calcium which are moderate. Phosphorus sorption may be an issue with this soil (Baker and Eldershaw 1993).

Table 55. Mean surface soil nutrients for the *Farnsfield* soil

pH	Org C	Tot N	C:N	Extractable P		Replace	DTPA Extractable		SO_4S	Exch. Aqueous Cations			
wter				Acid	Bicarb	K	Cu	Zn		ECEC	Ca	Mg	K
(1:5)	(%)	(%)		(mg/kg)		(meq/100g)	(mg/kg)		(mg/kg)		(meq/100g)		
5.8	1.2	0.11	11	4	8	0.39	0.7	0.6	-	4	2.1	0.85	0.31
acid	low	low		vlow	vlow	med	med	med			med	vlow	med

This table presents the mean surface results of ten analysed reference sites, BSS 12, MBS 88, BUN 110, MON CB5, QCB 143, CBW 1, 2, 3, ATB 8 and 11. General fertility ratings from Bruce and Rayment (1982), vlow – very low; low; med – medium.

Salinity and sodicity: Salt and sodicity levels are negligible (Figures 33a and 33b) because the *Farnsfield* soil is sandy, permeable, well drained and occupies elevated landscape positions.

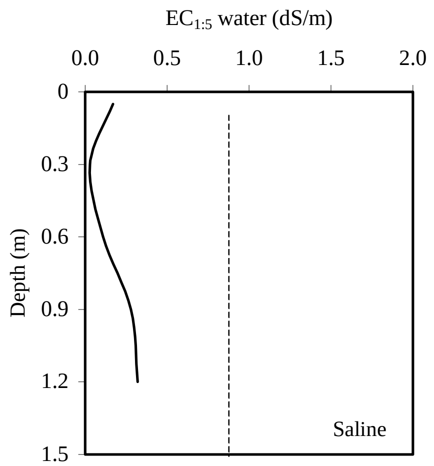


Figure 33a. Mean profile salinity for the *Farnsfield* soil

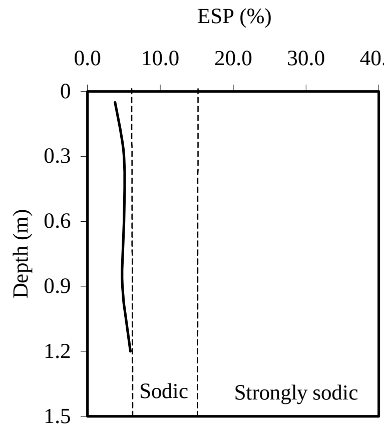


Figure 33b. Mean profile sodicity (ESP) for the *Farnsfield* soil

Physical characteristics: The *Farnsfield* soil has a loose to firm sandy surface with massive structure. The surface soil is susceptible to sheet erosion while subsoils are deep, well drained and without restrictions to plant roots.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. For the reference sites associated with this soil, estimated PAWC is between 43 and 84 mm. Low water holding capacity in the thick sandy surface horizons associated with this soil significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid to neutral pH trend, with pH values in the subsoil 5.5–7.0. The profile is dominated by the sand fraction and has a very low cation exchange capacity, typical of soils developed on deeply weathered sedimentary rocks.

Table 56. Mean soil profile analytical data for the *Farnsfield* soil

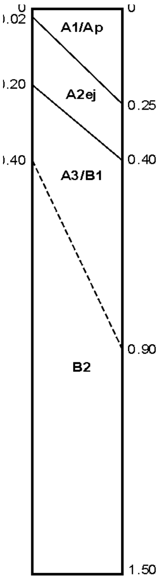
Depth	pH	Sand	Silt	Clay	CEC	Base Status	Exch. Alcoholic Cations				Ca/Mg	Clay activity
							Ca	Mg	Na	K		
(m)		(%)	(%)	(%)	(meq/100g)		(meq/100g)					
0–0.1	5.8	82	9	9	4	-	2.1	0.85	0.11	0.31	2.47	0.44
0.2–0.3	5.5	77	9	13	2	-	1.2	0.69	0.11	0.13	1.74	0.15
0.5–0.6	5.7	65	7	29	3	9	1.4	1.0	0.13	0.10	1.40	0.10
0.8–0.9	5.6	54	7	39	4	9	1.6	1.5	0.19	0.06	1.07	0.10
1.1–1.2	5.8	56	8	38	3	9	1.3	2.0	0.20	0.04	0.65	0.08

This table presents the mean results of ten analysed reference sites, BSS 12, MBS 88, BUN 110, MON CB5, QCB 143, CBW 1, 2, 3, ATB 8 and 11.

Littabella (Lt)

Concept: Sandy or loamy surface (0.02–0.25 m) over a yellow or grey massive sandy loam to clay loam sandy subsoil on local alluvium.

Aust. Soil Classification: Yellow or Grey Kandosol; Orthic Tenosol.
Great Soil Group: Yellow earth, no suitable group, earthy sand.
Principal Profile Form: Um5.52, Um4.23, Gn2.71, Gn2.94, Uc5.22.
.

Typical Profile	Soil Description
	The surface soil (A1, Ap, A2ej) is a black or grey, sandy loam to fine sandy clay loam with massive or single grain structure. The lower half of this horizon is sometimes bleached. Surface thickness varies from 0.2 to 0.4 m; pH 5.5 to 6.5. A transitional horizon (A3, B1) is developed between the surface soil and the subsoil. It occurs as a brown or grey, sandy loam to loam fine sandy with massive or single grain structure. This horizon is typically 0.2–0.5 m thick; pH 6.0 to 8.0. The subsoil (B2) is a yellow or grey, sandy loam to clay loam sandy with massive or single grain structure. Subsoil horizons occur anywhere below 0.4 to 0.9 m; pH 6.0 to 8.0.

Depth (m)

Landform: Levees, scrolls and channel benches on alluvial plains of local creeks.

Parent material: Quaternary alluvium (Qa) – predominantly sandy sediments

Soil associations: The *Littabella* soil is associated with the *Peep* (Sodosol), *Woober* (Hydrosol) and *Timbrell* (Hydrosol) soils on levee back slopes.

Vegetation: Mostly cleared, with isolated Moreton bay ash (*Corymbia tessellaris*) and forest red gum (*Eucalyptus tereticornis*).

Land use: Native pasture beef cattle grazing.

Land and soil limitations: Frost, low plant available water capacity, flooding.

Soil fertility: Most plant nutrients are expected to be in low supply due to the sandy nature of this soil. No analysed reference sites are available.

Salinity and sodicity: Profiles are typically low in salt and non-sodic throughout, due to sandy soil texture and relatively elevated landscape positions (ie. levees and channel benches).

Physical characteristics: The *Littabella* soil has a loose or soft, sandy, structureless surface soil. Profiles are typically highly permeable and moderately well drained.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. PAWC for this soil is estimated at less than 50 mm. Low water holding capacity associated with the sandy nature of the profile significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid to neutral pH trend, with pH values in the subsoil 6.0–8.0. The profile is dominated by the sand fraction and is expected to have a low cation exchange capacity. Further analytical data is unavailable for this soil.

Rudosols

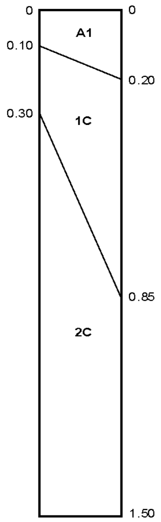
Rudosols are soils that have negligible (rudimentary) pedological organisation apart from the minimal development of an A1 horizon. There is little or no texture or colour change with depth unless stratified and the soils are apedal or only weakly structured. They are usually young soils.

Only two Rudosols (*Baddow* (Ba), *Johnson* (Js)) have been mapped. They are confined to alluvium along the Mary River and occupy 461 ha or 2.5% of the study area. Although of limited extent, both represent important agricultural soils.

Baddow (Ba)

Concept:	Layered sandy soil developed on channel benches of the Mary River.
Aust. Soil Classification:	Stratic Rudosol.
Great Soil Group:	Alluvial soil, siliceous sand.
Principal Profile Form:	Uc1.23, Uc1.21.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1) is a brown or grey, sand to sandy loam with massive structure. Surface thickness varies from 0.10 to 0.20 m; pH 6.0 to 7.0.

A number of distinct brown, sand to loamy sand alluvial layers (C) are normally present below the surface soil. They have single grain or massive structure, and occur anywhere below 0.1 to 0.2 m; pH 6.0 to 7.5.

Landform: Channel benches, levees and scrolls within the Mary River floodplain.

Parent material: Quaternary Holocene alluvium (Qha1,Qha2) – predominantly sandy sediments.

Soil associations: The *Baddow* soil is associated with the *Copenhagen*, *Mary* and *Walker* (Dermosol) soils.

Vegetation: Mostly cleared.

Land use: Improved and native pasture beef cattle and dairy grazing, sugar cane.

Existing land degradation: Invasive weeds in some cleared areas, stream bank erosion.

Land and soil limitations: Frost, low plant available water capacity, flooding.

Soil fertility: Most plant nutrients are in moderate to high supply, with the exception of sulfur.

Table 57. Surface soil nutrients for the *Baddow* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)
6.2	0.83	0.05	17	130	75	0.70	1.1	1.3	2.5	8	4.3	3.0	0.74
neutral	low	low		vhigh	high	high	med	med	vlow		med	med	high

This table presents surface results from analysed reference site GCL 9005. General fertility ratings from Bruce and Rayment (1982), vlow – very low; low; med – medium; high.

Salinity and sodicity: Salt and sodicity levels are negligible (Figures 34a and 34b) because the *Baddow* soil is highly permeable and occurs in landscape positions that are moderately well drained to well drained.

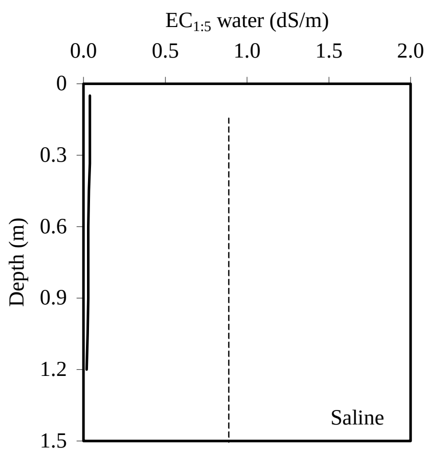


Figure 34a. Profile salinity for the *Baddow* soil

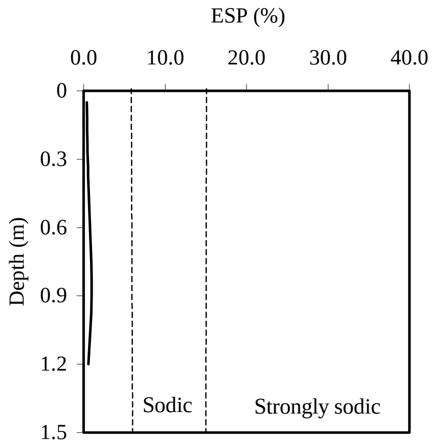


Figure 34b. Profile sodicity (ESP) for the *Baddow* soil

Physical characteristics: The *Baddow* soil has a loose or soft, sandy surface soil with massive structure.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. For reference site GCL 9005 PAWC is estimated at 54 mm. Low water holding capacity associated with the sandy nature of the profile significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid to neutral pH trend, with pH values in the subsoil 6.0–7.5. The profile is dominated by the sand fraction and has a low cation exchange capacity.

Table 58. Soil profile analytical data for the *Baddow* soil

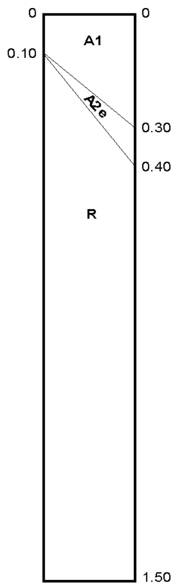
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	CEC (meq/100g)	Base Status	Exch. Alcoholic Cations Ca (meq/100g)	Mg (meq/100g)	Na (meq/100g)	K (meq/100g)	Ca/Mg	Clay activity
0–0.1	6.2	87	8	4	8	-	4.0	2.9	0.03	0.51	1.38	-
0.2–0.3	6.3	92	5	4	6	-	3.5	2.6	0.03	0.29	1.35	-
0.5–0.6	6.4	90	7	3	6	-	3.3	2.5	0.05	0.23	1.32	-
0.8–0.9	6.8	78	10	12	9	78	5.2	3.8	0.09	0.32	1.37	-
1.1–1.2	7.0	87	7	5	8	-	4.4	3.4	0.05	0.18	1.29	-

This table presents results from analysed reference site GCL 9005.

Johnson (Js)

Concept: Shallow sandy soil overlying a cobble layer on a Tertiary–Quaternary alluvial peneplain.
Aust. Soil Classification: Clastic Rudosol; Bleached-Leptic Tenosol.
Great Soil Group: Lithosol.
Principal Profile Form: Uc1.21.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2e) is a black or grey, sand to sandy clay loam single grain or massive structure. Significant gravel, stones or cobbles are normally present and the lower quarter of this horizon is typically bleached. Surface thickness varies from 0.1 to 0.4 m; pH 5.5 to 6.5.

Below the surface soil is a layer of waterworn cobbles. This horizon occurs anywhere from 0.1 to 0.4 m.

Landform: Level to gently inclined peneplain derived from a relict Tertiary – Quaternary age flood plain of the Mary River.

Parent material: Relict Tertiary–Quaternary alluvium (TQa). Includes cobbles, gravels, pebbles and sand.

Soil associations: The *Johnson* soil is associated with the *Butcher* (Sodosol) soil in some areas.

Vegetation: Tall (10 to 20 m) dry sclerophyll woodland of spotted gum (*Corymbia citriodora* ssp. *varigata*), pink bloodwood (*C. intermedia*), Moreton bay ash (*C. tessellaris*), forest red gum (*Eucalyptus tereticornis*), narrow-leaved ironbark (*E. crebra*) and Queensland peppermint (*E. exserta*).

Land use: Native pasture beef cattle grazing.

Existing land degradation: Invasive weeds in some cleared areas.

Land and soil limitations: Frost, low plant available water capacity, rockiness.

Soil fertility: Most plant nutrients are expected to be in low supply due to the sandy and gravelly nature of the parent material. No analysed reference sites are available.

Salinity and sodicity: This soil has low salt levels and is non-sodic throughout. It is developed from sandy, porous parent material and occupies imperfectly drained to moderately well drained, elevated landscape positions, above the surrounding plains.

Physical characteristics: Cobbles are common to abundant on the surface of this soil and are typically encountered anywhere within the upper 0.1–0.4 m of the profile. The surface soil (when present) has a loose to firm surface condition. Profiles are imperfectly to moderately well drained because the subsoil cobble layer is moderately permeable and the peneplains upon which the soil has formed are elevated and isolated from local watertables.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. The cobble layer in this soil, (between 0.1 and 0.4 m) is loose rather than cemented, and allows root development to occur. PAWC for this soil is estimated at less than 50 mm. Low water holding capacity associated with the sandy nature of the profile and the large volume of cobbles present, significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid pH trend, with pH values throughout the profile 5.5–6.5. Sand, gravel and stone dominate the particle size fraction and cation exchange capacity is expected to be very low. Further analytical data is unavailable for this soil.

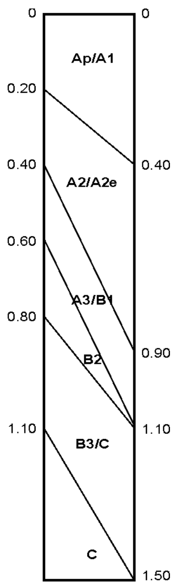
Tenosols

Tenosols are soils with only weak pedological organisation apart from the A horizons. They differ from Rudosols in that they have A horizons that are more than weakly developed; or an A2 horizon; or a weakly developed B horizon. Only two tenosols *(Rothchild* (Rt), *Winfield* (Wf)) have been mapped. They are associated with the deeply weathered quartzose sandstones of the *Myrtle Creek Sandstone* (RJdm) and cover 1419 ha or 7% of the survey area.

Rothchild (Rt), Rothchild podosolic variant (PtPv)

Concept:	Bleached brown or yellow massive sand on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Bleached-Orthic or Orthic Tenosol.
Great Soil Group:	(Bleached) Earthy sand, Earthy sand.
Principal Profile Form:	Uc2.21, Uc4.21, Uc4.22.

Typical Profile



Depth (m)

Soil Description

The surface soil (Ap, A1)) is a black or grey, loamy sand to sandy loam with single grain or massive structure. The lower half of this horizon is bleached (A2e) or paler in colour (A2). Surface thickness varies from 0.4 to 0.9 m; pH 5.5 to 7.0.

The subsoil (B2) is a brown or yellow, loamy sand to sandy loam with massive structure. Significant coarse fragments are frequently present. Subsoil thickness varies from 0.05 to 0.2 m; pH 6.0 to 6.5.

Below the subsoil, the profile grades into weathered sandstone (B3, C) and rock fragments become more abundant with depth. This transitional horizon occurs anywhere below 0.8 to 1.1 m and is about 0.3–0.4 m thick. Weathered rock is normally encountered below 1.1 to 1.5 m.

Rothchild podosolic variant (RtPv) has similar characteristics to those described above, except a transitional horizon (B3) dominated by organic-aluminium and sesquioxide-organic complexes, is normally present. This layer can be loose or partly cemented. Refer to Podosols for more detail

.

Landform: Level plains to gently inclined (0–5%) slopes and crests on rises and low hills.

Parent material: Deeply weathered quartzose sandstones of the *Myrtle Creek Sandstone* (RJdm)**.**

Soil associations: The *Rothchild* soil is associated with the *Winfield* (Tenosol) soil on crests and upper slopes and the *Tirroan* (Sodosol) soil on lower slopes.

Vegetation: Mid high to tall (10 to 18 m) dry sclerophyll open forest of broad-leaved white mahogany (*Eucalyptus umbra*), brown bloodwood (*Corymbia trachyphloia*) and pink bloodwood (*C. intermedia*).

Land use: Remnant forest, native pasture beef cattle grazing.

Existing and land degradation: Sheet erosion, invasive weeds in some cleared areas.

Land and soil limitations: Frost on lower slopes, soil erosion, low plant available water capacity.

Soil fertility: Most plant nutrients are typically in low supply because the soil is formed from quartzose sandstones. Analytical data is only available for a site that has been irrigated and fertilised and is not necessarily representative.

Table 59. Surface soil nutrients for the *Rothchild* soil

pH water (1:5)	Org C (%)	Tot N (%)	C:N	Extractable P Acid (mg/kg)	Extractable P Bicarb (mg/kg)	Replace K (meq/100g)	DTPA Extractable Cu (mg/kg)	DTPA Extractable Zn (mg/kg)	SO_4S (mg/kg)	Exch. Aqueous Cations ECEC (meq/100g)	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)
6.1	0.82	0.04	21	99	70	0.08	0.4	0.4	-	3	2.0	0.24	0.08
neutral	Low	vlow		high	high	vlow	med	low			med	vlow	vlow

This table presents surface results from analysed reference site ATB 7. General fertility ratings from Bruce and Rayment (1982), vlow – very low; low; med – medium, high.

Salinity and sodicity: Salt and sodicity levels are negligible because the *Rothchild* soil is highly permeable and occupies landscape positions that are well drained to rapidly drained.

Physical characteristics: Surface soils vary from soft to weakly hardsetting. Subsoils are bleached or pale and indicate the soil has been subject to intense weathering over a long period. In some profiles the subsoil is weakly cemented and forms a Bhs horizon (*Rothchild podsolic variant*). It does not however restrict root development. Subsoils are highly permeable and well drained to rapidly drained depending on landscape position.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD is >1.0 m and is not limited by physical restrictions to plant roots. For reference site ATB 7, estimated PAWC is 55 mm. Low water holding capacity associated with the sandy nature of the profile significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid pH trend, with pH values in the subsoil 6.0–6.5. Profiles are dominated by the sand fraction and cation exchange capacity is very low.

Table 60. Soil profile analytical data for the *Rothchild* soil

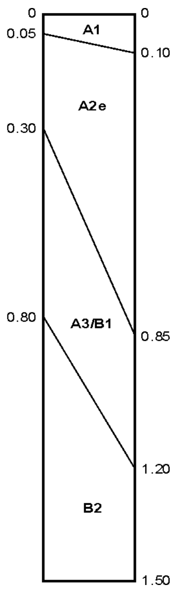
Depth (m)	pH	Sand (%)	Silt (%)	Clay (%)	CEC (meq/100g)	Base Status	Exch. Alcoholic Cations Ca (meq/100g)	Mg (meq/100g)	Na (meq/100g)	K (meq/100g)	Ca/Mg	Clay activity
0–0.1	6.1	89	6	3	3	-	2.0	0.24	0.05	0.08	8.33	-
0.2–0.3	5.3	91	6	1	2	-	0.68	0.08	0.05	0.08	8.50	-
0.5–0.6	4.9	93	4	2	<1	15	0.14	0.04	0.05	0.06	3.50	0.40
0.8–0.9	5.5	89	6	3	<1	15	0.19	0.13	0.10	0.03	1.46	0.20

This table presents results from analysed reference site ATB 7.

Winfield (Wf)

Concept:	Bleached massive grey sand on deeply weathered coarse grained sedimentary rocks.
Aust. Soil Classification:	Bleached-Orthic Tenosol.
Great Soil Group:	(Bleached) Earthy sand.
Principal Profile Form:	Uc2.23, Uc2.22.

Typical Profile



Depth (m)

Soil Description

The surface soil (A1, A2e) is a grey, sand to loamy sand with single grain or massive structure. The lower three-quarters of this horizon is bleached. Surface thickness varies from 0.30 to 0.85 m; pH 5.0 to 6.0.

Between the surface soil and the subsoil is a transitional horizon (A3, B1). This horizon is a mottled, grey, brown or yellow, loamy sand to sandy loam with massive structure. Horizon thickness varies from 0.35 to 0.5 m; pH 5.5 to 6.0.

The subsoil (B2) is a mottled, grey, loamy sand to sandy loam with massive structure. Subsoil horizons occur anywhere below 0.8 to 1.2 m; pH 5.5 to 6.0.

Landform: Level plains to gently inclined slopes on rises and low hills.

Parent material: Deeply weathered quartzose sandstones of the *Myrtle Creek Sandstone* (RJdm).

Soil associations: The *Winfield* soil is associated with the *Rothchild* (Tenosol) soil on crests and upper slopes and the *Tirroan* (Sodosol) soil on lower slopes.

Vegetation: Mid-high to tall (10 to 18 m) dry sclerophyll open forest of broad-leaved white mahogany (*Eucalyptus umbra)*, brown bloodwood (*Corymbia trachyphloia*), pink bloodwood (*C. intermedia*).

Land use: Remnant forest, native pasture beef cattle grazing, rural residential.

Existing land degradation*:* Sheet erosion, invasive weeds in some cleared areas.

Land and soil limitations: Frost on lower slopes, soil erosion, low plant available water capacity.

Soil fertility: Most plant nutrients are typically in low supply because the soil is formed from quartzose sandstones.

Salinity and sodicity: Salt and sodicity levels are negligible because the *Winfield* soil is highly permeable.

Physical characteristics*:* Surface soils are loose and subject to seasonal saturation. Subsoils are bleached and indicate the soil has been subject to intense weathering over a long period. Subsoils are highly permeable and imperfectly to poorly drained.

Effective Rooting Depth (ERD) and Plant Available Water Capacity (PAWC): ERD >1.0 m and is not limited by physical restrictions to plant roots. PAWC for this soil is estimated at less than 50 mm. Low water holding capacity associated with the sandy nature of the profile significantly restricts final PAWC levels.

Subsoil analytical properties: This soil has an acid pH trend, with pH values in the subsoil 5.5–6.0. Profiles are dominated by the sand fraction and cation exchange capacity is very low. Further analytical data is unavailable for this soil.

4. Land Evaluation

Limitations to irrigated land uses

A set of land use requirements for plant growth, machinery use, land preparation, irrigation and the prevention of land degradation has been defined for agricultural land uses in Queensland (Land Resources Branch Staff 1990). To assess the suitability of any parcel of land for a particular use, it is necessary that each of these land use requirements be considered. Attributes of land, which cause it to have less than optimum conditions for a particular use, are known as limitations. Management is concerned with overcoming or reducing the effects of these limitations.

The dominant irrigated land uses in the Gundiah–Curra area involve spray irrigation of a wide range of crops and trickle irrigation of horticultural crops and tree crops. Crops include asparagus, avocado, beans, citrus, crucifers (cabbage and cauliflowers), cucurbits (melons and pumpkins), grape, lucerne, lychee, improved pasture, macadamia, maize, mango, navy bean, peanut, pineapple, exotic pines, potato, sorghum, soybean, stone fruit, sugarcane, sweet corn, sweet potato, and vegetables (small crops). Furrow irrigation of sugarcane and a limited range of other crops has also been assessed. The land use requirements and limitations identified as important for successful irrigated agricultural production in the Gundiah–Curra area are listed in Table 61.

Table 61. Land use requirements and limitations for irrigated farming systems in the Gundiah–Curra area

Land use requirements	Limitations
Frost free	climate (cf)
Adequate rainfall (rain fed crops only)	climate (cp)
Adequate water supply	water availability (m)
Adequate nutrient supply	nutrient deficiency (nd)
Adequate retention of added nutrients against leaching	nutrient leaching (nl)
Low nutrient fixing conditions	nutrient fixation (nf)
Low levels of toxic elements	element toxicity (nt)
Adequate soil aeration	wetness (w)
Adequate soil depth for physical support	soil depth (pd)
Absence of damaging floods	flooding (f)
Rock-free	rockiness (r)
Adequate production area	landscape complexity (x)
Level land surface	microrelief (tm)
Land surface of acceptable slope	slope (ts)
Ease of seedbed preparation and plant establishment	surface condition (ps)
Suitable timing for cultivation	narrow moisture range (pm)
Ability to harvest underground crops	soil adhesiveness (pa)
Minimum soil loss from erosion	water erosion (e)
Minimum potential to cause secondary salinity	secondary salinisation (ss)
Efficient water recharge of the soil profile	soil profile recharge (ir)
Efficient furrow infiltration	furrow infiltration (if)

(Land Resources Branch Staff, DPI 1990)

All the limitations listed do not necessarily apply to each land use or to all soils but are still assessed as part of the process. Some limitations are more important for some soils. The limitations appropriate to the Gundiah–Curra area are discussed individually. Management options for reducing the effects of these limitations are also discussed and have been adapted from that developed for the Burdekin River Irrigation Area surveys (Donnollan 1991).

Climate (cf)

Climatic factors do not vary significantly over the study area, with the exception of frost incidence. Frosts can suppress the growth of sensitive crops, kill plants or reduce yield through damage to flowers or fruits. Local experience on the frequency and severity of frosts, in combination with landscape position were used to determine the limitation classes for various crops (Appendix V). Seasonal adaptation and tolerance of crops was considered, for example, frosting was not assessed for summer crops.

Generally, the incidence and severity of frosts in the study area is influenced by position in the landscape. Hilltops receive fewer and less severe frosts and are suitable for frost sensitive crops such as avocados and mangoes. The low-lying channel benches and depressions in the terraces along the Mary River and the plains along local creeks can receive a large number (>20) of severe frosts per year. These severely affected areas limit the choice of crops to deciduous plants such as low-chill stone fruits, grapes, and tolerant small crops and field crops. A quarter of the survey area can be affected by severe frosts.

Water availability (m)

All plants require an adequate water supply for optimum growth. Crop yield is directly related to the amount of water stored in the soil available for plant growth. Plant available water capacity (PAWC) is a measure of the amount of soil water (mm) between field capacity and wilting point (-1500 kPa) over the effective rooting depth. Gardner and Coughlan (1982) concluded that sodic subsoils offer resistance to plant roots and restrict water entry because of unfavourable structure, high ESP or high bulk density. In general, the presence of strongly sodic subsoil material (ESP >15) restricts root development and is an indicator of effective rooting depth. For most soils, PAWC tends to decrease with depth due to increasing bulk densities and lower root densities (Littleboy 1997).

Effective rooting depth was taken to be 1.0 m; or the depth to rock, hardpans, high salt levels (>0.8 dS/m) or where a rapid increase in profile electrical conductivity indicates the depth of regular wetting (ie. salt bulge), if <1.0 m depth. Restrictions to root growth caused by nutrient deficiencies below the layer of fertiliser placements (eg. the plough layer) were not assessed but are recognised as a possible limitation to rooting depth.

In irrigated situations, a reduced PAWC means more frequent waterings are required to attain optimum yield. For example, in the Maryborough–Bundaberg area, evaporation rates are six mm/day during summer and approximate the evapotranspiration rates for mature crops (Bourne and Harris 1985). A soil with a PAWC of 100 mm, could be watered every 17 days, whereas a soil with a PAWC of only 50 mm would require watering every 8 days and any excess application would be lost to deep drainage or runoff. The ability to recharge the soil water deficit completely within the irrigation period is also important. Incomplete profile recharge will reduce the amount of water available for crop growth and therefore require more frequent irrigation (see soil profile recharge limitation) (Wilson *et al.* 1999).

The ease with which water is extracted from the soil by a plant becomes more difficult as the soil dries, and plants often suffer water stress before all available water is extracted. Shaw and Yule (1978) suggest that irrigation should be applied when accumulative evapotranspiration is 60% to 80% of PAWC. This is often termed 'readily available water' and is important for irrigation scheduling to optimise yields.

The decision on when to irrigate and how much water to apply can be determined by considering the soil water store, drainage below the active root zone, runoff and the amount of water used by the crop (Yule 1989). This practice, called irrigation scheduling, should aim to optimise crop productivity, improve water use efficiency and reduce the likelihood of drainage and salinity problems (Keefer 1989).

The correlation between evaporation from a Class A pan and crop evapotranspiration is well recognised and has been used for many years as an indicator of crop water use (Bourne and Harris 1985). The relationship is expressed as a number (ie. crop co-efficient – Kc) and depends on the crop type, planting date and stage of growth (Doorenbos and Pruitt, 1977). Bureau of Sugar Experiment Stations (BSES) staff have developed a chart that outlines how to use pan evaporation figures to determine sugarcane water use. The chart and Daily Class A pan evaporation for Bundaberg are available on request from BSES.

Estimated PAWC (Shaw and Yule 1978, Littleboy 1997) is largely determined by predicted rooting depth, the amount of hard segregations or rock in the profile and clay content of the soil.

Typically, the sandy soils (*Baddow*, *Littabella*, *Rothschild* and *Winfield*), sandy surfaced sodic texture contrast soils (*Butcher sandy variant*, *Doongul*, *Robur and Tirroan*) and shallow rocky soils (*Isis rocky phase*, *Johnson*, *Owanyilla rocky phase, Tiaro rocky phase* and *Tirroan rocky phase*) have very low PAWC values (<50 mm). Some sodic texture contrast soils (*Kolan* and *Owanyilla*) with very shallow rooting depths (<0.4 m) also have very low PAWC values. In contrast, deep (>1 m), loamy to clayey surfaced, structured soils *(Bidwill, Bucca, Jumpo, Granville, Gutchy, Mary, Miva, Mungar, Pelion, Timbrell, Watalgan*, *Woober*, and *Walker*) generally have high PAWC values (>100 mm).

Very low soil water availability (<50 mm PAWC) is a common limitation in the survey area, affecting over 8271 ha or 40% of the study area. The rooting depth of different crops (eg. shallow rooted root crops) and irrigation methods (eg. micro, spray or furrow) has been taken into account when determining suitability (Appendix V).

Further detail on estimated PAWC for each soil is presented in Chapter 3.

Nutrient deficiency (nd)

Addition of fertilisers is an accepted practice for many land uses. This limitation is used where nutrient levels are inherently low and amelioration to improve soil fertility and crop yield requires large initial fertiliser application. Fertility data from this study indicates some level of phosphorus and nitrogen is required by all unfertilised soils in the study area. The level of application will depend on the type of land use and intensity of production proposed.

Soils overlying deeply weathered sedimentary rocks *(Alloway, Isis, Kepnock, Robur, Rothchild, Winfield)* represent the most deficient soil in the study area. They are typically low to very low in all nutrients and particularly potassium and calcium in the subsoil. Calcium deficiency in the subsoil is difficult to correct due to strong calcium absorption by cation exchange sites on clay and organic matter, in the soil. As a result, applied calcium does not move readily from the placement area. Comparison of surface applications versus slotting of calcium into the subsoil requires investigation, particularly the effects excess calcium may have on other cations (Mg, K, Na, Al, trace elements) in the highly weathered low cation exchange capacity (<5 meq/100 g) soils in the study area (Wilson *et al.* 1999).

Limitation classes for nutrient deficiency (Appendix V) are based on critical levels of phosphorus and potassium. Trace elements were not considered as they represent a minor cost to production.

Soils with very low phosphorus (<10 ppm) occupy 14 290 ha or 70% of the study area, while those with low potassium (<0.2 meq/100 g) occupy 11 717 ha or 57% of the study area.

Nutrient leaching (nl)

Nutrient leaching below the root zone occurs on well drained or highly permeable soils. It is usually associated with soils that have sandy textures and/or low cation exchange capacity (especially <5 meq/100 g) in the subsoil. Nitrates are readily leached in any permeable soil, while cation (Ca, K, trace elements) losses are mainly associated with soils that are both permeable and low in cation exchange capacity. Soils prone to nutrient leaching include sandy or loamy textured uniform soils

(*Baddow, Copenhagen, Isis rocky phase, Littabella, Rothchild, Tirroan Rocky phase* and *Winfield*), well-drained red soils (*Bidwill* and *Farnsfield*), and soils low in effective cation exchange capacity (*Alloway, Isis, Kepnock* and *Tirroan).* Split fertiliser applications or slow release fertilisers may be beneficial with these soils to limit nutrient losses below the root zone and avoid possible watertable contamination. Nutrient leaching associated with highly permeable soils (below depths of 1.5 m) occurs on 762 ha or 4% of the study area.

Nutrient fixation (nf)

In some soils nutrients may become bonded or 'fixed' to soil minerals unavailable for plant growth. Soils prone to nutrient fixation typically include humic or organic soils and soils high in iron-aluminium oxides (Wilson 1997). As such, the *Walker* and *Bidwill* soils appear subject to phosphorus fixation in some situations. Limitation classes are shown in Appendix V. Humic soils have not been recorded in the study area, although soils surrounding some of the undisturbed lagoons may have humic horizons.

Element toxicity (nt)

Plant growth may be inhibited either by high absolute levels or a high relative proportion of a specific cation (eg. aluminium) in solution. In particular, strongly acidic soils (pH <5.5) may have high levels of elements such as aluminium and manganese. Podosols, Kurosols and highly leached Hydrosols frequently have strongly acid pH (Wilson 1997). Crop tolerance to these conditions needs to be considered and may be subject to aluminium or manganese toxicities. Limitation classes presented in Appendix V are based on soil pH in the top 0.3 m. Strongly acid soils (pH <5.5) occupy 508 ha or 3% of the area.

Wetness (w)

Waterlogging or excessively wet soil reduces oxygen supply to the roots of plants and soil microorganisms and affects chemical reactions (Yule 1989). Less water and nutrients are taken up by the roots when the soil is wet and this reduces growth and yield (Hodgson 1986). Tolerance to waterlogging depends on crop type, stage of growth and soil and air temperatures (Williamson and Kriz 1970). For example, sugarcane is moderately to highly tolerant to short periods of waterlogging while maize is relatively intolerant (low tolerance) (Landon 1984). Most horticultural crops are susceptible to some degree of waterlogging and wetness.

To reduce waterlogging, excess water must be removed from the plant root zone quickly. Management options to improve drainage include laser levelling, increasing slope, or elevation, installation of underground or surface drains, shorter more frequent irrigation scheduling and ensuring adequate bed height. Wetness can cause problems with timeliness of operations resulting in delays in seedbed preparation, planting, weed and insect control, and harvesting. Reduced yields or loss of a complete crop may result if planting cannot be carried out when required.

Within the study area, wetness limitations are typically associated with poorly drained or very poorly drained soils that occupy backplains, drainage depressions or lower slope positions. Within the soil landscape developed on deeply weathered sediments poorly drained soils are restricted to drainage depressions or lower slope positions and include the *Robur*, *Tirroan* and *Winfield* soils.

Within alluvial landscapes, poorly drained soils are located mainly in drainage depressions or backplains on older alluvium where slight changes in elevation can be critical. Soils in this group include *Granville, Miva, Mungar, Pelion, Timbrell*, *Woober* and *Walker*. These soils usually have strongly sodic (ESP >15) subsoils that restrict drainage and require surface drains to improve drainage (Wilson 1997).

The ability to dispose of water is an important consideration in the management of soils, which occur in low lying areas or on level plains. Subsurface drainage is impractical in most sodic soils due to the impermeable and dispersible nature of the subsoil. Limitation classes are presented in Appendix V. A total of 3569 ha or 17% of the area has been assessed as having a poorly drained horizon within 1 m of the soil surface.

Soil depth (pd)

All crops require an adequate depth of soil to provide physical support for the aerial portion of the plant. The effects of rooting depth on water availability and wetness have been discussed earlier. Requirements for physical support will increase with crops that have large canopies such as tree crops. Lodging and uprooting of trees is a significant issue in shallow, wet soils during windy conditions.

Effective rooting depth is determined by the depth of soil to rock, hardpan or other impermeable layers (see water availability limitation). Limitation classes present in Appendix V have been determined through consultation with crop specialists and local producers (Wilson 1997). Soils with <0.3 m in depth are relatively uncommon and occupy only 972 ha or 5% of the study area.

Flooding (f)

Flooding for the purposes of this study is defined as overflow from natural watercourses and does not include surface water ponding due to insufficient drainage capacity. Flood attributes, which most affect agriculture, include the depth and duration of inundation, flood velocity, rate of water level rise and the time of year and frequency of occurrence (Lawrence *et al.* 1982). The extent to which a flood becomes damaging from an agricultural perspective is largely dependant upon the type of crop.

Problems of flooding include an increased incidence of weeds and diseases, and difficulties with machinery operations. The deposition of sand and silt or the removal of topsoil through scouring and sheet erosion has resulted in many cane assignments in Queensland being transferred away from flood -rone land. There are a number of environmental and infrastructure costs associated with flooding, which need to be recognised and considered against the agricultural benefits of farming in flood prone areas (Wilson 1997).

Floods within the study area are mainly associated with rain depressions or cyclones and major floods usually occur following heavy rainfall in the upper catchment. Rainfall in the local area, even if significant, usually results only in flooding of limited duration (Wilson 1997).

Agricultural development in the area has continued to expand onto more fertile flood-prone lands and many high risk areas now require significant land management to avoid instability and degradation. Appropriate management includes not clearing existing vegetation within 40 metres of the river bank, maximising height and cover of crops during flood prone times of the year (to protect the soil against erosive flooding), and establishing permanent pastures where deposition and scouring regularly occur (Wilson 1997). Stream channels and steep banks should not be developed for agricultural purposes. In such areas, the remnant vegetation should be maintained (Wilson 1997) and protected.

Most floods are restricted to the relatively narrow channel benches and terraces of the Mary River, as well as local creeks. Sand and silt deposition, bank erosion and scouring are most severe where water velocities are high. Typically, the lower channel benches are the most severely and most regularly affected for this reason.

Within the study area, most channel benches and terraces and some of the plains on the highest terrace adjacent to the Mary River have been assigned a flood limitation. The highest terrace is inundated during very large floods because of the sinuous nature of the river near Munna Creek and the presence of ‘choke points’ upstream of Emery’s Bridge and at Miva. The plains of local creeks flood with backup waters when the Mary River is in flood because local floodwaters have difficulty draining away.

Crop damage depends on crop type and susceptibility to flooding. Sugarcane is moderately tolerant of inundation but the level of crop damage will vary depending upon variety. Horticultural crops, such as small crops (melons, pumpkins, tomatoes, capsicums), avocados, papaws, pineapples, citrus and mangoes are very sensitive to flooding. Lychees are more tolerant and will withstand flooding for short periods, while field crops, such as maize, sorghum and soybeans are considered sensitive (Wilson 1997).

A flood limitation has been assigned to landscape positions that are subject to one in ten year floods or more frequent. As such, flooding is estimated to affect an estimated 926 ha or 5% of the study area.

Rockiness (r)

Rock fragments of any size and/or bedrock within the plough layer will interfere with the use of agricultural machinery and possibly cause damage. The volume of rock fragments within the soil is extremely variable and difficult to estimate. Levels of tolerance also vary between farmers and between different agricultural enterprises (Wilson 1997). The affect of rockiness on PAWC has been considered earlier.

In general, crops that require several cultivations annually and have low harvest heights (sugarcane, navy beans, soybeans) are significantly affected by rock within the plough layer. Root crops (potato, peanuts) are typically most affected by this limitation due to harvesting requirements while horticultural tree crops, which do not require regular cultivation, are least effected (Wilson 1997).

The size and amount of coarse fragments, as defined by McDonald *et al.* (1990) have been used to determine the limitation classes presented in Appendix V. Within the study areas rock fragments are consistently a problem on the *Isis rocky phase, Johnson, Tirroan rocky phase* and *Tiaro rocky phase* soils. A total of 1592 ha or 8% of the study area is too rocky for most land uses.

Landscape complexity (x)

Effective management of suitable agricultural land requires that it is practical to utilise the area of land for a particular use. The size of production areas may be limited by complex soil patterns or by physical constraints such as creeks and gullies that dissect the land. Small and/or narrow and/or isolated land parcels can restrict on-farm layout, and the efficiency and ease of machinery use.

Assessment for this limitation is based on the size, accessibility and proximity of adjoining suitable land. When the area of suitable soil in a UMA is below the minimum production area (see Appendix V), the area of any contiguous suitable soil in adjacent UMAs is also included in the assessment of production area size. Criteria relating to production area size are dependant on the type of agricultural enterprise. For example, field crops such as maize and sorghum, will be more severely affected by the presence of small areas than high value horticultural crops (see Appendix V).

Landscape complexity due to gullies or stream channels dissecting land into small areas is a minor limitation within the study area.

Microrelief (tm)

Microrelief refers to local relief of up to a few metres about the plane of the land surface (McDonald *et al.* 1990). Large microrelief (>0.3 m) causes uneven cultivation and impedes the trafficability of machinery. The most common form of microrelief within the study area are small gilgai (<0.3 m). These affect the efficiency of irrigation and cause uneven crop productivity due to wetness in depressions. Laser levelling is often necessary to enable efficient irrigation to occur and the extent of laser levelling depends on the vertical interval of the gilgai. Generally, problems with plant growth increase with the depth of cut and fill due to exposure of subsoil material with adverse chemical and physical properties. Loveday (1981) states that after irrigation, filled areas are likely to settle to varying degrees and will necessitate re-levelling to eliminate low spots. The soil should be cultivated to the depth of greatest fill to decrease the incidence of differential settling.

Soils with weakly developed gilgai include the *Granville, Gutchy, Miva, Mungar, Pelion, Timbrell, Woober* soils. These soils are largely developed areas which are not already cultivated, cover only a minor part of study area. Extreme care in levelling gilgai on these soils during development is necessary to avoid exposure of strongly sodic subsoil material. Gypsum will be necessary to assist crop establishment and improve water infiltration where levelling is undertaken.

Slope (ts)

The slope (or topography) limitation provides an assessment of the ease and practicality of machinery operations in the context of overall efficiency, as well as slope limits for the safe use of machinery.

The slope limit for safe and efficient use of machinery is 15%. Slopes >15% occupy 1867 ha or 9% of the study area. However, it is important to recognise that the majority of land with a slope greater than 15% within the study area, with the exception of the Ferrosol *(Bidwill),* is unsuitable or marginal for agricultural development due to other limitations as well.

Surface condition (ps)

The establishment of a uniform plant stand of desired density is important for successful crop production. Germination, seedling emergence and crop establishment may be affected by adverse physical conditions of the soil surface. These conditions include hardsetting, crusting or coarse structure. Limitation classes presented in Appendix V are determined by the severity of hardsetting and crusting behaviour and/or the size of coarse surface structure.

Smith and McShane (1981), Gardner and Coughlan (1982) and Elliott and McDonald (1989) have demonstrated that emergence and crop establishment are significant issues with hardsetting sodic soils. Within the study area, sodic texture contrast soils with shallow loamy (fine sandy loam to clay loam) hardsetting A horizons (*Butcher, Doongul, Givelda, Kolan, Owanyilla, Peep*) are most affected and are subject to crusting, excessive clodiness and variations in soil moisture across the seedbed. Retention of crop residues, minimum tillage and green cane harvesting will assist in maintaining and improving soil structure on these soils. Application of gypsum to the soil or irrigation water will also reduce crusting and clodiness where sodic clay is exposed.

Soils with hardsetting surfaces high in fine sand and silt, and low in organic matter (*Kepnock, Littabella, Timbrell, Woober*) are subject to slaking and sealing following wetting. Problems with seedling emergence and infiltration on these soils may require the addition of gypsum during irrigation or careful management (ie. planting into moist soil, practices to increase organic matter levels) for successful establishment and continued productivity.

Strongly hardsetting soils associated with loamy (fine sandy or silty) surface textures are common and affect 11 636 ha or 57% of the study area.

Narrow moisture range (pm)

Most soils have an optimal moisture range during which tillage is efficient, practical and causes minimal compaction. This applies particularly to surface soils in the clay loam to clay range. The most opportune moisture content to cultivate such soils lies just below the plastic limit (PL), where the soil is just dry enough to shatter without smearing or remoulding (Utomo and Dexter 1981).

Similarly, Braunack and McPhee (1988) showed that a finer tilth was produced at soil water contents nearer the plastic limit, than with wetter profiles. Increasing the number of implement passes also produces a fine seedbed, but is inefficient and increases the risk of compaction and structured decline.

The clay soils *(Bucca, Granville, Gutchy, Jumpo, Mungar, Miva, Pelion, Timbrell and Woober)* have a narrow moisture range for tillage, while the hardsetting fine sandy loam to clay loam fine sandy surface soils *(Butcher, Kepnock, Kolan, Owanyilla, Peep)* have a moderate moisture range for tillage. Limitation classes presented in Appendix V are based on texture and structural stability (in the surface soil), and through consultation with landholders on the severity of the local problem. Soils with a narrow moisture range occupy 5171 ha or 25% of the study area.

Soil adhesiveness (pa)

Crops that produce their harvestable material below the ground surface, such as peanuts and potatoes, require soils that do not adhere to the harvested product. This limitation is most severe on massive, loamy surfaced soils and clays. Limitation classes presented in Appendix V are based on texture, consistence and structure in the surface soil. Strongly adhesive soils include the *Bucca, Butcher, Granville, Mungar, Miva,* and *Walker* soils. These soils occupy 535 ha or 3% of the study area.

Water erosion (e)

Water erosion causes long-term productivity decline on unprotected sloping land through the loss of soil, organic matter and nutrients. More tangible effects include crop damage, higher working costs, uneven harvest heights and damage caused to crop land and infrastructure by silt deposition, scouring and gully formation (Wilson 1997).

Within the study area, erosion potential is determined by the interaction between slope, soil erodablity (ie. stable vs unstable soils) and crop management. Slope limits for the soils and crops identified in the study are outlined in Appendix V. Land with slopes less than the slope limits indicated are considered suitable for permanent cultivation. Slope limits set for land uses such as horticultural tree crops and pastures are steeper than for other uses because almost no cultivation is required, and levels of permanent surface cover are much higher (Wilson 1997).

Stable soils on slopes <8% occupy 2 336 ha or 11%, while unstable soils on slopes <5% occupy 7737 ha or 38% of the area.

Secondary salinisation (ss)

Under stable climatic conditions, in a natural environment, a hydrological balance typically exists between water intake from rainfall and water lost through plant uptake, evaporation, runoff and deep drainage (Shaw *et al.* 1986). Practices associated with agriculture, particularly clearing and irrigation, significantly influence the hydrological balance. Increased deep drainage may cause watertables to rise, and result in expressions of secondary salinity, irrespective of groundwater quality (ie. saline and non saline). High salt levels are often associated with fine-grained sedimentary rocks (siltstones and mudstones), while coarse-grained sandstones and granites typically exhibit low salt levels.

In the Gundiah–Curra area, salinisation occurs where long-term evaporation and capillary rise from groundwater sources close to the land surface leads to surface accumulation of evaporative salts in valley flats, drainage depressions and on plains. Salinisation also occurs on lower slopes where seepages occur.

Intake or recharge areas are typically associated with permeable elevated landscapes where regular deep drainage below the root zone forms a major component of the hydrological balance. These recharge areas tend to occur in upslope positions, on convex topography and are often associated with shallow and/or permeable soils overlying fractured rock (Shaw *et al.* 1986). Within the study area, all soils on upper slopes act as intake areas (Appendix V).

In discharge (seepage) areas, there is an upward or lateral component to groundwater flow near the soil surface that may result in secondary salinisation. Discharge areas frequently occur at the lower break of slope, within a catenary sequence, or in poorly incised low lying flats, or in regions of concave slope. Seepage areas can also occur in midslope positions at contacts between permeable and impermeable layers.

Where changes in land use or land management lead to increases in deep drainage and additions to groundwater in recharge areas, salinisation of discharge areas may follow. In such cases landscape management to reduce deep drainage is required. Furrow irrigation is not recommended on soil recharge areas because of difficulties in controlling water application and minimising drainage. Spray irrigation or trickle irrigation is recommended in such situations to avoid excessive losses to deep drainage.

Shaw *et al.* (1982) considered that effective drainage is difficult to achieve, particularly where sodic soils of low hydraulic conductivity are present in potential discharge areas. Soils within the study area with such characteristics include the *Pelion, Timbrell* and *Woober* soils. Any area with existing natural salinisation is considered unsuitable for development.

In the survey area, approximately 175 ha (<1%) is currently affected by secondary salinisation due to seepage on lower slopes (21 ha) and shallow watertables on plains and valley flats (154 ha). A further 825 ha (4%) of land is at risk from secondary salinisation if used for irrigated agriculture and/or cleared, even where appropriate land management practices are used. Another 5215 ha (25%) of land is at risk from secondary salinisation if the land is poorly managed under irrigated agriculture (ie. inefficient irrigation practises, waterlogging, excessive deep drainage).

Soil profile recharge (ir)

Recharging the soil water deficit completely within an irrigation period (the period over which water is applied) is important in irrigation scheduling to maximise crop growth and water use efficiency. Irrigation application rates must match infiltration rates over the irrigation period to avoid incomplete recharge of the rooting zone and to avoid excess runoff. If incomplete profile recharge occurs, irrigation will be required more frequently or for longer periods. For on-farm irrigation cycles using spray or furrow irrigation methods, high volumes (eg. 50 mm) are often applied over short periods (eg. 2 to 3 hours). These application rates often exceed surface infiltration and subsoil permeability rates.

Local experience indicates that soils with fine sandy loam to clay loam fine sandy surface slake and surface seal following irrigation (particularly spray irrigation). Similarly soils that have slow or very slow subsoil permeability have a reduced ability to recharge the soil profile and are less prone to deep drainage losses. Within the study area the *Bucca, Beenham, Butcher, Granville, Kolan, Mungar, Miva, Owanyilla, Timbrell* and *Woober* soils have poor profile recharge characteristics.

Furrow infiltration (if) (deep drainage)

With furrow irrigation, water application rates and the volume of water applied are often difficult to control and monitor accurately. The water application rate needs to match the permeability of the soil to avoid excess deep drainage (Loveday 1981) contributing to rising watertables. In addition, paddock design particularly furrow gradient and furrow length, need to match soil permeability and expected water application rates to avoid waterlogging of sensitive crops in the upper end of the furrow. Where shorter furrows are adopted to avoid such problems increased management is normally required.

Where furrow irrigation management has difficulty in regulating water application amounts, such as drainage in recharge areas or undulating landscapes, deep drainage can contribute significantly to groundwater rises in lower landscape positions, and is therefore inappropriate (Appendix V). On level plains where there is no inflow of groundwater from adjacent areas, deep drainage on very slowly permeable to slowly permeable soils can often be managed effectively to avoid watertable rises. This is particularly effective on incised or elevated alluvial plains where excess deep drainage can flow laterally into incised stream channels. The sodic soils *Butcher, Granville, Gutchy, Miva, Mungar* and *Pelion* which occur on alluvial plains can generally be managed effectively in this way. Within declared groundwater areas, pumping of groundwater is another effective means of controlling watertable rises provided water quality is acceptable for reuse. However declared groundwater areas do not exist within the study area.

Land suitability

Land resource information collected during this study has been used to determine the suitability of individual unique map areas (UMAs) for 36 land uses. This process has assessed a range of soil and land attributes to establish limitations to sustainable agricultural production. A classification system (see Appendix V) previously developed to assess the suitability of land in the Coastal Burnett–Wide Bay region (Wilson 1997) for irrigated sugarcane, horticultural crops, grain crops and pastures was adopted. In addition, suitability for plantation forestry (exotic pine) under rain fed conditions has been assessed.

The limitations to sustainable agricultural production were identified for each of the 420 unique map areas (UMAs) delineated in the study. The severity of each limitation was assessed on a 1 to 5 scale in line with the methodology described by Land Resources Branch Staff (1990):

Class 1 Suitable land with negligible limitations;
Class 2 Suitable land with minor limitations;
Class 3 Suitable land with moderate limitations;
Class 4 Marginal lands which is presently considered unsuitable due to severe limitations; and
Class 5 Unsuitable land.

The overall suitability class for each UMA for each land use has been determined by the most severe limitation. Where the effects of a combination of limitations have considered to be additive, the final suitability class assigned to the UMA has been downgraded.

An assessment of the attributes, limitations and suitability ratings for each UMA and each of the different land uses is recorded in the *Soil and Land Information (SALI)* databases at the Natural Resource Sciences Centre, NR&M, Indooroopilly. Table 62 shows the areas of suitable, marginal and unsuitable land for the 36 land uses.

In Table 62, three irrigation systems are identified: spray (using travelling irrigators or other overhead systems); furrow/row (where water is flood irrigated down furrows/rows) and trickle (microirrigation). When determining land suitability for furrow/row system, profile recharge (ir) and deep drainage (if) are two additional limitations considered. For more information on these limitations see Appendix V.

Table 62 shows 4563 ha or 22% of the survey area is currently suitable (classes 1–3) for spray-irrigated sugar cane; 2162 ha or 11% is suitable for furrow-irrigated sugarcane, mainly along the alluvial plains of the Mary River and its major tributaries. For other crops such as lychees large areas have been identified as suitable for production under trickle irrigation systems, but only minor areas are suitable for furrow irrigation systems.

The location of suitable land for a particular crop can be easily identified from the land suitability map produced for each land use. These are available from NRM&E offices at Bundaberg or Indooroopilly or from the CD ROM version of this report. The land suitability map for trickle irrigated lychees has been included with this report as an example.

Table 62. Irrigated land suitability classes and areas (ha) for different land uses within the study area.

Land use	Irrigated land suitability				
	Suitable (ha)			Marginal (ha)	Unsuitable (ha)
(All land uses are irrigate by overhead spray systems unless otherwise indicated)	Class 1	Class 2	Class 3	Class 4	Class 5
Asparagus*		355	1284	4996	13805
Avocado (trickle irrigated)*		114	97	1522	18706
Beans*		142	445	1249	18604
Capsicum (trickle irrigated)		142	711	5782	13805
Cruciferae (trickle irrigated)	13	417	1255	4950	13805
Curcubit (furrow/row irrigated)			134	4327	15979
Curcubit		142	711	5782	13805
Grapes (trickle irrigated)*		258	1359	1786	17036
Lucerne*		169	851	810	18611
Lychee (trickle irrigated)		306	5039	8813	6283
Macadamia nuts (trickle irrigated)*		137	600	1388	18316
Maize (furrow/row irrigated)				3228	17212
Maize*		355	614	4600	14871
Sweet Corn (furrow/row irrigated)			3	3246	17191
Sweet corn*		146	449	5013	14832
Mango (trickle irrigated)*		256	599	7510	12075
Navy bean (furrow/row irrigated)			30	1272	19138
Navybean*		157	982	655	18646
Improved pastures*	194	1171	4994	10299	3782
Peanut (furrow/row irrigated)		157	11	1291	19138
Peanut*		154	784	853	18646
Pineapple*		325	394	5624	14268
Potato			1218	3473	15424
Potato (furrow/row irrigated)		171	297	4164	15979
Exotic pine silviculture rain fed			1657	7459	11153
Sorghum (furrow/row irrigated)		355		3228	17212
Sorghum*			614	4600	14871
Soya bean (furrow/row irrigated)		325		3207	17234
Soya bean*			608	2837	16670
Sugarcane (furrow/row irrigated)		409	2162	5132	13146
Sugarcane*		129	4154	6143	9735
Sweet potato		142	689	5755	13867
Tomato (trickle irrigated)		137	711	5782	13805
Citrus tree crops (trickle irrigated)*		258	797	1998	17509
Stone fruit tree crops (trickle irrigated)*		142	912	2234	17036
Zucchini (trickle irrigated)			711	5782	13805

*Crops used to assess Agricultural Land Classes

Agricultural Land Classification

To assist local authorities with strategic planning, the land suitability information has been simplified into a four-category system of agricultural land classes. This is a statewide scheme of land classification, which can be used to identify valuable agricultural land (ie. good quality agricultural land of GQAL) and is based on crops considered important in a particular area (Land Resources Branch Staff 1990). In the Gundiah–Curra area, the crops indicated by a * [in Table 62] have been used to determine the agricultural land class. Table 63 shows the areas of each agricultural land class.

Class A land includes land that is suitable for most agricultural land uses in a particular area including improved pastures. Class B land is considered marginal crop land but is suitable for pastures and/or some crops with specialised requirements. Class C land is suitable for improved pastures. Class D land is not suitable for agricultural land uses.

Table 63. Areas of each Agricultural Land Class

Agricultural Land Class	Area (ha)	Percentage
Class A – Crop land	5116	24
Class B – Limited crop land	5641	26
Class C – Pasture land (includes A and B class land)	10945	51
Class D – Non-agricultural land	10698	49

Agricultural Land Class maps can be obtained from NRM&E offices at Bundaberg or Indooroopilly or from the CD-ROM version of this report.

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APPENDIX I

Soil profile classes

Conventions used in the descriptions of the morphology, landscape and vegetation of the soil profile classes

A soil profile class is a three dimensional soil body or group or soil bodies, such that any profile within the body(s) has a similar number and arrangement of major horizons whose attributes primarily morphological, are within a defined range. All profiles within the units have similar parent materials. The soil profile class may be at varying levels of generalisation depending primarily on the scale of the survey and density of ground observations.

A **soil variant** is a soil with profile attributes clearly outside the range of defined soil types but not extensive enough to warrant defining a new type.

A **soil phase** is a subdivision of a soil profile class based on attributes that have particular significance in the use of the soil, for example, rocky phase.

Australian Classification as described by Isbell (1996) are listed in order of frequency of occurrence.

Great Soil Group as described by Stace *et al.* (1968) are listed in order of frequency of occurrence.

Principle Profile Form (PPF) as defined by Northcote (1979) are listed in order of frequency of occurrence.

Geology as defined on the Maryborough 1:250 000 geology series map, 1992.

Surface characteristics as in McDonald *et al.* (1990).

Landform as in McDonald *et al.* (1990).

Vegetation structural formation as in McDonald *et al.* ((1990)

Vegetation species listed in order of frequency of occurrence. "/" means with or without.

The pH profiles **are based on field determination for each horizon.**

Horizons as in McDonald *et al.* (1990).

Textures are field textures as in McDonald *et al.* (1990)

Structure as in McDonald *et al.* (1990).

Segregation as in McDonald *et al*. (1990).

Boundary type as in McDonald *et al.* (1990).

Frequency of occurrence

Frequently = >30% of occasions
Occasionally = <30% of occasions

Colour codes (moist) are those of Munsel soil colour charts (1994) while colour nomenclature is based on the colour class limits of Isbell (1996).

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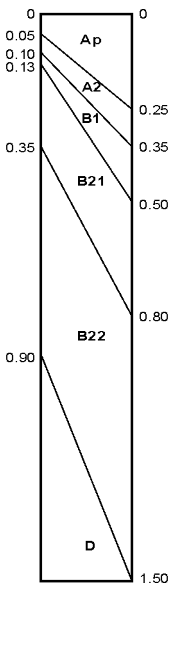
Aldershot (Ad)

Concept:	Massive loamy surface over a non-sodic red structured clay on alluvium of the Mary River.
Australian Classification:	Red Dermosol.
Great Soil Group:	Red brown earth.
Principal Profile Form:	Dr2.21, Gn3.22, Gn3.72
Surface characteristics:	Hardsetting.
Geology:	Quaternary Pleistocene Alluvium (Qpa).
Landform:	Relict levees on former flood plains.
Vegetation:	Cleared.

Depth (m)



Ap:	Grey, black or brown (7.5YR 3/2; 10YR 4/1, 4/2, 4/3); fine sandy loam to fine sandy clay loam; massive; pH 5.5 to 6.5. Clear to gradual change to
A2:	Occurs in less disturbed soils; sandy clay loam to silty clay loam; massive; pH 6.0 to 6.5. Abrupt to clear change to
B1:	Occasionally present; brown (7.5YR 4/4; 10YR 4/3, 4/4); fine sandy light to light medium clay; weak to moderate 2 to 10 mm subangular blocky, <2 to 10% manganiferous nodules or soft segregations <2 to 6 mm; pH 6.0 to 7.0. Clear to gradual change to
B21:	Red or brown (5YR 4/3, 4/4; 10YR 5/3); clay loam sandy to light medium clay; weak to moderate 5 to 10 mm subangular blocky; < 2% manganiferous nodules <2 mm; pH 6.3 to 7.0. Clear to gradual change to
B22:	Red (2.5YR 4/6; 5YR 4/4, 5/6); light clay to light medium clay; moderate to strong 5 to 20 mm angular blocky or subangular blocky; <2% manganiferous nodules <2 mm; pH 6.5 to 7.5. Clear to gradual change to
D:	Occasionally occurs; brown (7.5YR 4/6); clay loam sandy; massive; pH 7.0 to 7.5.

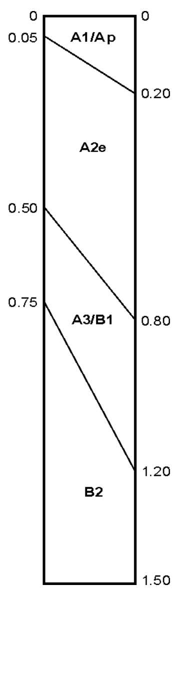
Sites: 119.

Analysed site: GCL 9000.

Alloway (Al)

Concept:	Bleached sandy surface over a mottled, non sodic, structured, gleyed subsoil on deeply weathered coarse grained sedimentary rocks.
Australian Classification:	Grey Chromosol, Redoxic Hydrosol.
Great Soil Group:	Gleyed podzolic soil.
Principal Profile Form:	Dg2.41, Dg4.41, Dy3.41, Dy5.42, Gn3.04
Surface characteristics:	Hardsetting or loose.
Geology:	Elliot Formation (Te).
Landform:	Level plains to hillslopes on gently undulating rises. Slopes 0 to 2%.
Vegetation:	15 to 18 m sparse to mid-dense *Eucalyptus umbra / Melaleuca viridiflora /Corymbia trachyphloia / Corymbia intermedia/Eucalyptus hallii/E.acmenoides*

Depth (m)



A1/Ap:	Grey (7.5YR 4/1, 4/2, 5/2; 10YR 4/1, 4/2, 5/1, 5/2); loamy sand to sandy loam; massive; pH 5.0 to 6.0. Clear to gradual change to
A2e:	Conspicuously bleached. Occasionally mottled; loamy sand to sandy loam; massive; pH 5.5 to 6.0. Clear to diffuse change to
A3/B1:	Mottled; grey or yellow (10YR 6/3, 6/4, 6/5, 7/2, 7/3, 7/4, 8/3); sandy clay loam or occasionally clay loam sandy increasing to sandy light clay in the B1; massive in A3 or weak 2 to 10 mm polyhedral or subangular blocky in the B1; frequently 2 to 50% ferruginous nodules 2 to 20 mm; pH 5.5 to 6.5. Clear to diffuse change to
B2:	Mottled; grey or occasionally yellow (10YR 6/2, 6/3, 7/1, 7/2, 7/3, 7/4, 8/1, 8/2, 8/3; 2.5Y 7/1, 7/2, 8/2); light clay to medium clay; moderate or strong 2 to 10 mm polyhedral or subangular blocky; frequently 2 to 50% ferruginous nodules 2 to <60 mm; pH 5.5 to 6.5.
Site:	212.

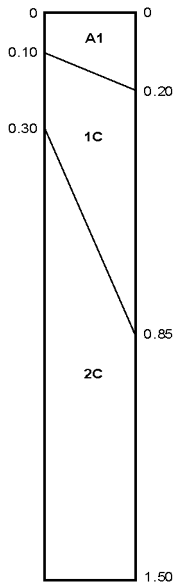
Analysed site: BUN 121.

Baddow (Ba)

Concept: Layered sandy soil developed on channel benches of the Mary River.

Australian Classification: Stratic Rudosol.
Great Soil Group: Alluvial soil, siliceous sand.
Principal Profile Form: Uc1.23, Uc1.21
Surface characteristics: Loose or soft.
Geology: Quaternary Holocene Alluvium (Qha1).
Landform: Channel benches, levees and scrolls on flood plains of the Mary River.
Vegetation: Mostly cleared.

Depth (m)



A1: Brown (10YR 4/3, 4/2); sand to sandy loam; massive; pH 6.0 to 7.0. Clear change to

1C: Brown (10YR 4/3, 4/4, 5/4); sand to loamy sand; single grain or massive; pH 6.0 to 7.0. Clear change to

2C: Brown (10YR 4/3, 4/4); sand or fine sand; single grain; pH 6.5 to 7.5.

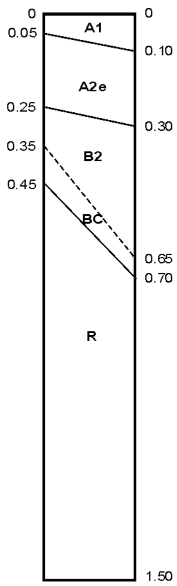
Sites: 42, 71, 173, 188, 201, 202, 309.

Analysed site: GCL 9005.

Beenham (Bh)

Concept: Texture contrast soil with brown or grey loamy surface over red or brown acid clay subsoil on moderately weathered phyllite.
Australian Classification: Grey and Yellow Chromosol.
Great Soil Group: Soloth, gleyed and yellow podsolic.
Principal Profile Form: Dy3.41, Dy2.41
Surface characteristics: Hardsetting.
Geology: Phyllite of the Kin Kin Beds (Rk).
Landform: Hillslopes of rises and low hills.
Vegetation: 18 to 25 m mid-dense *Eucalyptus* major, *Flindersia australis, E. intermedia, E. fibrosa* ssp. *fibrosa, E. tereticornis.*

Depth (m)



A1: Black (7.5 YR, 10YR, 3/2); loam; moderate, <2 mm, granular; 0–20% fine phyllite; pH: 6.5 to 7. Abrupt to clear change to

A2e: Conspicuously bleached; clay loam; weak or massive; 2–10% fine phyllite; pH: 6 to 6.5. Abrupt change to

B2: Mottled, yellow or grey (10YR, 2.5Y, 6/3, 6/4); clay loam; moderate to strong 2 to 5 mm subangular blocky; 2–10% fine phyllite; pH: 5.5 to 6. Clear or gradual change to

BC: Mottled, Grey (2.5Y 5/3, 6/3); light medium clay to medium clay; weak, 2 to 5 mm, blocky; 50 to >90%, fine phyllite; pH: 5.0 to 5.5.

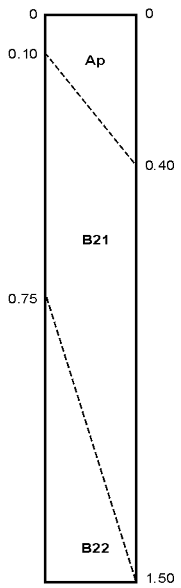
R: Weathered phyllite.

Sites: 337, 338.

Bidwill (Bd)

Concept: Red structured clay soil on deeply weathered andesite of the Grahams Creek Formation.
Australian Classification: Red Ferrosol.
Great Soil Group: Krasnozem, Euchrozem.
Principal Profile Form: Uf5.21, Uf5.22
Surface characteristics: Hardsetting.
Geology: Andesite of the Grahams Creek Formation (Jkg)
Landform: Hillcrests of rises and low hills.
Vegetation: Cleared.

Depth (m)



Ap: Red or occasionally black (2.5YR 3/4, 4/4; 5YR 3/2, 3/3, 4/4); light clay to light medium clay; moderate to strong 2 to 5 mm granular; pH 5.5 to 6.5. Clear to diffuse change to

B21: Red (2.5YR 3/3, 3/6, 4/4, 4/6; 10R 4/4); light clay to light medium clay; strong 2 to 5 mm polyhedral; 0–10% manganiferous nodules <2 to 20 mm; pH 5.5 to 7.0. Clear to diffuse change to

B22: Occasionally occurs; mottled; red (10R 4/4; 2.5YR 4/4, 4/6); light clay to medium clay; strong 2 to 5 mm polyhedral; 0–10% manganiferous <2 to 10 mm; pH 6.0 to 7.0.

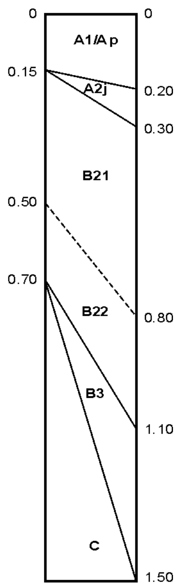
Sites: 109, 184, 196, 252.

Analysed site: MTL 246, BUN 11.

Bucca (Bc)

Concept: Mottled grey or brown acid clay on moderately weathered fine grained sedimentary rocks.
Australian Classification: Grey or Brown Dermosol and Brown or Grey Vertosol.
Great Soil Group: No suitable group, affinities with brown or grey clay.
Principal Profile Form: Uf3, Uf6.41, Ug5.24, Ug5.35
Surface characteristics: Hardsetting.
Geology: Mudstones and occasionally rhyolite and tuffs of Grahams Creek Formation (Jkg), Tiaro Coal Measures (Jdt), Maryborough Formation (Km).
Landform: Hillslopes of rises and low hills.
Vegetation: 18 to 25m closed or dense scrub, *Lophostemon suaveolens / Eucalyptus siderophloia / Eucalyptus moluccana / Corymbia citriodora*, occasionally *C. tereticornis.*

Depth (m)



A1/Ap: Grey, brown or occasionally black (10YR 3/2, 4/1, 4/2, 4/3, 4/4; 7.5YR 3/4, 4/3); light clay to medium clay; weak to strong 2 to 10 mm cast or granular or blocky; pH 4.5 to 5.5. Abrupt to clear change to

A2j: Undisturbed sites have sporadically bleached. Light medium clay; moderate 2 to 5 mm subangular blocky. Clear change to

B21: Mottled; grey or brown (7.5YR 5/2, 5/4, 5/6; 10YR 4/2, 5/3, 6/2, 6/3); medium clay to heavy clay; strong 2 to 10 mm lenticular or subangular blocky; frequently with ferruginous nodules; occasionally slickensides; pH 4.0 to 5.5. Gradual to diffuse change to

B22: Mottled; grey (7.5YR, 10YR 5/2, 6/2, 6/3, 7/2); medium clay to heavy clay; strong 2 to 20 mm lenticular or subangular blocky; frequently with ferruginous nodules and slickensides present; pH 4.0 to 5.0.

B3: Occasionally mottled; grey (2.5Y, 10YR, 7.5YR 5/2, 5/3, 6/1, 6/2, 7/2, 8/1; 2.5Y 5/4); light to heavy clay; moderate to strong 2 to 10 mm, subangular blocky; 2 to 50% mudstone, tuff or rhyolite pebbles 2 to 20 mm; pH 5.0 to 5.5 Clear to diffuse change to

C: Weathered mudstone, tuff or rhyolite.

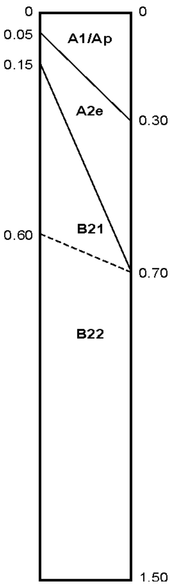
Sites: 85, 193, 199, 209, 229, 253.

Analysed site: MTL 9002.

Butcher (Bt)

Concept: Fine loamy surfaced, sodic texture contrast soils on alluvial plains of the Mary River.
Australian Classification: Brown Sodosol, Grey Sodosols, minor Redoxic Hydrosols.
Great Soil Group: Soloth, solodic soil.
Principal Profile Form: Dy3.41, Dy3.42, Dy3.43
Surface characteristics: Hardsetting.
Geology: Quaternary Pleistocene Alluvium (Qpa).
Landform: Alluvial plain.
Vegetation: Cleared.

Depth (m)



A1/Ap: Dark or grey (7.5YR 3/2, 4/2; 10YR 4/1, 4/2, 5/2); fine sandy clay loam, clay loam fine sandy or silty clay loam; massive to weak 2 to 5 mm cast; pH 5.5 to 6.5. Clear to abrupt change to

A2e: Conspicuously bleached. Mottled; loam fine sandy, clay loam fine sandy or silty clay loam; massive; frequently <2 to 50% manganiferous nodules <6 mm; pH 5.5 to 6.5. Sharp to abrupt change to

B21: Mottled; grey or brown (7.5YR 4/2, 5/2, 5/3; 10YR 4/2, 5/2, 5/3, 5/4, 6/3); light medium clay to medium clay; strong 5 to 20 mm subangular or angular blocky; frequently <2 to 50% manganiferous nodules <6 mm; pH 5.5 to 6.5. Diffuse change to

B22: Mottled; grey or brown (10YR 4/4, 5/4, 6/1, 6/2, 6/3; 2.5Y 5/2, 6/3); light medium clay to heavy clay; strong 10 to 20 mm angular blocky or 20 to 50 mm prismatic; pH 5.8 to 8.5.

Sites: 6, 39,45, 49, 54, 56, 70, 94, 140, 142, 144, 147, 159, 175, 205, 217, 284.

Analysed sites: MTL 315, BUN 113.

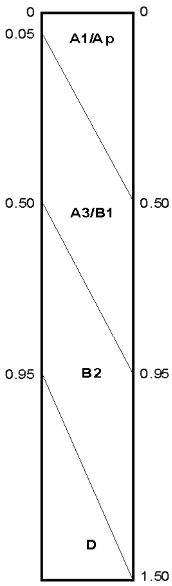
(BtSv) Butcher Sandy variant:
A1/Ap: Sandy loam to fine sandy loam textures.
A2e: Sand to sandy loam textures.

Sites: 233, 238, 311.
Analysed site: BUN 119.

Copenhagen (Co)

Concept: Layered soil with a loamy surface gradually increasing to sandy clay subsoils on terraces of the Mary River.
Australian Classification: Brown or Black Dermosol.
Great Soil Group: Prairie soil, Alluvial soil.
Principal Profile Form: Gn3.22, Um5.52, Um6.31, Um6.32, Uf6.31
Surface characteristics: Firm or soft.
Geology: Quaternary Holocene Alluvium (Qha1).
Landform: Channel benches or levees of the Mary River.
Vegetation: Mostly cleared.

Depth (m)



A1/Ap: Brown or black (10YR 4/4, 4/3, 4/2; 7.5YR 3/2); loam to clay loam; massive to strongly 2 to 5 mm subangular blocky; pH 6.0 to 7.5. Clear to gradual change to

A3/B1: Brown (10YR 4/3, 4/4); loam to fine sandy light clay; weak 2 to 5 mm subangular blocky; pH 6.0 to 7.5. Clear to diffuse change to

B2: Black or brown (10YR 2/2, 3/2, 4/3, 4/4); sandy clay loam to fine sandy light clay; moderate 2 to 5 mm subangular blocky; pH 6.5 to 7.5. Clear to diffuse change to

D: Brown (10YR 4/3, 4/4, 5/4); fine sand to fine loamy sand; single grain; pH 6.5 to 7.5.

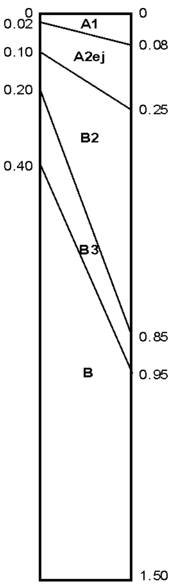
Sites: 68, 69, 208, 215, 255, 294, 308.

Analysed site: GCL 9008.

Doongul (Do)

Concept: Sodic texture contrast soil with a very shallow (<0.25 mm) bleached clay loam surface over a coarse structured, mottled, grey clay on weathered microdiorite.
Australian Classification: Grey Sodosol, Brown Sodosol.
Great Soil Group: Soloth, solodic soil, Solodized solonetz.
Principal Profile Form: Dy2.41, Dy3.42, Dy3.41, Dy2.32
Surface characteristics: Hardsetting.
Geology: Hornblende-phyric microdiorite (JKi).
Landform: Hillslopes of undulating rises.
Vegetation: 22 to 30 m sparse to mid-dense *Corymbia citriodora / Eucalyptus siderophloia / Eucalyptus moluccana / Eucalyptus tereticornis.*

Depth (m)



A1: Black or grey (7.5YR 3/2, 4/2); sandy clay loam to clay loam sandy; massive or weak 2 to 5 mm granular; pH 5.5 to 6.0. Clear abrupt change to

A2ej: Conspicuously bleached, occasionally sporadically bleached. Frequently mottled; sandy clay loam to clay loam sandy; massive; pH 5.7 to 6.3. Abrupt to sharp change to

B2: Frequently mottled especially in upper B2; grey or brown (5YR 5/2, 5/3; 7.5YR 4/2, 5/2, 5/3; 10YR 5/2, 5/3); light medium to medium clay; moderate or strong 20 to 100 mm prismatic or columnar or 10 to 20 mm angular blocky; pH 5.5 to 7.0. Clear to gradual change to

B3: Occasionally mottled; grey or brown (5YR 5/2, 5/3; 7.5YR 5/2, 5/3, 6/4; 10YR 4/2, 6/2); sandy light medium clay to medium clay with rock fragments; moderate or strong 20 to 50 mm prismatic or 5 to 20 mm angular blocky; pH 5.5 to 7.5. Clear to gradual change to

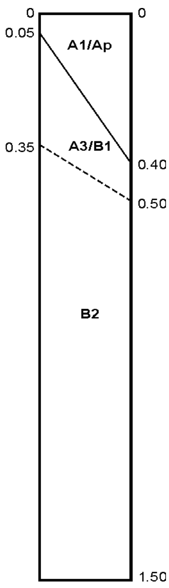
C: Weathered rock.

Site: 78.

Farnsfield (Ff)

Concept: Sandy surface over a red, massive subsoil on deeply weathered coarse grained sedimentary rocks.
Australian Classification: Red Kandosol.
Great Soil Group: Red earth.
Principal Profile Form: Gn2.11, Gn2.12, Um5.52
Surface characteristics: Firm to loose.
Geology: Sandstones of the Elliot Formation (Te).
Landform: Level plains to hillslopes on gently undulating plains and rises.
Vegetation: Cleared.

Depth (m)



A1/Ap: Red, brown or black (2.5YR 3/3, 4/2, 4/3; 5YR 3/2, 4/2, 4/3; 7.5YR 3/3, 4/3); loamy sand to sandy loam; massive; pH 5.5 to 6.5. Abrupt to clear change to

A3/B1: Frequently occurs. Red or brown (2.5YR 3/4, 4/3, 5/6; 5YR 3/3, 3/6, 4/4; 7.5YR 4/4); sandy clay loam to clay loam sandy; massive; pH 5.5 to 7.0. Diffuse change to

B2: Red (10R 4/6, 4/8; 2.5YR 4/6, 4/8); sandy clay loam, clay loam sandy, clay loam, light clay; massive or weak 2 to 10 mm subangular blocky or polyhedral; pH 5.5 to 7.0.

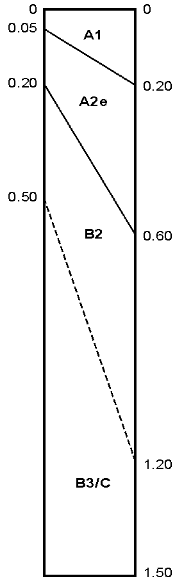
Site: 51.

Analysed sites: ATB 2, QCB 143, MBS 88, BUN 110

Gigoon (Gn)

Concept: Sodic texture contrast soil with a coarse sandy surface over a brown or grey clay subsoil on weathered microdiorite or granite.
Australian Classification: Brown Sodosol, Grey Sodosol.
Great Soil Group: Soloth, solodized solonetz, solodic soil.
Principal Profile Form: Dy5.41, Dy3.42, Dy3.41, Dy3.43, Dg4.41
Surface characteristics: Soft to firm.
Geology: Granites of the Hornblende-phyric Microdiorite (JKi).
Landform: Hillslopes of rises, low hills and hills.
Vegetation: 15 to 25 m mid-dense *Eucalyptus crebra / Corymbia citriodora / E. tereticornis / C. intermedia / E. exserta / E. siderophloia*

Depth (m)



A1: Black or grey or occasionally brown (7.5YR 2/2, 3/2, 3/3, 4/1, 4/2); loamy sand to sandy loam; massive; pH 5.5 to 6.0. Clear to gradual change to

A2e: Conspicuously bleached. Loamy sand to sandy loam; massive; pH 5.5 to 6.0. Abrupt to sharp change to

B2: Mottled; brown or grey or occasionally yellow (7.5YR 4/2, 5/2, 5/3, 5/4, 6/3; 10YR 4/2, 5/2, 5/3, 6/2, 6/3, 6/4, 7/2, 7/3); sandy light clay to sandy medium heavy clay; moderate or strong 50 to 100 mm columnar; 20 to 100 mm prismatic or 10 to 50 mm angular blocky; pH 5.5 to 9.5. Gradual to diffuse change to

B3: Mottled; brown or grey (7.5YR 5/3, 6/3; 10YR 5/2, 6/4); sandy clay to sandy light medium clay; weak or moderate 10 to 20 mm angular blocky or 20 to 50 mm prismatic; pH 5.5 to 9.0. Clear to diffuse change to

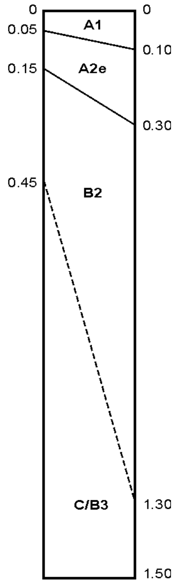
C: Weathered rock.

Site: 192.

Givelda (Gv)

Concept: Sodic texture contrast soil with a very shallow (<0.3 mm) loamy surface over a brown or yellow clay subsoil on moderately weathered fine grained sedimentary rocks.
Australian Classification: Brown Sodosol, Yellow Sodosol.
Great Soil Group: Soloth, solodic soil.
Principal Profile Form: Dy3.41, Dy3.42
Geology: Siltstones and fine sandstones of the Burrum Coal Measures (Kb), Maryborough Formation (Km) and Grahams Creek Formation (JKg).
Landform: Hillslopes on rises and low hills.
Vegetation: 18 to 20 m mid-dense *Eucalyptus moluccana / E.crebra / Corymbia citriodora / E. tereticornis.*

Depth (m)



A1: Black or grey (7.5YR 3/2, 4/2; 10YR 3/2); fine sandy clay loam to clay loam fine sandy; massive or weak 2 to 5 mm cast; pH 5.8 to 6.5. Clear change to

A2e: Conspicuously bleached. Mottled; fine sandy clay loam to clay loam fine sandy; massive; frequently manganiferous nodules; pH 5.8 to 6.0. Abrupt to sharp change to

B2: Mottled; brown or yellow, rarely red (5YR 4/4, 5/4, 5/6; 7.5YR 4/3, 5/4, 6/4, 6/6; 10YR 5/4, 5/6, 6/4) frequently becoming paler (10YR 5/2, 6/2) at depth; medium clay to heavy clay; strong 5 to 20 mm angular blocky or 20 to 50 mm prismatic parting to 10 to 20 mm angular blocky; frequently manganiferous nodules; pH 5.5 to 8.0. Clear to diffuse change to

C/B3: Weathered rock or clay with abundant rock fragments.

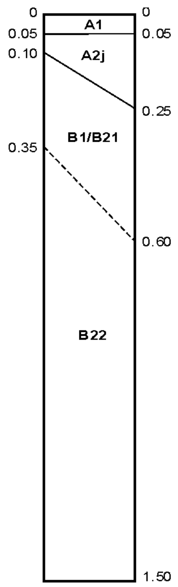
Sites: 340, 341, 365, 375.

Analysed site: CBW 911.

Granville (Gr)

Concept: Sporadically bleached acid grey clay on alluvial plains of the Mary River.
Australian Classification: Grey or Brown Dermosol, Brown Vertosol.
Great Soil Group: No suitable group.
Principal Profile Form: Uf3, Ug3.2
Surface characteristics: Hardsetting, usually with normal Gilgai.
Geology: Quaternary Pleistocene Alluvium (Qpa).
Landform: Relict alluvial plains and terrace flats.
Vegetation: Mostly cleared.

Depth (m)



A1: Black or grey (10YR 41, 4/2, 5/2, 6/2); light clay to light medium clay; moderate to strong 2 to 5 mm granular or subangular blocky; pH 5.5 to 6.0. Clear change to

A2j: Sporadically bleached. Mottled; light clay to light medium clay; moderate to weak 2 to 10 mm subangular blocky; 0 to 10% manganiferous nodules or soft segregation <2 to 6 mm; pH 5.5 to 6.0. Clear change to

B1/B2: Mottled; grey or brown (7.5YR, 10YR 4/2, 5/2, 5/3); light medium clay to medium clay; strong 2 to 10 mm subangular blocky; 0 to 10% manganiferous nodules or soft segregations <2 to 6 mm; pH 5.0 to 6.0. Gradual to diffuse change to

B22: Mottled; grey (7.5YR 5/1, 5/2; 10YR 5/2, 6/2; 2.5Y 6/1, 6/2); medium heavy to heavy clay; strong 2 to 5 mm lenticular; none to 10% manganiferous nodules or soft segregations <2 to 6 mm; pH 5.0 to 6.5.

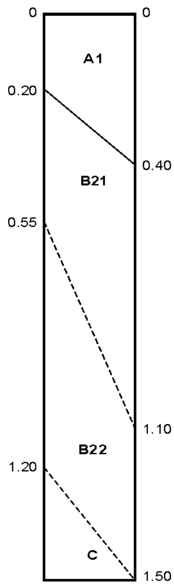
Sites: 32, 48, 203.

Analysed sites: BUN 109, MBS 17.

Gutchy (Gy)

Concept: Black clayey soil developed on alluvial fans.
Australian Classification: Grey Dermosol, Redoxic or Oxyaquic Hydrosol.
Great Soil Group: No suitable group, affinity with Prairie Soil.
Principal Profile Form: Uf6.32, Uf6.33
Surface characteristics: Firm.
Geology: Quaternary Alluvium (Qa).
Landform: Level to gently sloping alluvial fans of Mt Bauple
Vegetation: Mostly cleared with isolated trees of *Eucalyptus tereticornis / Eucalyptus siderophloia / Corymbia tessellaris / Angophora floribunda.*

Depth (m)



A1: Black or grey (10YR 2/1, 3/2, 4/1); light medium clay; strong; <2 to 10 mm granular or subangular blocky; pH: 6.0 to 7.0. Abrupt to clear change to

B21: Black or grey (10YR3/1; 2.5Y 4/2); medium to medium heavy clay; strong 2 to 10 mm, lenticular or angular blocky; pH 8.0 to 8.5. Diffuse change to

B22: Occasionally mottled, grey or brown (5Y 4/1, 5/1, 2.5Y 4/1, 5/3); medium clay to medium heavy clay; strong 2–10 mm, lenticular structure; <2%, ferruginous and calcareous nodules 2–20 mm; pH 8.5. Diffuse change to

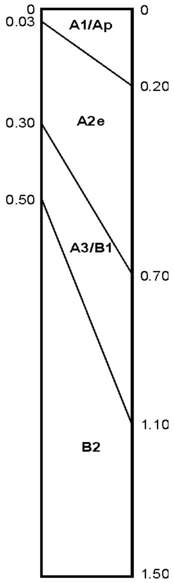
C: Occasionally present; grey (5Y 4/1); medium heavy clay; weak structure; <2, calcareous nodules; 10 to 20%, angular grit 2 to 6 mm; pH 9.0.

Sites: 148, 235, 271, 273.

Isis (Is)

Concept: Sandy bleached surface over a mottled, yellow, structured subsoil on deeply weathered coarse grained sedimentary rocks.
Australian Classification: Yellow Chromosol, Yellow Dermosol, Brown Chromosol, Brown Dermosol.
Great Soil Group: Yellow podzolic soil.
Principal Profile Form: Dy3.41, Gn3.84
Surface characteristics: Hardsetting or loose.
Geology: Elliot Formation (Te).
Landform: Level plains to hillslopes on gently undulating rises.
Vegetation: Mostly cleared.

Depth (m)



A1/Ap: Grey or occasionally black (7.5YR 4/1, 4/2, 5/1, 5/2; 10YR 3/1, 4/1 4/2, 5/1, 5/2, 5/3; 2.5Y 5/2, 5/3); sandy loam to fine sandy loam; massive; pH 5.5 to 6.5. Clear to diffuse change to

A2e: Conspicuously bleached. Sandy loam to fine sandy loam; massive; pH 5.5 to 6.5. Clear to diffuse change to

A3/B1: Yellow (10YR 6/4, 6/5, 6/6, 7/4, 7/5, 7/6); sandy clay loam, clay loam sandy increasing to sandy light clay, light clay in the B1; massive or weak 2 to 5 mm polyhedral; frequently ferruginous nodules 2 to 20 mm; pH 5.5 to 6.5. Clear to diffuse change to

B2: Mottled; yellow or occasionally brown (5YR 6/6, 7/5; 10YR 5/6, 6/4, 6/5, 6/6, 6/8, 7/5, 7/6); light clay to medium clay; moderate or strong 2 to 5 mm polyhedral or subangular blocky; frequently ferruginous nodules 2 to 60 mm; pH 5.5 to 6.5

Sites: 116, 220.

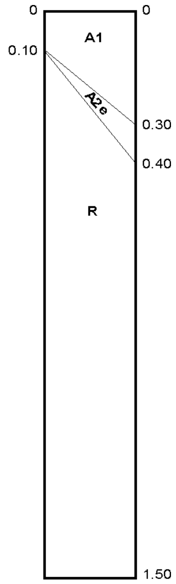
Analysed sites: MBS 31, 50, 62, QCB 137.

(IsRp) Isis Rocky phase: as above, with rock within 0.6 m depth and/or >10% surface coarse fragments which are >0.06 m in size.
Sites: 58, 66, 92, 95, 293.

Johnson (Js)

Concept: Shallow sandy soil overlying a cobble layer on a Tertiary- Quaternary alluvial peneplain.
Australian Classification: Clastic Rudosol, Bleached-Leptic Tenosol.
Great Soil Group: Lithosol.
Principal Profile Form: Uc1.21
Surface characteristics: Soft to firm
Geology: Tertiary-Quaternary Alluvium (TQa).
Landform: Gently sloping or flat peneplain.
Vegetation: 10 to 20m sparse *Corymbia citriodora* ssp. *citriodora, C. intermedia, C. tessellaris, Eucalyptus tereticornis, E. crebra, E. exserta.*

Depth (m)



A1: Black or grey (10YR 2/2, 3/2, 4/2, 5/2); sand to sandy clay loam; single grain or massive; 2–90% fine gravels, stones or cobbles; pH 5.5 to 6.5. Clear to gradual change to

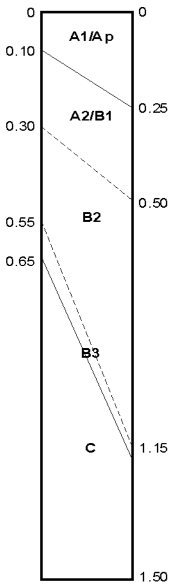
R: Water worn cobbles.

Sites: 13, 96, 118, 122, 158, 176, 204, 239, 254.

Jumpo (Jp)

Concept: Loamy to clayey surface over an acid to neutral mottled brown structured clay subsoil with manganiferous nodules throughout on deeply weathered andesite.
Australian Classification: Brown Dermosol, Yellow Dermosol.
Great Soil Group: No suitable group, affinity with xanthozem.
Principal Profile Form: Uf6.41, Uf4.42, Uf4.43, Gn3.72
Surface characteristics: Hardsetting.
Geology: Deeply weathered andesite of the Grahams Creek Formation (JKg).
Landform: Gently undulating hillslopes (3–8%) on rises.
Vegetation: 18 to 25 m mid-dense *Eucalyptus tereticornis / Lophostemon suaveolens / Eucalyptus siderophloia.*

Depth (m)



A1/Ap: Grey or brown (10YR 4/2, 4/3, 5/3); clay loam to silty light medium clay; weak to strong 2 to 5 mm granular or subangular blocky; 2 to 20% manganiferous nodules 2 to 6 mm; pH 6.0 to 7.0. Clear to gradual change to

A2/B1: Occasionally occurs; brown occasionally grey (10YR 5/4; 2.5Y 5/2, 5/4); light clay to light medium clay; moderate to strong 2 to 5 mm subangular blocky; 2 to 20% manganiferous nodules <2 to 6 mm; pH 6.0 to 6.5. Gradual change to

B2: Mottled; brown or occasionally yellow (10YR 5/4, 5/6, 6/6; 2.5Y 5/4); light clay to medium heavy clay; strong 2 to 10 mm subangular blocky or polyhedral; 2 to 50% manganiferous nodules <2 to 6 mm; pH 6.0 to 7.0. Diffuse to gradual change to

B3: Mottled; brown or grey (2.5Y 5/3, 6/2; 10YR 5/4, 6/2, 6/4); medium clay to heavy clay; moderate 2 to 10 mm angular blocky or 2 to 50 mm lenticular; 2 to 50 % manganiferous < 2 to 6 mm; pH 5.0 to 6.0. Clear change to

C: Weathered andesite.

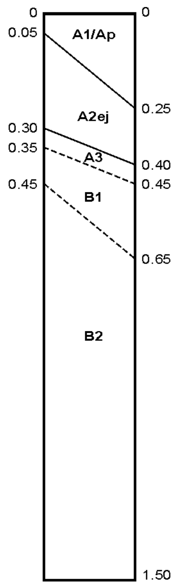
Sites: 107, 108.

Analysed site: MTL 9000.

Kepnock (Kp)

Concept: Loamy surface over a mottled, yellow, structured subsoil on deeply weathered fine-grained sedimentary rocks.
Australian Classification: Yellow or brown Dermosol, yellow or brown Chromosol.
Great Soil Group: Yellow podzolic soil, no suitable group.
Principal Profile Form: Gn3.84, Gn3.81, Dy3.41
Surface characteristics: Hardsetting.
Geology: Mudstones, siltstones, fine sandstones of the Elliot Formation (Te), Burrum Coal Measures (Kb), Maryborough Formation (Km).
Landform: Level plains to hillslopes on gently undulating rises.
Vegetation: Cleared.

Depth (m)



A1/Ap: Grey or black (7.5YR 3/2, 4/1, 4/2; 10YR 3/2, 4/2, 5/2, 5/3); fine sandy clay loam, sandy clay loam, clay loam, clay loam fine sandy; massive; pH 5.5 to 6.5. Clear change to

A2ej: Conspicuously or sporadically bleached. Fine sandy clay loam, sandy clay loam, clay loam fine sandy; massive; frequently 2 to 50% ferruginous nodules <6 mm; pH 5.5 to 6.0. Clear to gradual change to

A3: Frequently occurs. Mottled; yellow or brown (10YR 5/4, 6/4, 6/6); clay loam, clay loam fine sandy; massive or weak 2 to 5 mm polyhedral; frequently 2 to 50% ferruginous or ferromanganiferous nodules <20 mm; pH 5.5 to 6.5. Gradual to diffuse change to

B1: Frequently occurs. Mottled; yellow (7.5YR 5/5, 6/5; 10YR 6/4, 6/5, 6/6); clay loam sandy to light clay; weak or moderate 2 to 5 mm polyhedral or subangular blocky; 2 to 50% ferruginous or ferromanganiferous nodules <6 mm; pH 5.5 to 6.5. Gradual to diffuse change to

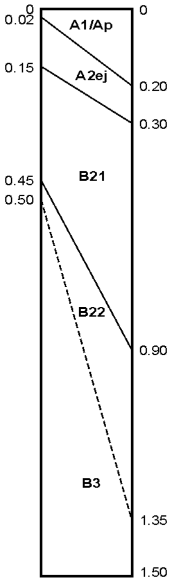
B2: Mottled; yellow or brown (7.5YR 6/5, 6/6, 7/6; 10YR 5/5, 6/5, 6/6, 6/8); light clay to medium clay; moderate or strong 2 to 5 mm polyhedral or subangular blocky; 10 to 50% ferruginous or ferromanganiferous nodules <20 mm; pH 5.5 to 6.5.

Analysed sites: CBW S9, S11, 5, 14, 17, 25.

Kolan (Ko)

Concept: Sodic texture contrast soil with a shallow (< 0.3 m), loamy surface over a red mottled, grey or brown clay subsoil on moderately weathered fine-grained sedimentary rocks.
Australian Classification: Grey or brown Kurosol, Grey or brown Sodosol.
Great Soil Group: Soloth.
Principal Profile Form: Dy3.41, Dy3.31
Surface characteristics: Hardsetting.
Geology: Mudstones, siltstones of the Burrum Coal Measures (Kb), Maryborough Formation (Km), Grahams Creek Formation (JKg), Tiaro Coal Measures (Jdt).
Landform: Hillslopes of rises and low hills. Slopes 1 to 15%.
Vegetation: 18 to 25 m mid-dense *Corymbia citriodora / Eucalyptus siderophloia / E. moluccana / E.acmenoides / E.exserta / E. fibrosa. E. moluccana* may be locally dominant.

Depth (m)



A1/Ap: Black or grey (7.5YR, 10YR 2/2, 3/1,3/2, 4/2, 4/3, 5/2, 5/3); fine sandy clay loam to clay loam fine sandy; massive to moderate 2 to 5mm granular or subangular blocky; pH 5.5 to 6.5. Abrupt to clear change to

A2ej: Occurs in undisturbed soils. Conspicuously or sporadically bleached. Fine sandy clay loam to clay loam fine sandy, massive or weak structure; frequently <2 to 50% ferruginous nodules <6 mm; pH 5.5 to 6.0. Sharp to abrupt change to

B21: Mottled; grey or brown (10YR 4/2, 5/2, 5/3, 6/2, 6/3, 6/4; 2.5Y 5/4); medium clay to heavy clay; strong 2 to 10 mm angular to subangular blocky; frequently <2 to 20% ferruginous nodules < 20 mm; pH. 5.0 to 6.0. Clear to gradual change to

B22: Red mottled; grey or brown (5YR, 7.5YR, 10YR 4/2, 4/3, 5/1, 5/2, 5/3, 6/1, 6/2, 6/3; 2.5Y 5/2, 5/4); medium clay to heavy clay; strong 20 to 50mm prismatic parting to moderate to strong 5 to 20mm angular blocky or moderate to strong 2 to 5 mm lenticular; frequently <2 to 10% ferruginous nodules 2 to 6 mm occasional slickensides present; pH 4.5 to 6.0. Gradual to diffuse change to

B3: Mottled: grey (10YR, 7.5YR 5/2, 5/3, 6/1, 6/2, 6/3, 7/1, 7/2; 2.5YR 7/2, 7/3); medium clay to heavy clay; moderate to strong 5 to 20 mm angular blocky or lenticular; fragments of mudstone or siltstone; pH 4.5 to 6.0.

Sites: 2, 15, 16, 17, 18, 20, 26, 29, 34, 41 52, 59, 72, 75, 76, 81, 90, 91, 106, 110, 127, 134, 137, 141, 151, 153, 157, 165, 166, 172, 190, 191, 250, 262, 289, 315, 320, 330, 339, 342, 343, 348, 357, 373, 378.

Analysed sites: BUN C3, MBS 52.

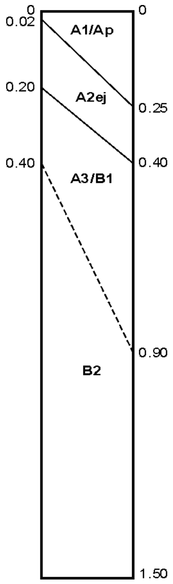
(KoRv) Kolan Red variant: Red Kurosol. Red B2 with 20 to 50% grey mottles. Analysed site: MBS 80.

(KoRp) Kolan Rocky phase: Grey Kurosol. As above with >20% coarse fragments in the surface or rock within 30 cm of the surface.

Littabella (Lt)

Concept: Massive, sandy to loamy soils on local alluvium.
Australian Classification: Yellow, grey or red kandosol, Orthic Tenosol.
Great Soil Group: Yellow earth, no suitable group, earthy sand.
Principal Profile Form: Um5.52, Um4.23, Gn2.71, Gn2.94, Uc5.22
Surface characteristics: Soft or loose.
Geology: Quaternary Alluvium (Qa).
Landform: Levees and scrolls on alluvial plains of local creeks.
Vegetation: Mostly cleared, minor dense scrub.

Depth (m)



A1/Ap: Black or grey (7.5YR 3/2, 4/2; 10YR 4/1); sandy loam, fine sandy loam, loam, fine sandy clay loam; massive, single grain or weak 2 to 5 mm cast or granular; pH 5.5 to 6.0. Clear to diffuse change to

A2ej: Occasionally occurs as a coloured (A2) horizon or sporadically or conspicuously bleached horizon; sandy loam, fine sandy loam, fine sandy clay loam; massive or single grain; pH 5.5 to 6.5.

A3/B1: Brown, grey or red (5YR 5/3, 5/4; 7.5YR 4/3, 5/4; 10YR 6/3, 7/5); sandy loam to loam fine sandy; massive or single grain; pH 6.0 to 8.0. Diffuse change to

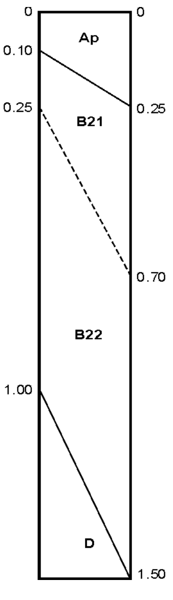
B2: Occasionally mottled; yellow or grey, occasionally red (5 YR 5/6; 7.5YR 6/3; 10 YR 6/2, 6/6, 7/1); sandy loam, fine sandy clay loam, sandy clay loam, clay loam sandy; massive or single grain; pH 6.0 to 8.0.

Site: 374.

Mary (My)

Concept: Brown structured non cracking clay on alluvium of the Mary River.
Australian Classification: Brown Dermosol.
Great Soil Group: Prairie soil.
Principal Profile Form: Gn3.21, Uf6.31
Surface characteristics: Hardsetting.
Geology: Quaternary Alluvium (Qa).
Landform: Alluvial plains.
Vegetation: Mostly cleared.

Depth (m)



Ap: Black or brown (10YR 3/1, 3/2, 4/3); silty clay loam to silty clay; weak to moderate 2 to 5 mm granular; pH 5.5 to 7.0. Abrupt to clear change to

B21: Brown (10YR 4/3, 5/4); light clay to medium clay; moderate to strong 5 to 10 mm subangular blocky or angular blocky; pH 5.5 to 7.0. Gradual to diffuse change to

B22: Brown (10YR 4/3, 5/4); medium clay to heavy clay; strong 5 to 10 mm subangular blocky or angular blocky; 0 to 20% manganiferous nodules or soft segregations <2 to 6 mm; pH 5.5 to 7.5.

D: Occasionally present; brown (7.5YR 5/8; 10YR 3/6, 5/4); loamy fine sand to fine sandy light clay; massive to weak subangular blocky; pH 7.0 to 8.0.

Sites: 4, 44, 55, 57, 145, 218, 295, 317, 322.

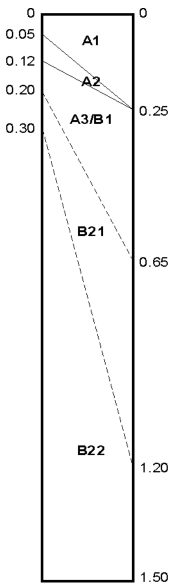
Analysed site: MTL 350.

(MyDv) Mary Dark Variant: Black Dermosol Black (7.5YR 3/2) throughout profile.
Sites: 5, 7, 8, 10, 11, 60, 61, 63, 67, 120, 146, 174, 228, 247, 256, 258, 286, 290, 307, 310, 313.
Analysed site: 9007.

Miva (Mv)

Concept: Sporadically bleached alluvial black clay on alluvium of the Mary River.
Australian Classification: Black Dermosol.
Great Soil Group: No suitable group, affinity with black clay; solodic.
Principal Profile Form: Uf3, Uf6.32, Dd1.13
Surface characteristics: Hardsetting.
Geology: Quaternary Pleistocene alluvium (Qpa).
Landform: Alluvial plains.
Vegetation: Mostly cleared. Tall (20 to 25 m) isolated *Eucalyptus crebra, E. moluccana, E. tereticornis.*

Depth (m)



A1: Black or grey (10YR 3/2, 4/2; 2.5Y 5/2); clay loam to light clay; moderate to strong 2 to 5 mm granular or subangular blocky; pH 6.5 to 7.0. Clear to gradual change to

A2j: Present in undisturbed sites. Sporadically bleached. Light clay to light medium clay; moderate 2 to 10 mm subangular blocky; none to 20% manganiferous soft segregation <2 to 6 mm; pH 6.5 to 7.0. Clear to gradual change to

A3/B1: Grey or brown (10YR 3/2, 4/4; 2.5Y 4/2, 5/2, 5/3); light medium clay to medium clay; strong 2 to 10 mm subangular blocky; none to 20% manganiferous nodules or soft segregations <2 to 6 mm; pH 7.0 to 8.0. Gradual change to

B21: Black (7.5YR 3/2, 10YR 2/2, 3/2, 2.5Y 3/2); medium clay to medium heavy clay; moderate prismatic 10 to 20 mm parting to strong 2 to 10 mm lenticular or subangular blocky; <2 to 20% manganiferous nodules <2 to 6mm; pH 7.5 to 9.5.Gradual change to

B22: Black or brown (10YR 3/2, 3/3, 4/3, 4/4, 7.5YR 3/4, 4/4); medium clay to medium heavy clay; strong prismatic 20 to 100 mm parting to strong angular 2 to 20 mm; <2 to 10% manganiferous nodules <2 to 6 mm none to <2% calcareous nodules or soft segregations 2 to 6 mm; slickensides present; pH 8.5 to 9.5.

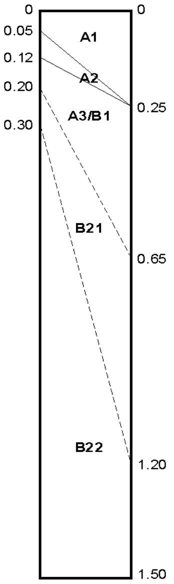
Sites: 40, 249, 265, 266, 287.

Analysed site: GCL 9001.

Mungar (Mg)

Concept: Sporadically bleached alkaline non cracking grey clay on alluvial plains of the Mary River.
Australian Classification: Brown Dermosol, Grey Dermosol, Redoxic Hydrosol.
Great Soil Group: No suitable group, affinities with grey clay.
Principal Profile Form: Uf3, Uf6.41
Surface characteristics: Occasionally present hardsetting, with normal gilgai when not cultivated.
Geology: Quaternary Pleistocene Alluvium (Qpa).
Landform: Relict alluvial plains, backplains and terrace flats.
Vegetation: Mostly cleared.

Depth (m)



A1: Black or grey (10YR 3/2, 4/2; 2.5Y 5/2); silty light clay to silty light medium clay; moderate to strong 2 to 5 mm granular or subangular blocky; pH 6.5 to 7.0. Clear to gradual change to

A2j: Present in undisturbed sites. Sporadically bleached. Light clay to light medium clay; moderate 2 to 10 mm subangular blocky; none to 20% manganiferous soft segregation <2 to 6 mm; pH 6.5 to 7.0. Clear to gradual change to

A3/B1: Occasionally mottled; grey or brown (10YR 3/2, 4/4; 2.5Y 4/2, 5/2, 5/3); light medium clay to medium clay; strong 2 to 10 mm subangular blocky; none to 20% manganiferous nodules or soft segregations <2 to 6 mm; pH 7.0 to 8.0. Gradual change to

B21: Occasionally mottled; grey or brown (10YR 5/4, 5/6; 2.5Y 5/2, 5/3, 5/4, 6/1, 6/2); medium clay to medium heavy clay; weak to moderate prismatic 10 to 20 mm parting to strong 2 to 10 mm lenticular or subangular blocky; <2 to 20% manganiferous nodules <2 to 6mm; pH 7.5 to 9.5. Gradual change to

B22: Brown or grey (10YR 4/4, 5/3, 5/4; 2.5Y 5/3, 5/4, 6/3); medium clay to medium heavy clay; strong 2 to 50 mm lenticular structure; <2 to 10% manganiferous nodules <2 to 6 mm none to <2% calcareous nodules or soft segregations 2 to 6 mm; slickensides present; pH 8.5 to 9.5.

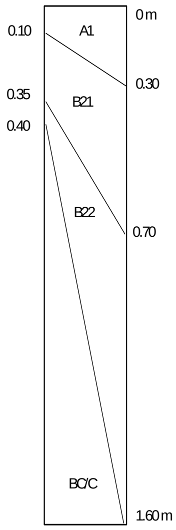
Sites: 3, 12, 38, 65, 93, 115, 123, 133, 186, 187, 206, 216, 227, 261, 283, 291, 296, 298, 299.

Analysed site: MTL 9006.

Neerdie (Nd)

Concept: Black to brown clay loam to light clay surface over a brown to grey acid clay subsoil on phyllite.
Australian Classification: Brown, yellow and grey Dermosol.
Great Soil Group: No suitable group.
Principal Profile Form: Uf6.4, Uf4.4, Gn3.21, Uf6.33
Surface characteristics: Hardsetting.
Geology: Phyllite of the Kin Kin beds.
Landform: Moderately undulating hillslopes on low hills.
Vegetation: No data.

Depth (m)

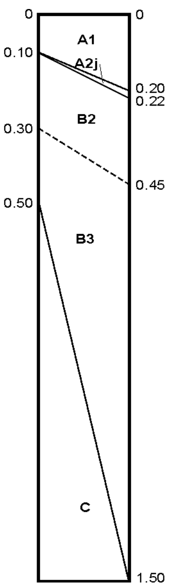


Analysed site: MRC 606.

Netherby (Nb)

Concept: Black or grey structured clayey surface, frequently with a sporadically bleached horizon, overlying a brown or grey structured clay developed from andesite.
Australian Classification: Brown or Grey Dermosol.
Great Soil Group: No suitable group, affinity with prairie soil.
Principal Profile Form: Gn3.63, Gn3.83
Surface characteristics: Firm.
Geology: Andesite of the Grahams Creek Formation (JKg).
Landform: Hillslopes on undulating or rolling undulating rises and low hills (4–20%).
Vegetation: Mostly cleared.

Depth (m)



A1: Black or grey (10YR 3/1, 3/2, 4/2; 7.5YR 3/2); clay loam to light medium clay; strong <2 mm granular or 2 to 5 mm subangular blocky; occasionally <2 to 10% ferruginous nodules <2 to 6 mm; andesite fragments 2 to 6 mm; pH 6.0 to 7.0. Clear to gradual change to

A2j: Sporadically bleached. Clay loam to light clay; moderate to strong 2 to 5 mm subangular blocky 2 to 10% manganiferous soft segregations and nodules <2 to 6 mm; 0 to 20% andesite fragments 2 to 6 mm; pH 7.0 to 7.5. Clear change to

B2: Occasionally mottled; brown or grey (10YR 4/1, 4/3, 5/3, 5/6; 2.5Y 4/2); light medium clay to medium clay; strong 2 to 5 mm subangular blocky structure; 0 to 10% manganiferous nodules <2 to 6 mm; pH 7.0 to 8.0. Gradual change to

B3: Mottled; brown or grey (10YR 5/6; 2.5Y 4/2, 5/1); light medium clay to medium clay; moderate 10 to 20 mm prismatic; <2% manganiferous soft segregations and/or nodules 2 to 6 mm; 0 to <2% andesite fragments 2 to 6 mm; pH 8.0 to 9.5. Abrupt change to

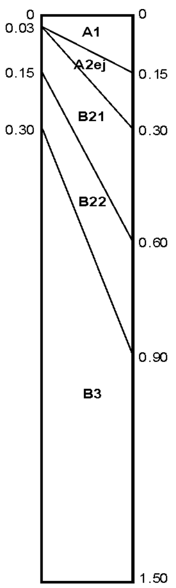
C: Weathered andesite fragments 2 to 60 mm.

Sites: 86, 246.

Owanyilla (Ow)

Concept: Sodic texture contrast soil with a loamy surface over a mottled brown or grey subsoil on moderately weathered intermediate igneous rocks.
Australian Classification: Brown or Grey Sodosol, soloth.
Great Soil Group: Solodic soil.
Principal Profile Form: Dy3.32, Dy3.33, Dy3.43, Dy3.42
Surface characteristics: Hardsetting.
Geology: Andesite of the Grahams Creek Formation (Jkg), Microdiorite of unnamed intrusives (Jki).
Landform: Hillslopes on gently undulating to undulating rises
Vegetation: 12 to 20 m mid-dense *Corymbia citriodora / Eucalyptus moluccana / Eucalyptus siderophloia*.

Depth (m)



A1: Black or grey (7.5YR 3/2; 10YR 4/2); fine sandy loam to clay loam; massive to weak 2 to 5 mm granular; pH 5.5 to 6.0. Clear change to

A2ej: Conspicuously or occasionally sporadically bleached. Fine sandy loam to clay loam; massive to weak 2 to 5 mm granular; pH 5.5 to 6.5. Abrupt to sharp change to

B21: Mottled; brown or occasionally grey (10YR 5/2, 5/3, 5/4); light medium clay to medium heavy clay; moderate to strong 5 to 10 mm angular blocky or 20 to 100 mm prismatic; frequently ferromanganiferous nodules 2 to 20 mm; pH 5.5 to 7.0. Gradual to diffuse change to

B22: Mottled; brown, grey or occasionally yellow (2.5YR 5/3; 7.5YR 5/2; 10YR 5/3, 6/4); medium clay to heavy clay; moderate to strong 2 to 5 mm lenticular or 20 to 100 mm prismatic; frequently 2 to 20 mm ferromanganiferous nodules; pH 6.0 to 7.0. Gradual to diffuse change to

B3: Mottled; brown, grey or yellow (2.5YR 5/3, 5/4; 7.5YR 5/2; 10YR 6/4); medium clay to heavy clay with rock fragments; moderate 5 to 20 mm angular blocky; pH 6.5 to 9.0.

Sites: 23, 103, 105, 117, 126, 180, 189, 194, 267, 269, 274, 319, 358.

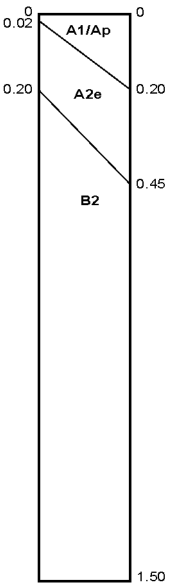
Analysed sites: MTL 282, MBS 10, GCL 9002.

Owanyilla Rocky phase (OwRp): Weathered rock within 20 cm of the surface.
Site: 185.

Peep (Pp)

Concept: Sodic texture contrast soil on local alluvium.
Australian Classification: Grey Sodosol, Brown Sodosol, Grey Kurosol, minor Redoxic Hydrosol.
Great Soil Group: Solodic soil, soloth.
Principal Profile Form: Dy3.42, Dy3.41, Dy3.43
Surface characteristics: Hardsetting or soft.
Geology: Quaternary Alluvium (Qa).
Landform: Alluvial plain.
Vegetation: 15 to 20 m sparse to mid-dense, variable, *Eucalyptus umbra / Angophora leiocarpa / E. exserta / Melaleuca species or E. moluccana / E. tereticornis.*

Depth (m)



A1/Ap: Grey or black (7.5YR 3/2, 4/2, 5/1, 5/2, 5/3, 10YR 3/2, 4/2,5/2, 5/3, 6/3); fine sandy loam, fine sandy clay loam, clay loam fine sandy, silty clay loam; massive; pH 5.5 to 6.0. Clear to gradual change to

A2e: Conspicuously bleached. Mottled; loam fine sandy, clay loam fine sandy, silty clay loam; massive; 0 to 10% manganiferous nodules, <2 to 6 mm; pH 5.5 to 6. Abrupt to clear change to

B2: Mottled; grey or brown (7.5YR 4/2, 5/2, 5/3, 6/2, 6/3; 10YR 4/2, 5/1, 5/2, 5/3, 6/2, 6/3, 7/1, 7/2); light medium clay to medium heavy clay; moderate or strong 5 to 20 mm angular blocky or 20 to 50 mm prismatic parting to angular blocky; 0 to 10% manganiferous soft segregations; none to few mangan cutans; pH 5.0 to 8.0.

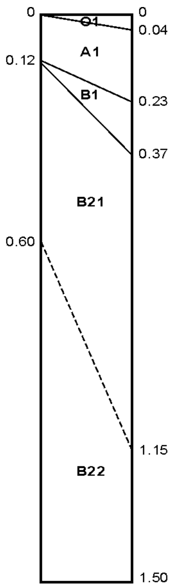
Sites: 143, 368.

Analysed site: BUN 117.

Pelion (Pe)

Concept: Cracking clay on alluvial plains derived from andesite of the Grahams Creek Formation.
Australian Classification: Aquic Vertosol, Brown or Grey Vertosol.
Great Soil Group: Weisenboden, Brown or Grey Clay.
Principal Profile Form: Ug5.33, Ug5.16
Surface characteristics: Self mulching, and cracking if not in a swamp.
Geology: Alluvium (Qa) derived from andesite of the Grahams Creek Formation (JKg).
Landform: Swamps and alluvial plains.
Vegetation: Mostly cleared.

Depth (m)



O1/2: Occasionally present, root mat.

A1: Root mottling; black or grey (10YR 3/2, 4/1; 2.5Y 4/1); light medium clay to medium clay; strong <2 mm granular or 2 to 5 mm subangular blocky; pH 6.0 to 8.5. Clear to diffuse change to

B1: Occasionally present. Black or brown (10YR 3/2; 2.5Y 4/3); light medium clay to medium clay; strong 2 to 5 mm subangular or lenticular structure; 0 to <2% manganiferous nodules <2 mm; clay cutans present; pH 7.0 to 8.5. Diffuse change to

B21: Occasionally mottled; black, brown or grey (10YR 3/1, 4/1, 4/2, 5/3; 2.5Y 2/1, 3/1); medium clay; strong 2 to 20 mm lenticular; 0 to <2% manganiferous nodules <2 mm and/or <2% calcareous nodules 20 to 60 mm; clay cutans present; pH 8.0 to 9.0. Gradual to diffuse change to

B22: Mottled; grey (2.5Y 4/1, 5/2; 5Y 5/2); light medium clay to medium clay; strong 2 to 5 mm lenticular; <2% manganiferous nodules <2 mm; pH 9.0 to 9.5.

Sites: 88, 97, 128, 171, 178, 198, 210, 211, 224, 244, 268, 324.

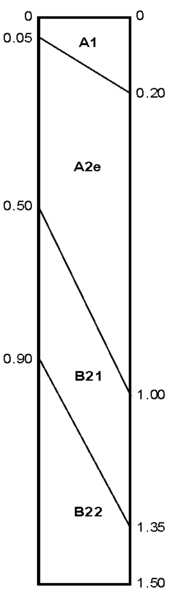
Analysed site: MTL 9003.

Pelion Dark variant (PeDv): Black Vertosol. Same as above but black colour throughout. Not mottled. Sites: 231, 272, 306, 316. Analysed site: GCL 9003.

Robur (Rb)

Concept: Sodic texture contrast soil with moderately deep (0.5 to1.0 m) sandy surface over a grey or gleyed clay subsoil on deeply weathered coarse grained sedimentary rocks.
Australian Classification: Redoxic Hydrosol, Grey Sodosol.
Great Soil Group: Soloth, minor solodic soil.
Principal Profile Form: Dy3.41, Dg2.41, Dg2.42, Dy5.41, Dg 4.41
Surface characteristics: Hardsetting or loose.
Geology: Elliott Formation (Te).
Landform: Drainage depressions and lower slopes of plains and rises.
Vegetation: 10 to 18 m sparse to mid-dense *Eucalyptus umbra / Melaleuca viridiflora / E. hallii / Corymbia trachyphloia*, frequently with an understorey of *Banksia oblongifolia / Banksia robur*.

Depth (m)



A1: Grey (7.5YR 4/1, 4/2, 5/1, 5/2; 10YR 4/1, 4/2, 5/1, 5/2, 5/4, 6/2); loamy sand to sandy loam, massive; pH 5.5 to 6.0. Clear to gradual change to

A2e: Conspicuously bleached. Loamy sand to sandy loam; massive; pH 5.5 to 6.0. Abrupt to clear change to

B21: Mottled; grey (10YR 6/1, 6/2, 6/3, 7/2, 7/1, 7/3); sandy light clay to medium heavy clay; moderate or strong 10 to 50 mm angular blocky or prismatic; frequently <2 to 20% ferruginous nodules 2 to 20 mm; pH 5.0 to 6.5. Gradual to diffuse change to

B22: Mottled; grey (10YR 6/1, 6/2, 6/3, 7/1, 7/2, 8/1; 2.5YR 7/1); sandy light medium clay to heavy clay; strong 10 to 20 mm angular blocky or 20 to 50 mm prismatic parting to 10 to 20 mm angular blocky; occasional slickensides; frequently 2 to 50% ferruginous nodules 2 to 20 mm; pH 4.7 to 7.5.

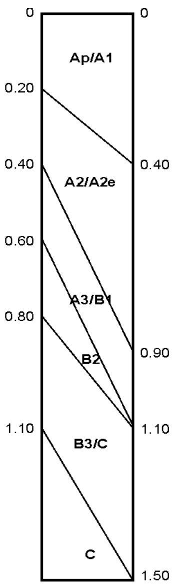
Site: 9.

Analysed sites: BUN 103, 107, QCB 178, 216.

Rothchild (Rt)

Concept: Bleached massive brown or yellow samd on deeply weathered coarse grained sedimentary rocks.
Australian Classification: Bleached-Orthic or Orthic Tenosol.
Great Soil Group: (Bleached) Earthy sand, Earthy sand.
Principal Profile Form: Uc2.21, Uc4.21, Uc4.22
Surface characteristics: Hardsetting.
Geology: Elliott Formation (Te).
Landform: Plains, and hillslopes and hillcrests on gently undulating rises. Slopes 0 to 5%.
Vegetation: 10 to 18 m mid-*dense Eucalyptus umbra / Corymbia trachyphloia / Eucalyptus hallii / C. intermedia.*

Depth (m)



Ap/A1: Black or grey (7.5YR 2/2, 3/2, 3/1, 4/1; 10YR 3/1, 3/2, 4/2); loamy sand to sandy loam; single grained or massive; pH 6.0 to 7.0. Clear to

A2/A2e: Conspicuously bleached. Occasionally coloured (10YR 4/4, 5/4, 6/2, 6/3); loamy sand to sandy loam; massive; pH 5.5 to 6.0. Gradual to diffuse to

A3/B1: Occasionally present, Brown to yellow (7.5YR 4/3, 4/4, 5/6; 10YR 5/6); loamy sand to sandy loam; single grained or massive; occasionally 2 to 10%; 2 to 20 mm ferromanganiferous nodules; 2 to 10%, 6 to 20 mm quartz coarse fragments; pH 6.0 to 6.5. Clear change to

B2: Occasionally mottled; brown to yellow (7.5YR 4/6, 6/4; 10YR 5/4, 5/6, 6/4, 6/6); loamy sand to sandy loam; massive; occasionally 10 to 20%; 2 to 20 mm ferromanganiferous nodules; frequently with 10 to 20% 6 to 20 mm quartz coarse fragments; pH 6.0 to 6.5. Diffuse to

B3/C: Decomposing sandstone, massive.

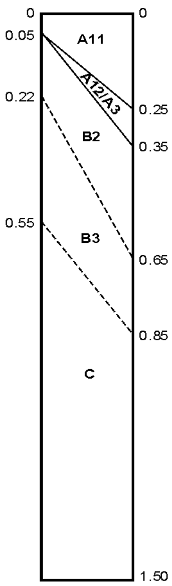
Sites: 346, 363, 383.

Rothchild Podosolic variant (RtPv): Same as above with a B2hs horizon on moderately weathered quartzone sandstone of the *Myrtle Creek Sandstone* (RJm). Sites: 347, 356.

Tiaro (Ta)

Concept: Structured black or brown clayey soil overlying weathering andesite or microdiorite rocks.
Australian Classification: Black or Brown Dermosol.
Great Soil Group: Prairie soil.
Principal Profile Form: Uf6.32, Gn3.92, Gn3.22
Surface characteristics: Firm. Very few to common andesite cobbles and stones.
Geology: Andesite of the Grahams Creek Formation (JKg) or Microdiorite of the unnamed intrusives (JKi).
Landform: Hillcrests and hillslopes on gentle to rolling undulating rises and low hills (2–15%).
Vegetation: Mostly cleared, occasional remnants of vine scrub species.

Depth (m)



A11: Black (10YR 3/1, 3/2; 7.5YR 3/2); clay loam to light clay; strong <2 mm granular or 2 to 5 mm subangular blocky; occasionally <2 to 10% ferruginous nodules 2 to 6 mm; pH 6.0 to 7.0. Sharp to abrupt change to

A12/A3: Black or brown (10YR 3/2, 3/3); light clay to light medium clay; strong 2 to 5 mm subangular blocky or polyhedral; 0 to 10% manganiferous or ferromanganiferous nodules <2 to 6 mm; occasionally <2% weathered rock fragments 2 to 6 mm; pH 6.0 to 7.0. Abrupt to clear change to

B2: Black or brown (10YR 3/2, 3/3, 5/4); light medium to medium clay; strong 2 to 5mm subangular blocky; 0 to 10% manganiferous nodule or soft segregations, <2 to 6 mm; 0 to 20% weathered rock fragments 2 to 20 mm; pH 7.0 to 8.0. Gradual to diffuse change to

B3: Brown or grey (10YR 4/2, 5/3; 2.5Y 5/2, 6/3); light clay to medium heavy clay; moderate 2 to 5 mm subangular blocky; 10 to 20% weathered rock fragments 2 to 20 mm; occasionally carbonate nodules, pH 7.5 to 8.0. Gradual to diffuse change to

C: Weathered rock.

Sites: 21, 87, 89, 98, 102, 104, 124, 125, 130, 131, 149, 152, 154, 163, 181, 195, 214, 222, 236, 263, 264, 276, 278, 300, 302, 303, 305, 312.

Analysed sites: MBS 89, BUN C2.

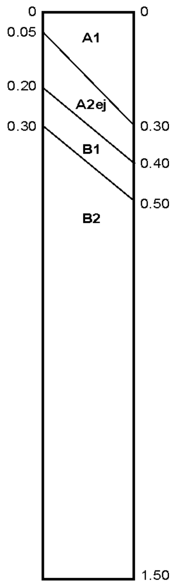
Tiaro Red variant (TaRv): Red B2 horizon. Site278.

Tiaro Rocky phase (TaRp): A1: as above, rock (C/R) within 0.3 m depth. Sites: 28, 161, 248, 270.

Timbrell (Tb)

Concept: Bleached non-cracking alkaline sodic clay on local alluvial plains.
Australian Classification: Redoxic and Oxyaquic Hydrosol, Brown Dermosol.
Great Soil Group: No suitable group, affinities with solodic soil.
Principal Profile Form: Uf6.41, Uf2, Uf3, Gn3.03, Gn3.06, Gn3.93
Surface characteristics: Hardsetting.
Geology: Quaternary Alluvium (Qa).
Landform: Alluvial plain.
Vegetation: 12 to 20 m mid-dense to dense *Eucalyptus tereticornis / Melaleuca quinquenervia /E. umbra / Lophostemon suaveolens / E. moluccana.*

Depth (m)



A1: Black or grey (10YR 3/2, 4/2, 5/2); silty clay loam, silty clay to light medium clay; moderate to strong 2 to 5mm subangular blocky or granular; none to <2% ferruginous nodules 2 to 6 mm; pH 5.5 to 6.5. Abrupt or clear change to

A2ej: Sporadically or conspicuously bleached. Mottled; silty clay loam, silty clay, light medium clay; massive to moderate 2 to 5mm subangular blocky; none to <2% ferruginous or manganiferous nodules 2 to 6 mm; pH 5.5 to 7.0. Abrupt or clear change to

B1: Occasionally mottled; grey (10YR 5/2, 6/1, 6/2; 2.5Y 6/2, 6/3); silty light clay to light medium clay; moderate to strong 2 to 5mm blocky or lenticular; none to <2% ferruginous or manganiferous nodules 2 to 6 mm; pH 6.0 to 7.5. Abrupt, clear or gradual change to

B2: Mottled; grey or brown (10YR; 2.5Y 5/1, 5/2, 5/3, 5/4, 6/2, 6/3); light medium clay to medium heavy clay; moderate to strong 2 to 10 mm lenticular or moderate to strong 10 to 100 mm prismatic structure parting to 2 to 10 mm blocky; occasional slickensides; <2 to 20% manganiferous or calcareous nodules <2 to 6 mm; pH 7.5 to 9.5.

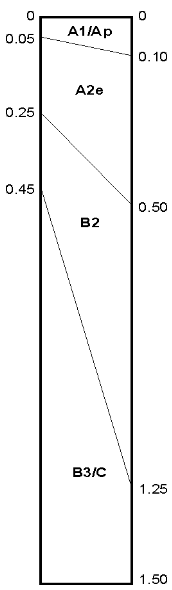
Sites: 19, 27, 35, 73, 101, 129, 150, 155, 164, 169, 325.

Analysed sites: MTL 299, GCL 9006.

Tirroan (Tr)

Concept: Sodic texture contrast soil with a bleached sandy surface over grey sandy clay subsoil on moderately weathered sandstones.
Australian Classification: Grey Sodosol or Brown Kurosol.
Great Soil Group: Soloth, rarely solodic soil.
Principal Profile Form: Dy3.41, Dy3.42
Surface characteristics: Hardsetting.
Geology: Sandstones of the Elliot Formation (Te). Tiaro Coal Measures (Jdt) and Myrtle Creek sandstone (RJdm).
Landform: Hillslopes on undulating rises and low hills.
Vegetation: 18 to 22m mid-dense, variable, *Eucalyptus acmenoides / Corymbia trachyphloia / E. umbra / E.exserta / C.intermedia / C. citriodora / Angophora leiocarpa.*

Depth (m)



A1/Ap: Black or grey (7.5YR 3/2, 4/2; 10YR 4/2); loamy sand, loamy fine sand, sandy loam; massive; pH 5.5 to 6.0. Clear change to

A2j: Conspicuously bleached. Mottled; loamy sand; massive; pH 5.5 to 6.0. Abrupt to sharp change to

B2: Mottled; grey or brown (7.5YR 4/2, 5/2, 6/1, 6/2; 10YR 5/2, 5/3, 6/2) frequently becoming paler at depth; sandy light medium clay to sandy medium heavy clay; weak to strong 10 to 50 mm prismatic or angular blocky; pH 5.0 to 6.0 rarely up to 8.0. Abrupt to gradual to change to

B3/C: Mottled; grey or brown (7.5YR 5/1, 5/2, 5/3, 6/1, 6/3; 2.5Y 6/2); sandy light medium clay to medium clay with sandstone fragments, strong 10 to 20 mm angular blocky; pH 5.0 to 6.0; or weathered rock.

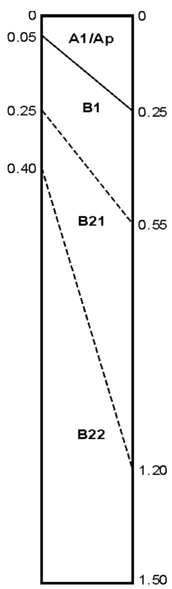
Sites: 1, 14, 30, 37, 43, 53, 99, 100, 112, 114, 132, 135, 136, 138, 160, 162, 167, 177, 219, 221, 226, 245, 277, 301, 344, 350, 351, 352, 361, 367, 377, 381.

(TrRp) Tirroan Rocky phase: Bleached Orthic Tenosol. A1/Ap/A2e: as per Tirroan. Rock encountered at less than 30 cm depth.
Sites: 46, 113, 156.

Walker (Wk)

Concept: Dark clay loam to clay surface over a mottled grey clay subsoil on alluvium of the Mary River.
Australian Classification: Grey, Brown or Black Dermosol.
Great Soil Group: Humic gley.
Principal Profile Form: Gn3.91, Gn3.92, Uf6.41, Uf6.22.
Surface characteristics: Hardsetting.
Geology: Quaternary Alluvium (Qa).
Landform: Alluvial plains.
Vegetation: Cleared.

Depth (m)



A1/Ap: Black or occasionally grey (7.5YR 2/2, 3/2, 4/2; 10YR 3/2); silty clay loam to light medium clay; moderate to strong 2 to 5 mm granular or subangular blocky; pH 6.0 to 6.5. Clear to abrupt change to

B1: Mottled; brown, black or occasionally grey (7.5YR 2/2, 3/1, 3/2; 10YR 3/2; 2.5Y 4/1); light medium clay to medium clay; strong 2 to 10 mm subangular blocky; pH 5.7 to 7.0. Gradual to diffuse change to

B21: Mottled; grey, or occasionally black (7.5YR 2/2, 4/2; 10YR 3/2, 4/1, 4/2); light medium clay to heavy clay; strong 2 to 10 mm subangular blocky; occasionally <2% manganiferous nodules <2 mm; pH 5.7 to 7.0. Gradual to diffuse change to

B22: Mottled grey (10YR 5/1, 5/2, 6/2; 2.5Y 4/1, 5/1); medium clay to heavy clay; strong 2 to 5 mm subangular blocky or lenticular; occasionally <2% manganiferous nodules <2 mm; pH 5.5 to 7.0.

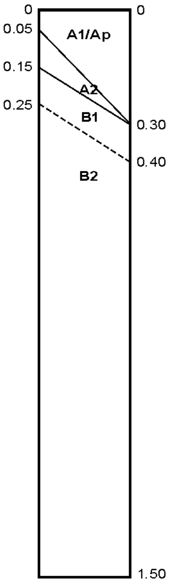
Site: 314.

Analysed site: BUN 108.

Watalgan (Wt)

Concept: Black or brown clay loam surface over a paler A2 horizon over a red structured clay subsoil on deeply weathered fine grained sedimentary rocks.
Australian Classification: Red Dermosol, Red Ferrosol.
Great Soil Group: Red podzolic soil.
Principal Profile Form: Gn3.14, Dr2.21, Gn3.11p, Uf6.31p
Surface characteristics: Hardsetting frequently ferruginous nodules 2 to 6 mm
Geology: Mudstones, siltstones, fine sandstones of the Elliot Formation (Te), Burrum Coal Measures (Kb), Maryborough Formation (Km).
Landform: Level plains to hillslopes of rises and low hills.
Vegetation: Mostly cleared. Minor 18 to 25 m mid-dense *Corymbia citriodora / Eucalyptus acmenoides /Eucalyptus siderophloia / Eucalyptus crebra.*

Depth (m)



A1/Ap: Black or brown (5YR 2/2, 3/2, 3/3; 7.5YR 2/3, 3/3, 4/3; 10YR 2/2, 2/3, 4/3, 4/4); clay loam; weak to strong 1 to 5 mm granular or cast; <2% to >50% ferruginous nodules <20 mm; pH 5 to 6. Clear to gradual change to

A2: Occurs in undisturbed soils. Red or brown (2.5YR 3/3, 4/3, 5YR 4/3, 4/4, 4/6, 7.5YR 4/4, 10YR 4/3, 4/4); clay loam, weak or moderate 2 to 5 mm granular or subangular blocky; <2 to >50% ferruginous nodules <20 mm; pH 5.5 to 6.0. Clear to gradual change to

B1: Red (10R 4/4; 2.5YR 3/4, 4/4, 4/6; 5YR 4/4, 4/6, 5/4, 6/3); light clay; moderate or strong 2 to 5 mm subangular blocky or polyhedral; <2 to >50% ferruginous nodules < 20 mm; pH 5.5 to 6.0. Gradual to diffuse change to

B2: Red (10R 3/6, 4/4, 4/6; 2.5YR 3/4, 3/6, 4/4 4/6, 4/8; 5YR 4/6, 4/8); light clay to medium clay; strong 2 to 5 mm polyhedral; <2 to 50% ferruginous nodules <20 mm; pH 5.5 to 6.3.

Sites: 111, 200.

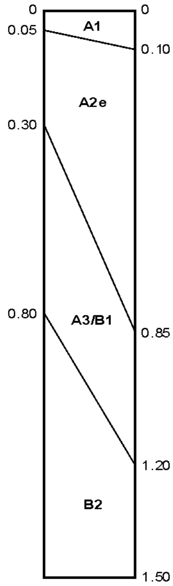
Analysed sites: BUN 3, 112, MBS 4, 5, 28, MTL9001

Watalgan Mottled variant (WtMv): Same as above but with a mottled B2. Analysed sites: BUN 115, 123.

Winfield (Wf)

Concept: Bleached, massive grey sand on deeply weathered coarse grained sedimentary rocks.
Australian Classification: Bleached-Orthic Tenosol, Redoxic Hydrosol.
Great Soil Group: (Bleached) earthy sand.
Principal Profile Form: Uc2.23, Uc2.22
Surface characteristics: Loose.
Geology: Myrtle Creek Sandstone (RJdm), Elliot Formation (Te).
Landform: Gently undulating hillslopes and level plains.
Vegetation: 10 to 18 m mid-dense *Eucalyptus umbra / Corymbia trachyphloia / C. intermedia / Eucalyptus hallii.*

Depth (m)



A1: Grey or occasionally black (7.5YR 3/1, 4/1, 4/2; 10YR 4/1, 5/1); sand to loamy sand; single grain or massive; pH 5.0 to 6.0. Clear to gradual change to

A2e: Conspicuously bleached. Sand to loamy sand; single grain or massive; pH 5.5 to 6.0. Diffuse change to

A3/B1: Mottled; grey, brown or yellow (7.5YR 5/3; 10YR 7/3, 7/4); loamy sand to sandy loam; massive; pH 5.5 to 6.0. Diffuse change to

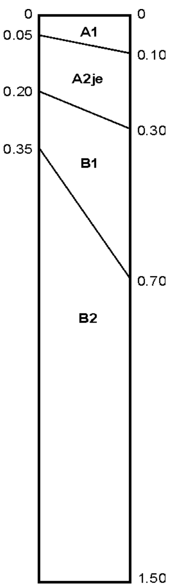
B2: Mottled; grey (7.5YR 6/3; 10 YR 7/2, 8/3); loamy sand to sandy loam; massive; pH 5.5 to 6.0.

Sites: 47, 360, 370.

Woober (Wb)

Concept: Bleached non-cracking acid clay on local alluvial plains.
Australian Classification: Redoxic Hydrosol.
Great Soil Group: No suitable group, affinities with soloth.
Principal Profile Form: Uf2, Uf3, Gn3.04, Gn3.05
Surface characteristics: Hardsetting.
Geology: Quaternary Alluvium (Qa).
Landform: Alluvial plain.
Vegetation: 12 to 20 m mid-dense to dense *Eucalyptus tereticornis / Melaleuca quinquenervia / E. umbra / Lophostemon suaveolens / E. moluccana / E. crebra.*

Depth (m)



A1: Dark or grey (7.5YR 2/1, 3/2, 4/2; 10YR 2/1, 3/2, 4/2, 5/2); silty loam, clay loam, silty clay to light medium clay; massive or weak 2 to 5 mm cast or granular; pH 5.0 to 6.5. Clear change to

A2je: Sporadically or conspicuously bleached. Mottled silty loam, clay loam, silty clay, light medium clay; massive; pH 5.5 to 6.0. Clear change to

B1: Mottled; grey (7.5YR, 10YR 5/2, 6/1, 6/2; 2.5Y 6/2, 6/3); light clay to light medium clay; moderate 10 to 20 mm angular blocky; pH 5.0 to 6.0. Clear to gradual change to

B2: Mottled; grey or brown (7.5YR 5/1, 5/2, 6/2; 10YR 5/1, 5/2, 5/3, 6/2; 2.5Y 5/2, 5/3, 6/2); light medium clay to medium heavy clay; strong 10 to 50 mm angular blocky or prismatic or 2 to 10 mm lenticular; occasional slickensides; pH 5.5 to 7.0.

Sites: 24, 25, 74, 168, 170, 241, 244, 281, 326, 327, 328, 331, 332, 333, 335, 336, 353, 362, 369, 372, 376, 380.

Analysed site: GCL 9004.

APPENDIX II

A key to the soils of the Gundiah–Curra study area

In classifying the soil profile, it is necessary to identify various horizons and materials. All terms used in the key are consistent with those defined by Isbell (1996), McDonald *et al.* (1990) or else as defined in the glossary at end of key (indicated by *).

To identify a soil at any site, the following procedure should be adopted:

1. Work successively through the key stepwise and select the first Australian soil Classification Order (eg. **PODOSOLS, VERTOSOLS** etc.) is indicative of that the soil being studied.
2. Select the appropriate soil landscape unit (ie. indicated by •••)
3. Then select the soil attributes that best describe the soil (ie. indicated by ••)

A. ***Soils that have a Bhs* or Bh* horizon.***

⇒ **PODOSOLS**

••• Soils on moderately weathered coarse grained sedimentary rock……………...……...	•• Presence of a Bhs ……	……………………………	• **Rothchild** (Rt)
	•• Bh horizon ....…………	……………………………	• **Rothchild podosolic variant** (RtPv)

****

B. Soils with:

1. a clay field texture or 35% or more clay in all horizons; and

2. unless wet, have open cracks at some time in most years which are at least 5 mm wide and extend upward to the surface or to the base of any plough layer, or thin surface horizon (eg. self mulch layer); and

3. at some depth in the profile have slickensides* and/or lenticular peds*.

⇒ **VERTOSOLS**

••• Soils on alluvial plains or swamps of local creeks.....………..	•• Black coloured upper B horizon and black lower B horizon ………………………	…………………………..	• **Pelion dark variant** (PeDv)
	•• Grey coloured lower B horizon ……………...	…………………………..	• **Pelion** (Pe)
••• Soils on alluvial plains of the Mary River ………………...	•• Alkaline (pH >7.0), black upper B subsoil …………….	…………………………..	• **Miva** (Mv)
	•• Alkaline (pH >7.0), grey or brown upper B horizon …….	…………………………..	• **Mungar** (Mg)
	•• Acid (pH <7.0) subsoil……	…………………………..	• **Granville** (Gr)
••• Soils on moderately weathered sedimentary rock …….	•• Brown or grey acid (pH <5.5) clay ……………….……...	…………………………..	• **Bucca** (Bc)

****

C. Soils in which the greater part of the profile is saturated for at least 2–3 months in most years.

⇒ HYDROSOLS

••• Soils on deeply weathered sedimentary rock	•• Sandy* A horizon ……...	• Uniform sandy* profile (sand to sandy loam throughout) …………………	• **Winfield** (Wf)
		• Sodic clay B horizon at >0.5 m.…...………………..	• **Robur** (Rb)
		• Non – sodic, clay B subsoil	• **Alloway** (Al)
••• Soils on alluvium ..	•• Along the Mary River ….	• Loamy* surface texture with a bleached A2 over a grey or brown clay……..…	• **Butcher** (Bt)
		• Acid (pH <7) clay soil with a sporadically bleached A2j subsoil………………..…..	• **Granville** (Gr)
		• Alkaline (pH >7.0) clay subsoil ……………….…...	• **Mungar** (Mg)
		• Black loamy* or clay surfaced gradational or uniform soil with an acid (pH <7.0), mottled, grey clay ….	• **Walker** (Wk)
	•• Along local creeks............	• Sandy* or loam* surface with a bleached A2 horizon over a sodic clay …….…….	• **Peep** (Pp)
		• Silty clay loam to clay surface with a bleached A2 horizon over an acid (pH <7.0), sodic clay.……...	• **Woober** (Wb)
		• Silty clay loam to clay surface with a bleached subsurface over an alkaline, sodic clay ……………………	• **Timbrell** (Tb)
	•• On alluvial fans ………...	• Grey, alkaline (pH >7.0) subsoil ……..….………...	• **Gutchy** (Gy)

****

D. ***Soils with a clear or abrupt textural B horizon* in which the major part of the upper 0.2 m of the B2 horizon has a pH < 5.5.***

⇒ KUROSOLS

••• Soils on moderately weathered sedimentary rock …….	•• Sandy* surface soil ..……	....	• **Tirroan** (Tr)
	•• Loamy* surface soil over a grey or brown clay with red mottles.....…………………..	• No rock before 0.3m depth	• **Kolan** (Ko)
		• Rock before 0.3m or >20% coarse fragments in the surface soil..........…………..	• **Kolan rocky phase** (KoRp)
	•• Loamy* surface soil over a red clay subsoil with grey mottles ……………………...	………………………………	• **Kolan red variant** (KoRv)
••• Soils on alluvium ..	•• Local creeks only ……….	………………………………	• **Peep** (Pp)

****

E. ***Soils with a clear or abrupt textural B horizon* in which the major part of the upper 0.2 m of the B2 horizon has a pH ≥ 5.5 and is sodic (ESP*≥ 6).***

⇒ SODOSOLS

••• Soils on phyllite ...	•• Loamy* A horizon ……...	………………………………	• **Beenham** (Bh)
••• Soils on microdiorite ………….	•• Sandy* surface soil…….....	………………………………	• **Gigoon** (Gn)
	•• Loamy* surface soil……..	………………………………	• **Doongul** (Do)
••• Soils on moderately weathered andesite…...…………..	•• Loamy* surface soil..……	………………………………	• **Owanyilla** (Ow)
••• Soils on moderately weathered sedimentary rock …....	•• Sandy* surface soil……...	………………………………	• **Tirroan** (Tr)
	•• Loamy* surface soil.……	• Brown or yellow clay subsoil , pH>6.0……….	• **Givelda** (Gv)
		• Grey or brown clay subsoil, pH < 6.0 …………...	• **Kolan** (Ko)
••• Soils on deeply weathered sedimentary rock ....…...........	•• Sandy* A surface soil.…..	• The A horizon ≥0.5 m ..….	• **Robur** (Rb)
••• Soils on alluvium	•• Along the Mary River…..	• Sandy* surface………….	• **Butcher sandy variant** (BtSv)
		• Loamy* surface………….	• **Butcher** (Bt)
	•• Along local creeks ……...	……………………………...	• **Peep** (Pp)

****

F. Soils with a clear or abrupt textural B horizon* in which the major part of the upper 0.2 m of the B2 horizon has a pH ≥ 5.5 and is not sodic (ESP* < 6).

⇒ CHROMOSOLS

••• Soils on phyllite…	•• Loamy* A horizon ……..	………………………………	• **Beenham** (Bh)
••• Soils on deeply weathered sedimentary rock …………………	•• Sandy* A horizon	• >10% cobbles or stones (>0.06 m) on the surface; or rock before 0.6 m…………...	• **Isis rocky phase** (IsRp)
		• Grey or pale yellow subsoil	• **Alloway** (Al)
	•• Loamy* A horizon..........	• Yellow or brown subsoil…	• **Isis** (Is) • **Kepnock** (Kp)

****

G. Soils with B2 horizons in which the major part* has a free iron oxide content greater than 5% Fe in the fine earth fraction (<2 mm) (Usually soils developed from basic rocks such as Basalt or Andesite). Soil profiles with B2 horizons in which at least 0.3 m has vertic properties* are excluded.

⇒ FERROSOLS

••• Soils on deeply weathered andesite …..	•• Red B2 horizon with strong polyhedral structure....	………………………………	• **Bidwill** (Bd)
••• Soils on deeply weathered sedimentary rock…………………...	•• Red B2 horizon with strong polyhedral structure…	• B2 horizon is mottled ……	• **Watalgan mottled variant** (WtMv)
		• B2 horizon is whole coloured ……………………	• **Watalgan** (Wt)

****

***H. Soils, with B2 horizons that have structure more developed than weak* throughout the major part of* **the horizon.**

⇒ DERMOSOLS

••• Soils on phyllite…	•• Clay loam or clay surface	………………………………	• **Neerdie** (Nd)
	•• Loamy* surface ……..….	………………………………	• **Beenham** (Bh)
••• Soils on moderately weathered andesite or microdiorite	•• Sporadically bleached subsurface……..…………...	• Brown or grey B2 horizon, mottled at depth …………….	• **Netherby** (Nb)
	•• Bleached subsurface…...	• Black or brown subsoil…..	• **Tiaro** (Ta)
		• Red subsoil……………..	• **Tiaro red variant** (TaRv)

••• Soils on deeply weathered andesite…...	•• Loamy* to clay surface.	• Mottled, brown or yellow subsoils with manganiferous nodules…………………	• **Jumpo** (Jp)
••• Soils on moderately weathered sedimentary rock	•• Grey or brown acid (pH<5.5) clay………………	………………………………	• **Bucca** (Bc)
••• Soils on deeply weathered sedimentary rock...........................	•• Sandy* surface ..……….	• Mottled, yellow or brown subsoil ……………………	• **Isis** (Is)
	•• Loamy* surface…...…….	• Mottled red subsoil……..	• **Watalgan mottled variant** (WtMv)
		• Red subsoil.........……….	• **Watalgan** (Wt)
		• Yellow or brown subsoil ..	• **Kepnock** (Kp)
••• Soils on alluvium of the Mary River…….	•• Sporadically bleached subsurface…..…………..	• Acid (pH<6.5), grey or brown mottled, upper B2 horizon……………………...	• **Granville** (Gr)
		• Alkaline (pH>6.5), grey or brown subsoil………………	• **Mungar** (Mg)
		• Alkaline (pH >6.5), black upper B2 horizon …..……….	• **Miva** (Mv)
	•• Bleached subsurface is absent …………………….....	• Red clay subsoil…………	• **Aldershot** (Ad)
		• Black or brown loamy* subsoil ……………………...	• **Copenhagen** (Co)
		• Mottled, grey clay subsoil	• **Walker** (Wk)
		• Brown clay subsoil …..…	• **Mary** (My)
		• Black clay subsoil ………	• **Mary dark variant** (MyDv)
••• Soils on alluvium of local creeks ……….	………………………………	• Alkaline (pH >7.0)subsoil	• **Timbrell** (Tb)
••• Soils on alluvial fans …………………..	………………………………	• Black or grey, clay……..	• **Gutchy** (Gy)

****

I. Soils which have:

1. well-developed B2 horizons in which the major part is massive* or has only a weak* grade of structure; and

2. a maximum clay content in some part of the B2 horizon which exceeds 15% (ie. > sandy loam).

⇒ KANDOSOLS

••• Soils on deeply weathered sedimentary rock…………………...	•• Sandy* surface ..…..…….	••Red subsoil …………….	• **Farnsfield** (Ff)
••• Soils on alluvium...	•• Along the Mary River…...	………………………………	• **Copenhagen** (Co)
	•• Along local creeks ..…….	………………………………	• **Littabella** (Lt)

****

J. Soils with negligible (rudimentary) pedological organisation apart from minimal development of an A1 horizon, or the presence of less than 10% of B horizon material in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the A1 horizon. There is little or no texture or colour change with depth unless stratifed or buried soils are present.

⇒ RUDOSOLS

••• Soils on alluvium	•• Along the Mary River ...	• >10% gravels, cobbles or stones (>0.02 m) on the surface; or rock before 0.4 m	• **Johnson** (Js)
		• Sandy* soil with obvious buried alluvial layers………..	• **Baddow** (Ba)
••• Soils on deeply weathered sedimentary rock …………………..	………………………………	• >10% cobbles or stones (>0.06 m) on the surface; or rock before 0.6 m……	• **Isis Rocky Phase** (IsRp)

****

K. Other soils with only weak* pedological organization apart from the A horizons. This group differs from Rudosols because A1 horizons are more than weakly developed, and horizon or weakly developed B horizon may be present.

⇒ TENOSOLS

••• Soils on moderately weathered andesite or microdiorite	•• Black clay surface over rock within 0.3 m; surface stones and boulders frequently present…………...	....	• **Tiaro rocky phase** (TaRp)
••• Soils on moderately weathered sedimentary rock .……	•• Sandy* A horizon……….	•• Rock before 0.3 m……..	• **Tirroan rocky phase** (TrRp)
••• Soils on deeply weathered sedimentary rock ………………….	•• Sandy* surface with a bleached A2 horizon ……….	•• >10% cobbles or stones (>0.06 m) on the surface; or rock before 0.6 m…………...	• **Isis rocky phase** (IsRp)
		•• Sandy* subsoil…………..	• **Winfield** (Wf)
		•• Sandy* brown or yellow subsoil …..……………..…	• **Rothchild** (Rt)
••• Soils on alluvium ..	•• Along the Mary River…...	•• >10% gravels, cobbles or stones (>0.02 m) on the surface; or rock before 0.4 m.	• **Johnson** (Js)
	•• Along local creeks …..…	•• Sandy* soil……………...	• **Littabella** (Lt)

****

Glossary

Bh horizons — Organic-aluminium compounds are strongly dominant with little or no evidence of iron compounds. Colours are usually dark with values <4 and chromas <3.

Bhs horizons — Iron and organic compounds are both present. Colours usually have a hue of 2.5YR to 10YR, and value/chroma of 3/3, 3/4, 3/6, 4/3 or 4/4 (see next page)

Clear or abrupt textural B horizons — The boundary between the horizon and the overlying horizon is clear, abrupt or sharp (<50 mm) and is followed by a clay increase (usually 20% increase) giving a strong texture contrast.

ESP — Exchangeable sodium percentage (exch Na/CEC x 100%)

Lenticular peds — Natural soil aggregates (ped) which are arranged around elliptical planes and are bounded by curved faces with acute vertices (angles <90^{o}). See McDonald *et al.* (1990) pp 130–132.

Loamy — Soil textures from the range fine sandy loam to clay loam fine sandy, (i.e. loamy and clay loamy texture ranges of Isbell (1996)).

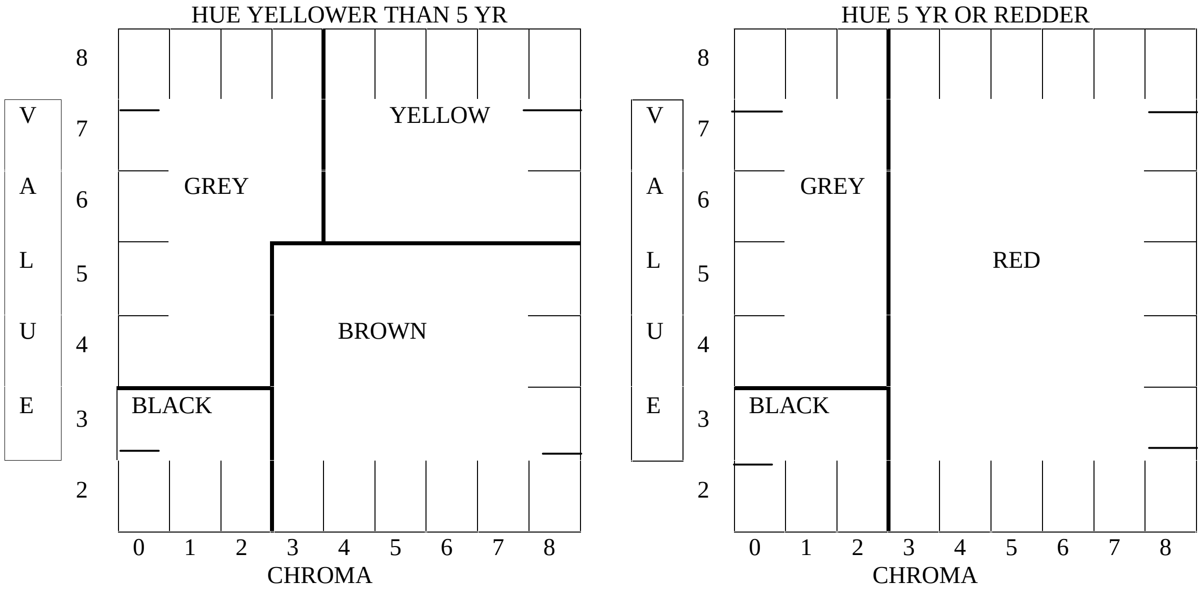
Massive — Soil material acts as a coherent mass (ie. >70% remains united) which is largely devoid of peds.

Sandy — Soil textures from the range sand to sandy loam (ie. sandy texture range of Isbell (1996)).

Slickensides — Polished, stress cutans with grooved or striated surfaces that are produced by one soil mass regularly sliding past another. (ie. coarse lenticular peds in a shrink-swell clay).

Weak grade of structure — Peds are indistinct and barely observable in undisplaced soil. When displaced, less than one-third of the soil material consists of peds.

Soil colour class limits



APPENDIX III

Morphological and analytical data for representative profiles 9000-9009

Soil Type: Aldershot (Ad)
Site No: 9000
A.M.G. Reference: 449748mE 7121097mN ZONE 56
Parent material: Quaternary Pleistocene alluvium (Qpa)
Australian Soil Classification: Haplic, Eutrophic, Brown, DERMOSOL.
Great Soil Group: No suitable group
Principle Profile Form: Gn3.15
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 1 %
Landform element type: Terrace flat
Landform pattern type: Terraced land
Vegetation: Cleared

Profile morphology:

Horizon	**Depth (m)**	**Description**
A1	0.00 to 0.15	Very dark greyish brown (10YR 3/2); clay loam, fine sandy; weak 2–5 mm subangular blocky structure; moderately moist weak strength; gradual change to
A2	0.15 to 0.26	Dark greyish brown (10YR 4/2); heavy clay loam, fine sandy; weak 2–5 mm subangular blocky structure; moderately moist firm strength; clear change to
B1	0.26 to 0.42	Dark brown (7.5YR 3/2); fine sandy light clay; moderate 10–20 mm prismatic structure; very few <2% fine <2 mm manganiferous soft segregations; dry firm strength; gradual change to
B21	0.42 to 0.75	Dark brown (7.5YR 3/4); light medium clay; moderate 20–50 mm prismatic structure; very few <2% fine <2 mm manganiferous soft segregations; dry very firm strength; diffuse change to
B22	0.75 to 1.21	Reddish brown (5YR 4/4); sandy light medium clay; moderate 20–50 mm prismatic structure; very few <2% fine <2 mm manganiferous soft segregations; dry very firm strength; clear change to
C	1.21 to 1.45	Strong brown (7.5YR 4/6); sandy clay loam; weak 20–50 mm prismatic structure; dry weak strength.

				Particle size					Exchangeable (Aqueous cations)							BAR	Disp.	Total element			
	mS/cm		%	%	%	%	%	%			meq%					%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	pH
B0–0.10	6.4	0.03	.0001						10	4.7	4.3	0.05	0.63								5.1
0–0.10	6.0	0.03	.003	3.94	14	41	23	21	11	5.3	4.7	0.11	0.44			13	0.62	0.047	1.374	0.009	4.8
0.25–0.35	6.5	0.01	.0001	5.44	12	43	22	23	11	5.6	5.4	0.13	0.10			12	0.71	0.029	1.327	<0.005	5.0
0.50–0.60	7.3	0.02	.0001	4.79	11	44	16	32	12	5.1	7.0	0.24	0.08			13	0.72	0.017	1.394	<0.005	5.9
0.80–0.90	7.6	0.03	.002	4.06	17	42	9	28	11	4.2	6.5	0.34	0.08			13	0.89	0.012	1.532	<0.005	6.3
1.10–1.20	7.8	0.02	.0001	3.10	25	43	8	23	10	3.7	6.0	0.30	0.08					0.013	1.731	<0.005	6.4

			Extract P		Repl	DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg		
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn
B0–0.10	2.1	0.17	27	36	0.5	50	36	1.3	4.2

Soil Type: Miva (Mv)
Site No: 9001
A.M.G. Reference: 451304mE 7124416mN ZONE 56
Parent material: Quaternary Pleistocene alluvium (Qpa)
Australian Soil Classification: Vertic, Calcic, Brown, DERMOSOL
Great Soil Group: No suitable group
Principle Profile Form: Uf6.32
Type of Microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 0 %
Landform element type: Terrace flat
Landform pattern type: Terraced land
Vegetation: Cleared

Profile Morphology:

Horizon	**Depth (m)**	**Description**
Ap	0.00 to 0.16	Dark greyish brown (10YR 4/2); light clay; moderate 2–5 mm subangular blocky structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength; abrupt change to
B1	0.16 to 0.45	Dark brown (7.5YR 3/2); light medium clay; strong 2–5 mm subangular blocky structure; few 2–10% fine <2 mm manganiferous nodules; moderately moist firm strength; diffuse change to
B21	0.45 to 0.72	Dark yellowish brown (10YR 4/4); medium clay; strong 2–5 mm subangular blocky structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength; gradual change to
B22	0.72 to 1.04	Dark yellowish brown (10YR 4/4); medium clay; moderate 2–5 mm angular blocky structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength; diffuse change to
B23	1.04 to 1.38	Brown (10YR 4/3); medium clay; strong 2–5 mm lenticular structure; very few <2% medium 2–6 mm calcareous soft segregations; moderately moist weak strength; common prominent stress cutans; diffuse change to
B3K	1.38 to 1.50	Brown (10YR 4/3); medium clay; strong 2–5 mm lenticular structure; few 2–10% medium 2–6 mm calcareous soft segregations; moderately moist firm strength; common prominent stress cutans.

						Particle size				Exchangeable (Alcoholic cations)						BAR	Disp.	Total element			
	mS/cm		%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	CEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	PH
B0–0.10	6.4	0.03	0.001						21	4.5	9.0	0.40	0.72								5.1
0.00–0.10	6.3	0.04	0.003	8.2	12	17	39	31	22	4.5	8.0	0.39	0.53			18	0.69	0.045	0.969	0.007	5.0
0.20–0.30	7.3	0.04	0.003	10.5	7	16	33	48	26	6.4	15	1.5	0.15			22	0.80	0.022	0.862	<0.005	5.8
0.50–0.60	8.2	0.22	0.026	11.3	3	13	30	56	26	5.6	19	3.1	0.10			23	0.86	0.010	0.873	<0.005	6.7
0.80–0.90	9.0	0.57	0.060	11.4	3	17	30	55	25	5.3	19	4.0	0.09			22	0.84	0.011	0.871	<0.005	7.6
1.10–1.20	9.1	0.66	0.073	10.2	2	17	31	53	26	5.2	20	5.2	0.12					0.011	0.906	<0.005	7.8
1.40–1.50	9.2	0.65	0.066						27	5.6	20	5.1	0.11								7.6

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	2.18	0.21	6	16	0.5	72	58	2.1	1.6	5.1

Soil Type: Owanyilla (Ow)
Site No: 9002
A.M.G. Reference: 452764mE 7124287mN ZONE 56
Parent material: Andesite of the Grahams Creek Formation (JKg)
Australian Soil Classification: Eutrophic, Subnatric, Brown, SODOSOL
Great Soil Group: Solodic
Principle Profile Form: Dy3.42
Type of Microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 3 %
Landform element type: Hillslope
Landform pattern type: Rises
Vegetation: Very tall open woodland (20–35m) of *Eucalyptus tereticornis* (forest red gum)

Horizon	Depth (m)	Description
A1	0.00 to 0.07	Very dark greyish brown (10YR 3/2); loam, fine sandy; massive structure; few 2– 10% fine <2 mm ferruginous nodules; dry very weak strength; clear change to
A2e	0.07 to 0.16	Dark greyish brown (10YR 4/2); fine sandy clay loam; massive structure; few 2–10% fine <2 mm ferruginous nodules; dry very weak strength; abrupt change to
B21	0.16 to 0.36	Brown (10YR 5/3); few 2–10% fine <5 mm distinct orange mottles; medium clay; very few <2% andesite small pebbles 2–6 mm; moderate 2–5 mm subangular blocky structure; few 2–10% fine <2 mm ferruginous nodules; dry strong strength; gradual change to
B22	0.36 to 0.71	Light brownish grey (10YR 6/2); common 10–20% medium 5–15 mm distinct orange mottles; light medium clay heavy; very few <2% andesite small pebbles 2–6 mm; moderate 10–20 mm prismatic structure; few 2–10% fine <2 mm ferruginous nodules; dry very firm strength; diffuse change to
B3	0.71 to 0.94	Pale brown (10YR 6/3); few 2–10% medium 5–15 mm distinct orange mottles; medium clay; common 10–20% andesite small pebbles 2–6 mm; moderate 2–5 mm subangular blocky structure; few 2–10% fine <2 mm ferruginous nodules; dry very firm strength; sharp change to
R	0.94 to 1.00	Rock.

				Particle size					Exchangeable Cations (Aqueous cations)							BAR	Dispersion	Total element			
	mS/cm		%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	PH
B0–0.10	6.5	0.03	0.001						10	5.3	3.8	0.14	0.41								5.2
0–0.10	5.9	0.03	0.001	3.63	16	44	25	14	6	2.9	2.9	0.18	0.27			12	0.60	0.030	0.314	0.009	4.8
0.20–0.30	6.6	0.06	0.006	11.9	22	15	11	53	16	3.8	11	1.5	0.09			24	0.80	0.021	0.188	<0.005	5.4
0.50–0.60	6.8	0.20	0.028	11.1	27	15	10	48	19	4.1	12	2.7	0.07			24	0.88	0.017	0.441	<0.005	6.0
0.80–0.90	6.6	0.33	0.045	10.3	29	18	12	43	21	4.1	13	3.5	0.05			22	0.93	0.017	0.633	<0.005	5.9

			Extract P		Repl	DTPA Extractable				
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	**Org C**	**Tot N**	**Acid**	**Bic**	**K**	**Fe**	**Mn**	**Cu**	**Zn**	**SO4-S**
B0–0.10	3.1	0.26	10	20	0.3	109	60	0.3	1.1	2.7

Soil Type: Pelion dark variant (PeDv)
Site No: 9003
A.M.G. Reference: 453431mE 7127469mN ZONE 56
Parent Material: Quaternary alluvium (Qa)
Australian Soil Classification: Endocalcareous - Endohypersodic, Self-mulching, Black, VERTOSOL
Great Soil Group: Black earth
Principle Profile Form: Ug5.24
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Periodic cracking, self-mulching

Slope: 0%
Landform element type: Plain
Landform pattern type: Alluvial plain
Vegetation: Very tall open woodland (20–35m) of *Eucalyptus tereticornis* (forest red gum)

Profile Morphology:

Horizon	Depth (m)	Description
A1	0.00 to 0.05	Very dark greyish brown (10YR 3/2); light clay; strong 2–5 mm subangular blocky structure; dry firm strength;
B1	0.05 to 0.25	Dark grey (10YR 4/1); light clay; strong 2–5 mm lenticular structure; moderately moist very firm strength; few faint slickensides;
B21	0.25 to 0.60	Very dark grey (10YR 3/1); medium clay; strong 2–5 mm lenticular structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength; few distinct slickensides;
B22	0.60 to 0.70	Dark grey (2.5Y 4/1); medium clay; strong 2–5 mm lenticular structure; very few <2% fine <2 mm manganiferous nodules; moderately moist weak strength; few distinct slickensides;
B23	0.70 to 1.50	Very dark grey (10YR 3/1); very few <2% medium 5–15 mm distinct brown mottles; light medium clay; moderate 20–50 mm prismatic structure; very few <2% medium 2–6 mm calcareous soft segregations; moderately moist weak strength;
B3	1.50 to 1.70	Dark grey (N40); few 2–10% medium 5–15 mm distinct brown, very few <2% medium 5–15 mm faint gley mottles; medium clay; moderate 20–50 mm prismatic structure; very few <2% medium 2–6 mm calcareous soft segregations; moderately moist firm strength.

				Particle size					Exchangeable (Alcoholic cations)							BAR	Disp.	Total element			
		mS/cm	%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	CEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	pH
B0–0.10	6.1	0.09	0.007						43	14	12	1.2	0.78								5.2
0–00.10	6.4	0.11	0.010	12.5	8	10	24	53	47	17	16	1.4	0.74			29	IS	0.084	0.715	0.027	5.6
0.15–0.25	6.7	0.11	0.011	16.2	6	6	18	68	44	18	18	2.3	0.23			33	IS	0.043	0.540	0.013	5.8
0.50–0.60	7.2	1.26	0.143	6.45	5	8	18	67	47	19	24	5.6	0.41			31	0.79	0.023	0.548	0.012	6.7
0.80–0.90	8.1	2.00	0.247	7.52	3	6	15	71	46	19	29	7.7	0.23			31	0.80	0.016	0.465	0.026	7.6
1.10–1.20	8.3	2.09	0.237	5.71	8	9	21	60	43	16	26	6.8	0.48					0.020	0.462	0.025	7.8
1.40–1.50	8.5	1.88	0.226						39	14	25	6.5	0.33								7.9

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	4.57	0.34	54	110	0.50	149	76	0.9	4.7	12

Soil Type: Woober (Wb)
Site No: 9004
A.M.G. Reference: 456036mE 7119279mN ZONE 56
Parent Material: Quaternary alluvium (Qa)
Australian Soil Classification: Magnesic-Natric, Dermosolic, Redoxic, HYDROSOL
Great Soil Group: No suitable group
Principle Profile Form: Gn3.04
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 1%
Landform element type: Plain
Landform pattern type: Alluvial plain
Vegetation: Cleared

Profile Morphology:

Horizon	Depth (m)	Description
A1	0.00 to 0.13	Dark greyish brown (10YR 4/2); few 2–10% fine <5 mm distinct orange mottles; silty clay loam; moderate 2–5 mm subangular blocky structure; dry weak strength; abrupt change to
A2e	0.13 to 0.27	Greyish brown (10YR 5/2); few 2–10% fine <5 mm faint orange mottles; silty clay loam; massive structure; very few <2% fine <2 mm manganiferous nodules; dry firm strength; clear change to
B1	0.27 to 0.41	Light yellowish brown (2.5Y 6/4); common 10–20% medium 5–15 mm distinct dark, few 2–10% fine <5 mm distinct orange mottles; silty light clay; moderate 2–5mm subangular blocky structure; common 10–20% fine <2 mm manganiferous nodules; dry strong strength; gradual change to
B21	0.41 to 0.68	Light yellowish brown (2.5Y 6/4); common 10–20% medium 5–15 mm distinct orange mottles; medium clay; moderate 20–50 mm prismatic structure; very few <2% fine <2 mm manganiferous nodules; moderately moist very firm strength; few prominent slickensides; diffuse change to
B22	0.68 to 1.04	Light brownish grey (2.5Y 6/3); common 10–20% medium 5–15 mm distinct orange, very few <2% medium 5–15 mm prominent red mottles; medium clay; very few <2% angular sandstone small pebbles 2–6 mm; strong 20–50 mm prismatic structure; moderately moist firm strength; gradual change to
B3	1.04 to 1.50	Grey (2.5Y 6/1); few 2–10% fine <5 mm distinct orange mottles; light medium clay; few 2–10% angular sandstone medium pebbles 6–20 mm; moderate 5–10 mm angular blocky structure; moderately moist firm strength.

				Particle size					Exchangeable (Aqueous cations)							BAR	Disp.	Total element			
		mS/cm	%	%	%	%	%	%				meq%				%	Ratio	%0	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	pH
B0–0.10	5.9	0.10	0.011						10	3.4	5.6	0.71	0.44								4.8
0–00.10	5.7	0.14	0.014	1.60	7	34	31	27	10	3.0	6.0	1.0	0.38			14	0.89	0.029	0.429	0.014	4.8
0.15–0.25	6.3	0.17	0.020	1.42	7	37	31	27	11	2.0	7.0	1.9	0.13			12	0.77	0.017	0.372	<0.005	5.0
0.50–0.60	5.9	0.94	0.130	2.60	3	30	23	47	25	1.0	13	11	0.23			20	0.96	0.009	0.424	0.011	5.2
0.80–0.90	5.5	1.14	0.164	3.22	<1	28	24	46	35	1.2	19	15	0.33			22	0.99	0.009	1.076	<0.005	4.9
1.10–1.20	5.6	0.91	0.129	3.27	7	28	31	33	35	1.3	19	15	0.30					0.023	1.260	<0.026	5.0
1.40–1.50	5.9	0.85	0.120						32	1.4	18	13	0.26								5.2

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	2.54	0.12	14	18	0.30	172	36	0.8	1.5	13

Soil Type: Baddow (Ba)
Site No: 9005
A.M.G. Reference: 449707mE 7130105mN ZONE 56
Parent material: Quaternary Holocene alluvial sand (Qha1, Qha2)
Australian Soil Classification: Stratic, RUDOSOL
Great Soil Group: Alluvial soil
Principle Profile Form: Uc5.11
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Loose

Slope: 5%
Landform element type: Scroll
Landform pattern type: Flood plain
Vegetation: Cleared

Profile Morphology:

Horizon	**Depth (m)**	**Description**
A1	0.00 to 0.12	Yellowish brown (10YR 5/4); loamy sand; single grain structure; moist very weak strength; gradual change to
C	0.12 to 0.77	Dark yellowish brown (10YR 4/4); sand; single grain structure; dry loose strength; clear change to
D1	0.77 to 1.08	Dark yellowish brown (10YR 4/4); sandy loam; massive structure; dry weak strength; clear change to
D2	1.08 to 1.20	Dark yellowish brown (10YR 4/4); loamy fine sand; single grain structure; dry very weak strength; clear change to
D3	1.20 to 1.45	Dark yellowish brown (10YR 4/4); fine sand; single grain structure; dry loose strength.

				Particle size					Exchangeable (Aqueous cations)							BAR	Disp.	Total element			
	mS/cm		%	%	%	%	%	%		meq%						%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Ex Acid	15	R1	P	K	S	PH
B0–0.10	6.2	0.05	0.002						8	4.3	3.0	0.03	0.74								5.5
0–0.10	6.2	0.04	0.002	0.8	50	37	8	4	8	4.0	2.9	0.03	0.51			5.8	0.11	0.039	1.773	<0.005	5.4
0.20–0.30	6.3	0.04	0.001	0.9	66	26	5	4	6	3.5	2.6	0.03	0.29			4.6	<0.10	0.031	1.894	<0.005	5.5
0.50–0.60	6.4	0.03	0.002	0.9	57	33	7	3	6	3.3	2.5	0.05	0.23			4.8	0.11	0.029	1.867	<0.005	5.6
0.80–0.90	6.8	0.03	0.001	1.22	23	55	10	12	9	5.2	3.8	0.09	0.32			7.1	0.75	0.033	1.668	<0.005	5.6
1.10–1.20	7.0	0.02	<0.0001	1.47	49	38	7	5	8	4.4	3.4	0.05	0.18					0.031	1.808	<0.005	5.8
1.35–1.45	7.0	0.02	<0.0001						6	3.3	2.7	0.05	0.10								5.9

			Extract P		Repl	DTPA Extractable				
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	0.83	0.05	130	75	0.7	72	13	1.1	1.3	2.5

Soil Type: Timbrell (Tb)
Site No: 9006
A.M.G. Reference: 448120mE 7133220mN ZONE 56
Parent material: Quaternary alluvium (Qa)
Australian Soil Classification: Natric, Dermosolic, Redoxic, HYDROSOL
Great Soil Group: Solodic soil
Principle Profile Form: Dy3.43
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 0%
Landform element type: Valley-flat
Landform pattern type: Plain
Vegetation: Cleared

Profile Morphology:

Horizon	Depth (m)	Description
A1	0.00 to 0.05	Dark greyish brown (10YR 4/2); silty loam; weak 2–5 mm subangular blocky structure; dry firm strength; sharp change to
A2e	0.05 to 0.12	Greyish brown (10YR 5/2); few 2–10% fine <5 mm distinct brown mottles; silty loam; massive structure; dry firm strength; abrupt change to
B1	0.12 to 0.22	Brown (10YR 5/3); few 2–10% medium 5–15 mm distinct brown mottles; silty light clay; moderate 2–5 mm subangular blocky structure; moderately moist firm strength; abrupt change to
B21	0.22 to 0.47	Greyish brown (2.5Y 5/3); very few <2% fine <5 mm faint orange mottles; medium clay; strong 5–10 mm angular blocky structure; dry firm strength; clear change to
B22	0.47 to 0.94	Brown (10YR 4/3); common 10–20% fine <5 mm faint orange mottles; light medium clay; moderate 20–50 mm prismatic structure; few 2–10% fine <2 mm manganiferous nodules; moderately moist firm strength; diffuse change to
B23	0.94 to 1.31	Light yellowish brown (2.5Y 6/4); few 2–10% fine <5 mm distinct orange mottles; light medium clay; strong 20–50 mm prismatic structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength; abrupt change to
B3	1.31 to 1.56	Light brownish grey (10YR 6/2); few 2–10% medium 5–15 mm distinct orange mottles; sandy light clay; light moderate 20–50 mm prismatic structure; very few <2% fine <2 mm manganiferous nodules; moderately moist firm strength.

				Particle size						Exchangeable (Alcoholic cations)							BAR	Disp.	Total element			
	mS/cm		%	%	%	%	%	%				meq%					%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	CEC	Ca	Mg	Na	K	AL	Ex Acid	15	R1	P	K	S	pH
B0–0.10	5.8	0.05	0.003						12	2.4	2.9	0.29	0.42								4.6
0–0.10	5.8	0.06	0.005	2.18	8	36	38	22	12	1.9	3.7	0.70	0.18			10	0.75	0.013	0.343	<0.005	4.4
0.12–0.22	6.0	0.12	0.013	2.52	6	26	34	35	15	3.3	7.5	1.8	0.14			15	0.84	0.011	0.427	<0.005	4.8
0.50–0.60	7.7	0.55	0.076	2.05	11	25	18	45	17	4.2	11	5.4	0.12			17	0.96	0.008	0.470	<0.005	6.2
0.80–0.90	8.2	0.80	0.113	2.21	13	27	14	46	20	4.1	12	6.7	0.14			19	0.97	0.008	0.403	<0.005	6.5
1.10–1.20	8.5	0.82	0.115	2.30	11	29	14	45	20	4.2	12	6.8	0.20					0.007	0.333	<0.005	6.7
1.40–1.50	9.3	0.59	0.066						13	3.3	8.7	4.7	0.12								7.1

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
0–0.10	2.29	0.15	3	5	0.3	102	35	0.3	1.1	3.7

Soil Type: Mary dark variant (MyDv)
Site No: 9007
A.M.G. Reference: 448117mE 7134815mN ZONE 56
Parent material: Quaternary Holocene alluvium (Qha)
Australian Soil Classification: Melanic, Eutrophic, Black, DERMOSOL
Great Soil Group: Prairie soil
Principle Profile Form: Gn3.42
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Hardsetting

Slope: 2%
Landform element type: Scroll
Landform pattern type: Flood plain
Vegetation: Cleared

Profile Morphology:

Horizon	**Depth (m)**	**Description**
Ap	0.00 to 0.20	Dark brown (7.5YR 3/2); clay loam, fine sandy; strong 2–5 mm subangular blocky structure; very few <2% fine <2 mm manganiferous nodules; dry firm strength; clear change to
B21	0.20 to 0.60	Dark brown (7.5YR 3/2); fine sandy light clay; moderate 2–5 mm subangular blocky structure; very few <2% fine <2 mm manganiferous nodules; dry strong strength; gradual change to
B22	0.60 to 1.25	Dark brown (7.5YR 3/2); light medium clay; strong 2–5 mm subangular blocky structure; very few <2% fine <2 mm manganiferous nodules; dry very firm strength.

						Particle size						Exchangeable (Aqueous cations)				BAR	Disp.		Total element		
	mS/cm		%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	PH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	pH
B0–0.10	6.6	0.06	0.001						15	7.9	6.4	0.08	0.94								6.2
0–0.10	6.6	0.05	0.002	1.74	5	53	21	21	17	8.9	7.2	0.20	0.31			13	0.61	0.058	1.332	<0.005	5.9
0.20–0.30	6.8	0.06	0.003	1.81	5	53	24	22	17	9.5	7.4	0.34	0.16			12	0.66	0.047	1.312	<0.005	5.9
0.50–0.60	6.9	0.04	0.003	2.13	11	45	22	24	18	10	7.5	0.41	0.19			13	0.70	0.046	1.418	<0.005	5.9
0.80–0.90	7.1	0.04	0.002	3.15	1	24	38	38	28	16	11	0.65	0.27			21	0.70	0.071	1.215	<0.005	6.0
1.10–1.20	7.3	0.03	0.0001	3.23	1	19	40	41	29	15	13	0.59	0.31					0.078	1.238	<0.005	5.9
1.40–1.50	7.2	0.03	0.0001						30	15	14	0.53	0.32								5.9

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	1.45	0.14	110	90	0.8	56	41	2.4	2.3	3

Soil Type: Copenhagen (Co)
Site No: 9008
A.M.G. Reference: 449887mE 7131590mN ZONE 56
Parent material: Quaternary Holocene alluvium (Qha1)
Australian Soil Classification: Haplic, Eutrophic, Black, KANDOSOL
Great Soil Group: Prairie soil
Principle Profile Form: Gn2.02
Type of microrelief: No microrelief
Surface coarse fragments: No coarse fragments
Condition of surface soil when dry: Firm

Slope: 7%
Landform element type: Levee
Landform pattern type: Flood plain
Vegetation: Cleared

Profile Morphology:

Horizon	**Depth (m)**	**Description**
Ap	0.00 to 0.30	Brown (10YR 4/3); fine sandy loam; weak 2–5 mm subangular blocky structure; dry weak strength; diffuse change to
A3	0.30 to 0.52	Brown (10YR 4/3); fine sandy loam; weak 2–5 mm subangular blocky structure; dry firm strength;
B2	0.52 to 1.20	Very dark greyish brown (10YR 3/2); fine sandy clay loam; weak 2–5 mm subangular blocky structure; moderately moist firm strength; gradual change to
B3	1.20 to 1.50	Dark greyish brown (10YR 4/2); fine sandy clay loam; massive structure; dry weak strength.

						Particle size					Exchangeable (Aqueous cations)					BAR	Disp.		Total element		
	mS/cm		%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	pH
B0–0.10	6.4	0.20	0.008						11	4.6	3.9	0.21	2.3								5.6
0–0.10	6.2	0.20	0.007	1.18	15	58	12	14	12	5.0	4.1	0.14	2.5			11	0.50	0.064	1.642	0.007	5.5
0.30–0.40	6.3	0.10	0.005						11	6.0	4.5	0.16	0.79								5.6
0.50–0.60	6.7	0.07	0.004	1.63	8	59	15	19	14	7.8	5.3	0.16	0.60			10	0.53	0.043	1.485	<0.005	5.9
0.80–0.90	6.7	0.08	0.005	1.87	2	56	20	23	17	11	6.3	0.21	0.37			12	0.51	0.046	1.380	<0.005	5.9
1.10–1.20	7.3	0.02	<0.0001	1.91	1	61	19	21	17	11	5.9	0.20	0.18					0.048	1.337	<0.005	6.1
1.40–1.50	7.4	0.02	<0.0001						15	8.9	5.4	0.16	0.16								6.1

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	1.47	0.15	160	150	1.9	110	46	1.5	3.1	17

Soil Type: Tirroan (Tr)
Site No: 9009
A.M.G. Reference: 451234mE 7134969mN ZONE 56
Parent material: Suitable sandstone of the Tiaro Coal Measures (Jdt)
Australian Soil Classification: Magnesic, Mottled-mesonatric, Brown, SODOSOL
Great Soil Group: Soloth
Principle Profile Form: Dy2.41
Type of microrelief: No microrelief
Surface coarse fragments: very few <2%, sandstone fragments
Condition of surface soil when dry: Firm

Slope: 6%
Landform element type: Hillslope
Landform pattern type: Rises
Vegetation: Very tall open woodland (20–35m) of *Corymbia citriodora* ssp. *varigata* (lemon-scented spotted gum)

Profile Morphology:

Horizon	**Depth (m)**	**Description**
A1	0.00 to 0.07	Yellowish brown (10YR 5/4); loamy fine sand; single grain structure; dry very weak strength; sharp change to
A2e	0.07 to 0.18	Brown (10YR 5/3); fine sand; single grain structure; dry loose strength; sharp change to
B2	0.18 to 0.55	Brown (10YR 5/3); common 10–20% medium 5–15 mm distinct orange mottles; fine sandy light clay; strong 2–5 mm subangular blocky structure; dry firm strength; clear change to
B3	0.55 to 0.80	Greyish brown (2.5Y 5/3); few 2–10% medium 5–15 mm distinct orange mottles; fine sandy clay loam; many 20–50% angular sandstone small pebbles 2–6 mm; moderate 2–5 mm subangular blocky structure; dry firm strength; sharp to
C	0.80 to 0.81	Very abundant >90% sandstone small pebbles 2–6 mm.

						Particle size				Exchangeable (Aqueous cations)						BAR	Disp.	Total element			
	mS/cm		%	%	%	%	%	%				meq%				%	Ratio	%	%	%	$CaCl_2$
Depth	pH	EC	Cl	ADMC	CS	FS	SI	CLA	ECEC	Ca	Mg	Na	K	Al	Acid	15	R1	P	K	S	PH
B0–0.10	5.6	0.04	0.002						3	1.2	1.8	0.09	0.44								4.6
0–0.10	5.9	0.02	0.0001	0.8	7	78	7	7	4	0.67	3.1	0.07	0.29			4.6	0.63	0.013	0.643	<0.005	4.7
0.10–0.20	5.9	0.02	<0.0001						4	0.33	3.5	0.13	0.16								4.7
0.20–0.30	5.7	0.11	0.010	1.22	4	61	10	25	8	0.09	6.3	1.3	0.20			11	0.87	0.012	0.813	<0.005	4.4
0.30–0.40	5.8	0.15	0.014						10	0.09	7.9	1.9	0.27								4.6
0.40–0.50	6.0	0.13	0.012						9	0.05	6.9	1.6	0.12								4.7
0.50–0.60	6.4	0.14	0.012	1.14	25	54	9	9	11	<0.026	8.3	2.2	0.07			6.9	0.83	0.016	1.214	<0.005	5.2

			Extract P		Repl		DTPA Extractable			
	%	%	mg/kg		meq%		mg/kg			mg/kg
Depth	Org C	Tot N	Acid	Bic	K	Fe	Mn	Cu	Zn	SO4-S
B0–0.10	1.36	0.05	27	11	0.40	82	14	0.2	2.3	2.2

APPENDIX IV

Land Suitability Classes

Class definition

Five land suitability classes have been defined for use in Queensland, with land suitability decreasing progressively from Class 1 to Class 5. Land is classified on the basis of a specified land use, which allows optimum production with minimal degradation to the land resource in the long term.

Class 1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
Class 2	Suitable land with minor limitations which either reduce production or require more than the simple management practices of Class 1 land to maintain economic production.
Class 3	Suitable land with moderate limitations which either further lower production or require more than those management practices of Class 2 land to maintain economic production.
Class 4	Marginal land which is presently considered unsuitable due to severe limitations. The long term or precise effects of these limitations on the proposed land use are unknown. The use of this land is dependent upon either undertaking additional studies to determine its suitability for sustained production or reducing the effects of the limitation(s) to achieve production.
Class 5	Unsuitable land with extreme limitations that preclude its use.

Land is considered less suitable as the severity of limitations for a land use increase, reflecting either (a) reduced potential for production and/or (b) increased inputs to achieve an acceptable level of production and/or (c) increased inputs to prevent land degradation. The first three classes are considered suitable for the specified land use as the benefits from using the land for that land use in the long term should outweigh the inputs required to initiate and maintain production. Decreasing land suitability within a region often reflects the need for increased inputs rather than decreased potential production. Class 4 is considered presently unsuitable and is used for marginal land where it is doubtful that the benefits in the long term will outweigh the inputs required to achieve and maintain production. It is also used for land where reducing the effect of a limitation may allow it to be upgraded to a higher suitability class, but additional studies are needed to determine the feasibility of this.

Class 5 is considered unsuitable land due to limitations that in aggregate are so severe that the benefits from using the land do not justify the inputs required to initiate and maintain production in the long term. It would require a major change in economics, technology or management expertise before the land could be considered suitable for that land use. Some class 5 lands however, such as escarpments, will always remain unsuitable for agriculture.

APPENDIX V

Coastal Burnett–Wide Bay

Land Suitability Classification Scheme for Irrigated Crops

The classification scheme provides a summary of each limitation and describes the effects of each limitation on plant growth, machinery use and land degradation. It also details how the soil/land attributes recorded are assessed and how the limitation classes are determined. The suitability classes used are defined in Appendix IV. The codes listed in this appendix for each limitation represent the soil/land attribute level recorded in the SALI UMA database.

Irrigation method is assumed to be spray (travelling irrigators or other overhead spray method) unless otherwise stated. Furrow irrigation is assessed as a separate land use. *Pinus* are rainfed. Pastures are not listed under the wetness and flooding limitations where species selection enables adaption to a wide range of conditions.

The agricultural land uses assessed include:

Asparagus
Avocado
Beans
Citrus
Cruciferae (cabbage, cauliflowers, etc)
Cucurbits (melons, pumpkins, zucchini)
Furrow irrigation (other than sugarcane)
Grape
Lucerne
Lychee
Improved pasture
Macadamia
Maize
Mango
Navybean
Peanut
Pineapple
Pinus
Potato
Sorghum
Soybean
Stonefruit (peaches, nectarines)
Sugarcane (spray irrigation)
Sugarcane (furrow irrigation)
Sweet corn
Sweet potato
Vegetables (capsicum, tomato)

CLIMATE (cf and cp)

Effect

Frosts may kill plants, suppress growth and reduce yield.

Assessment

The incidence and severity of frosts are used to distinguish affected areas.

Limitation class determination

Crop tolerance and local experience of the incidence and severity of frosts. For example, severe frosts cause severe damage to sugarcane stalk tissue which reduces sugar content unless it is harvested within two weeks, depending on weather conditions.

Attribute/Limitation level	**Suitability subclasses for various crops**				
Frost incidence/severity	**Avocado, Macadamia, Mango**	**Citrus, Vegetables, Cucurbits, Pineapple, Sweet Potato, Beans, Sweet Corn, Lychee**	***Pinus***	**Sugarcane**	**Cruciferae, Asparagus, Potato, Grapes. All other crops ***
Frost free to light frosts (hill tops or near coastal areas) Code: cf 1	2	1	1	1	1
Regular frosts Code: cf 2	5	3	3	2	1
Severe frosts (channel benches, depressions in lower terraces) Code: cf 3	5	4	4	3	1
Rainfall >1000 mm (Code: cp 1)			0**		
<1000 mm (Code: cp 2)			4		

* All other crops refers to crops listed in this appendix. Seasonal adaptation is not considered, eg. summer crops are not grown in winter.
** ‘0’ (zero) = suitable. Insufficient information to separate into Classes 1, 2 or 3.

WATER AVAILABILITY (m)

Effect

Plant yield will be decreased by periods of water stress particularly during critical growth periods.

Assessment

Plant available water capacity (PAWC) is used as a measure of the amount of soil water available to plants over the rooting depth.

PAWC is based on predicted values (Littleboy (1997), Shaw and Yule (1978)). Generally, soil texture, structure and clay mineralogy over the effective rooting depth[1] are important attributes affecting PAWC.

Limitation class determination

PAWC classes relate to the frequency of irrigation for spray or furrow irrigation only:

>100 mm = 15 days
75 to 100 mm = 12 to 15 days
50 to 75 mm = 8 to 12 days
<50 mm = <8 days

Irrigation frequency considers crop rooting depth, seasonal evaporation rates (6 mm/day in summer) and the amount of labour and equipment required. For example, shallow rooted crops require more frequent irrigation compared to deep rooted crops, while winter crops require less frequent irrigation compared to summer crops. More frequent irrigation requires a greater amount of labour and/or more equipment. Negligible limitations apply to microsprinkler or drip irrigation systems where small amounts of water are added frequently.

Attribute/Limitation level		**Suitability subclasses for various crops**				
Soil PAWC (to 1.0 m)		**Microsprinkler/drip irrigation - Avocado, Citrus, Macadamia, Mango, Lychee, Stone fruit, Grapes, Veges, Cruciferae**	**Cucurbits, Asparagus, Potato, Navybean, Beans, Sweet corn, Sweet potato**	**Peanuts, Lucerne, Maize, Sorghum (forage), Soybean, Pastures, Pineapples**	**Sugar cane**	***Pinus* (rainfed)**
>150 mm	Code: 1	1	2	1	1	1
125–150 mm	Code: 2	1	2	1	1	1
100–125 mm	Code: 3	1	2	1	1	1
75–100 mm	Code: 4	1	2	1	2	1
50–75 mm	Code: 5	1	2	2	3	2
<50 mm	Code: 6	1	3	3-4	4	3

[1] Effective rooting depth is taken to the depth of optimal water extraction by roots. For example, tree crops 1–1.5 m, small crops 0.5 m, field crops, sugarcane and grapes 1.0 m; or to the depth of high salt concentration, rock or impermeable layers.

WETNESS (w1, w2 and w3)

Effect
Waterlogged soils will reduce plant growth and delay effective machinery operations.

Assessment
Internal and external drainage are assessed. Indicator attributes of internal drainage include texture, grade and type of structure, colour, mottles, segregations and impermeable layers. Drainage class[1] and soil permeability[2] (McDonald *et al.* 1990) are assessed in relation to plant rooting depth. Slope and topographic position determine external drainage.

Limitation class determination
Consultation, crop tolerance information and the effects of delays in machinery operations.

[1] Drainage class: This accounts for all aspects of internal and external drainage in the existing state.

Drainage class
1 Very poorly drained
2 Poorly drained
3 Imperfectly drained
4 Moderately well drained
5 Well drained
6 Rapidly drained

[2] Permeability
H Highly permeable (Ks >500 mm/day)
M Moderately permeable (Ks 50–500 mm/day)
S Slowly permeable (Ks 5–50 mm/day)
V Very slowly permeable (Ks <5 mm/day)

Attribute/Limitation level	**Suitability subclasses for various crops**									
	(a) Depth req. 0 to 1.5 m (Code: w3)				**(b) Depth req. 0 to 1 m (Code: w1)**			**(c) Depth req. 0 to 0.5 m (Code: w2)**		
Drainage / soil permeability codes	**Avocado**	**Citrus, Macadamia**	**Mango**	**Lychees**	**Lucerne Stone-fruit, Grape**	**Maize, Sorghum (forage), Sweet corn, Soybean**	***Pinus***	**Sugar cane**	**Navybean, Peanuts, Beans**	**Veges, Cruciferae, Cucurbits, Asparagus, Potato, Pineapple, Sweet potato**
6H	1	1	1	1	1	1	1	1	1	1
5H	2	1	1	1	1	1	1	1	1	1
5M	3	2	1	1	2	1	1	1	2	1
4H	3	2	1	1	2	1	1	1	2	1
4M	4	3	2	1	3	2	1	1	3	2
4S	5	4	3	2	4	3	2	2	4	3
4V	5	4	3	2	4	3	2	2	4	3
3H	4	3	2	2	3	2	2	2	3	2
3M	5	4	3	2	4	3	2	2	4	3
3S	5	5	4	3	5	4	3	3	5	4
3V	5	5	4	3	5	4	4	3	5	4
2H	5	5	5	3	5	5	3	3	5	5
2M	5	5	5	3	5	5	3	3	5	5
2S	5	5	5	4	5	5	4	4	5	5
2V	5	5	5	4	5	5	5	4	5	5
1H	5	5	5	5	5	5	5	4	5	5
1M	5	5	5	5	5	5	5	4	5	5
1S	5	5	5	5	5	5	5	5	5	5
1V	5	5	5	5	5	5	5	5	5	5

SOIL DEPTH (pd)

Effect

Shallow soils limit root proliferation and anchorage. Plants may be uprooted during strong winds.

Assessment

Effective soil rooting depth: is defined as the depth to decomposing rock, hard pan or other impermeable layer; or the depth to high salt concentration.

Limitation class determination

Consultation.

Attributes/Limitation level		**Suitability subclasses for various crops**			
Effective soil depth		**Tree crops**	**Sugarcane**	***Pinus***	**All other crops**
> 1 m	Code: 1	1	1	1	1
0.6 to 1 m	Code: 2	2	1	2	1
0.4 to 0.6 m	Code: 3	3	1	4	1
0.3 to 0.4 m	Code: 4	4	2	5	1
< 0.3 m	Code: 5	5	5	5	5

SOIL NUTRIENT SUPPLY (nd, nl, nf, nr)

Effects

Reduced plant growth may be associated with the shortage (deficiency) or oversupply (toxicity) of mineral nutrients.

Assessment

The need for additional fertiliser treatment in excess of standard application rates and practices. Undeveloped soils low in nutrients will require additional fertiliser initially. Minor elements can be added at low cost. Assessment is based on the nutrient levels of the surface 0 to 0.3 m. Soils which are highly permeable to depth greater than the root zone have a high leaching potential. Loss of applied nutrients from the root zone of such soils often occurs. Humose and organic horizons (Isbell 1996) have the potential to absorb nutrients such as phosphorus.

Specific problems assessed are:

- Soils deficient in P and K (nd).
- Low nutrient retention capacity with high leaching rates (nl).
- Sorption of P in humose/organic soils (nf).
- Low pH as an indicator of possible element toxicity and reduced nutrient availability (nr).

Limitation class determination

- Nutrient deficient soils: Additional applications.
- Low nutrient retention: Split dressing and/or very high application rates.
- Nutrient sorption: Additional applications from 50 to 100% in excess of standard P application rates.
- pH: Documented data relating low pH to element toxicity and nutrient availability.

Attribute/Limitation level	Suitability subclasses for various crops	
	Pinus	**Other crops**
Nutrient deficiency (nd) (A combination of P and K levels)		
P>40 ppm and K >0.6 meq Code: P1K1	1	1
P>40 ppm and K 0.2–0.6 meq Code: P1K2	1	1
P>40 ppm and K <0.2 meq Code: P1K3	2	2
P 20–40 ppm and K >0.6 meq Code: P2K1	1	1
P 20–40 ppm and K 0.2–0.6 meq Code: P2K2	1	1
P 20–40 ppm and K <0.2 meq Code: P2K3	2	2
P 10–20 ppm and K >0.6 meq Code: P3K1	1	2
P 10–20 ppm and K 0.2–0.6 meq Code: P3K2	1	2
P 10–20 ppm and K <0.2 meq Code: P3K3	2	2
P <10 ppm and K >0.6 meq Code: P4K1	2	2
P <10 ppm and K 0.2–0.6 meq Code: P4K2	2	2
P <10 ppm and K <0.2 meq Code: P4K3	2	2
Nutrient leaching (nl)		
No restriction: Code 0	1	1
Highly permeable soils with watertable fluctuations deeper than 1.5 m (where W3 limitation between 3H and 6H): Code 1	2	2
Nutrient fixation (nf)		
No restriction: Code 0	1	1
Humic/organic soils. Code:1	2	2
Nutrient reaction (nr)		
Soil pH to 0.3 m:		
pH >6.5 Code: 5	1	1
pH 6.0–6.5 Code: 4	1	1
pH 5.5–6.0 Code: 3	1	1
pH 5.0–5.5 Code: 2	1	2
pH <5.0 Code: 1	1	2

ROCKINESS (r)

Effect

Coarse (rock) fragments[1] and rock in the plough zone can damage and/or interfere with the efficient use of agricultural machinery. Surface rock in particular interferes with harvesting machinery for sugarcane, soybean, root crops and some vegetables.

Assessment

Based on the size, abundance (McDonald *et al.* 1990) and distribution of coarse fragments in the plough layer, as well as machinery and farmer tolerance of size and content of coarse fragments.

Limitation class determination

Consultation, particularly farmer tolerances which are implicitly related to profitability and technological capability.

Attribute		**Limit. level**	**Suitability subclasses for various crops**				
Size	**Abund. %**	**Code**	**Avocado, Macadamias, Citrus, Mango, Lychee, Stone fruit, Grapes, Pastures**	**Sugar cane, Pineapple *Pinus***	**Maize, Sorghum (forage), Sweet corn**	**Soybean, Veges, Cucurbits, Lucerne, Cruciferae, Asparagus, Beans**	**Peanut, Sweet potato, Potato, Navybean**
	None	R0	1	1	1	1	1
6–20 mm (Pebbles)	<2	P1	1	1	1	1	2
	2–10	P2	1	1	1	2	3
	10–20	P3	1	1	2	3	4
	20–50	P4	1	2	3	4	5
	>50	P5	2	3	4	5	5
20–60 mm (Gravel)	<2	G1	1	1	1	2	3
	2–10	G2	1	1	2	3	4
	10–20	G3	1	2	3	4	5
	20–50	G4	2	3	4	5	5
	>50	G5	3	4	5	5	3
60–200 mm (Cobble)	<2	C1	1	1	2	3	4
	2–10	C2	1	2	3	4	5
	10–20	C3	2	3	4	5	5
	20–50	C4	3	4	5	5	5
	>50	C5	4	5	5	5	5
200–600 mm (Stone)	<2	S1	1	2	3	4	5
	2–10	S2	2	3	4	5	5
	10–20	S3	3	4	5	5	5
	20–50	S4	4	5	5	5	5
	>50	S5	5	5	5	5	5
>600 mm (Boulders or rock)	<2	B1/R1	2	3	4	5	5
	2–10	B2/R2	3	4	5	5	5
	10–20	B3/R3	4	5	5	5	5
	20–50	B4/R4	5	5	5	5	5
	>50	B5/R5	5	5	5	5	5

[1] Coarse fragments are particles greater than 2 mm and not continuous with underlying bedrock (McDonald *et a.*, 1990). Rock is defined as being continuous with bedrock.

MICRORELIEF (tm)

Effect

Microrelief causes irregular and reduced crop productivity across a paddock due to uneven water distribution, for example, water ponding in depressions.

Assessment

Levelling of uneven surface is required for efficient irrigation and surface drainage. The vertical interval (VI) of gilgai, channel and other microrelief dictates the amount of levelling required.

Limitation class determination

Local opinion and consultation.

		Suitability subclasses for various crops
Attribute	**Limitation level**	**All crops**
Vertical Interval		
VI <0.1m	Code: 0	1
VI 0.1 to 0.3m	Code: 1	3
VI 0.3 to 0.6 m	Code: 2	4
VI >0.6 m	Code: 3	5

FLOODING (f)

Effect

The effects of flooding include yield reduction or plant death caused by anaerobic conditions and/or high water temperature and/or silt deposition during inundation. Other effects include physical removal or damage to the crop by flowing water, floodplain erosion and/or siltation and damage to infrastructure such as irrigation equipment.

Assessment

Assessing the effects of flooding on an individual UMA is difficult. Flooding frequency is useful to distinguish between suitable and unsuitable land, but only in extreme frequency situations or for intolerant crops. Where flood frequency is significant but not extreme, a '0' (zero) has been used to indicate the occurrence of flooding. Due to insufficient knowledge[1], it is not used to downgrade the final suitability class however.

Limitation class determination

Consultation.

Attribute/Limitation level	**Suitability subclasses for various crops**			
Flooding frequency (A.R.I.)	**Sugarcane, Soybean, Maize, Sorghum (forage), Asparagus, Sweet corn**	**Avocado, Macadamias, Citrus, Pineapple, Mango, Lychee, Stone fruits, Grapes**	**Lucerne, Navybean, Beans, Peanuts, *Pinus***	**Veges, Cucurbits, Potato, Sweet potato, Cruciferae**
No flooding or flooding less than 1 in 10 years. Code: 0, 1	1	1	1	1
Flooding frequency of approximately 1 in 2 to 1 in 10 years — levees and back swamps and some higher channel benches. Code: 2	0	5	0	1
Flooding frequency approaches annual occurrence — lower channel benches. Code: 3	4	5	5	1

[1] Sugarcane is commonly grown on these lands despite regular flooding. The real effects of flooding do not detract from the value of the land.

LANDSCAPE COMPLEXITY (x)

Effect

An area of suitable land may be too small to justify its use as an isolated production area for a particular land use. This occurs where there is soil complexity or topographic dissection.

Assessment

After the limitation classes for all other limitations are determined for each UMA, one or more of the following are assessed:

- Area of contiguous suitable soil less than the minimum production area[1].
- Dissected topography.

When the area of contiguous suitable soil in a UMA is less than a minimum production area, the area of any contiguous suitable soil in adjacent UMAs is also included in the assessment of the minimum production area. Distance to adjoining irrigation and/or other infrastructure is important, for example, if greater than 0.5 km, suitability is downgraded.

Limitation class determination

The minimum production areas for each land use are determined by consultation. The suitability may be modified according to the proximity and extent of non-contiguous suitable land.

Attribute/Limitation level		**Suitability subclasses for various crops**						
Production area (ha)		**Veges, Sweet potato, Sweet corn, Cruciferae, Asparagus, Beans**	**Mango, Avocado, Macadamias, Citrus, Lychee, Stone fruits, Pineapple, Grapes**	**Sugarcane, Lucerne**	**Sorghum (forage), Maize, Peanut, Soybean, Navybean**	**Cucurbits, Potato**	***Pinus***	**Pastures**
>10	Code: 0	1	1	1	1	1	1	1
5–10	Code: 1	1	1	1	4	1	1	1
2.5–5	Code: 2	1	1	3	5	2	4	1
1.5–2.5	Code: 3	1	2	4	5	2-3	5	1
<1.5	Code: 4	4	3	5	5	4	5	1

[1] Minimum production area: The minimum area of land which is practicable to utilise for a particular land use. It may be based on implicit economic criteria, but is not related to an 'economic production unit' or so called 'living area'.

TOPOGRAPHY (ts)

Effect

The safety and/or efficiency of farm vehicle operation is affected by:

- land slopes in relation to roll stability and side slip.
- erosion control layouts on land with significant variability in the degree and direction of slopes (eg. complex slopes). It is particularly important with row crops where final layouts on such lands will involve short rows and sharp curves.

Assessment

- Steepness of slope in relation to safety and efficiency.
- Variation in slope causing short rows in erosion control layouts.
- Variation in slope direction causing excessive row curvature in erosion control layouts.

Limitation class determination

- Local experience and consultation regarding the upper machinery slope limit for various land uses.
- Farmer tolerance of short rows.
- Inability of trailing implements to effectively negotiate curves with less than 30 m radius.

Attribute/Limitation level	Suitability subclasses for various crops		
Slope (%)	Avocado, Citrus, Stone fruits, Mango, Lychee, Macadamias, Grapes, *Pinus*	Sugarcane, Maize, Veges, Sorghum (forage), Soybean, Peanut, Cucurbits, Sweet corn, Sweet potato, Pineapple, Navybean, Lucerne, Cruciferae, Asparagus, Potato, Beans	Pastures
0–15% Code: 0	1	1	1
15–20% Code: 1	2	4	1
20–30% Code: 2	4	5	2
>30% Code: 3	5	5	5
Complex slopes 0–15% Code: C	1	0[1]	1

[1] Complex slopes are not downgraded. A ‘0’ (zero) is used to flag that minimum tillage and modified erosion control structures have to be applied in lieu of conventional erosional control structures.

SOIL PHYSICAL CONDITION (ps, pm, pa)

Effect

- Problems with germination and seedling development during crop establishment are typically associated with adverse physical conditions in the surface soil, such as hardsetting behaviour, coarse aggregates and crusting clays (ps).
- Soils with a narrow moisture range for cultivation can create difficulties in achieving favourable tilth (pm).
- Soil adhesiveness can cause harvest difficulties and affect the quality of subsurface harvest material (pa).

Assessment

- Soils with indicative morphological properties are evaluated in the context of local experience or knowledge of plant characteristics, (eg. seed size, tuberous roots).
- Local experience indicates problems associated with certain soils (eg. narrow moisture range for cultivation).

Limitation class determination

- Plant tolerance limits and requirements in relation to germination and harvesting are matched with soil properties and supported by local experience.
- Local opinion is used to assess the severity of problems associated with narrow moisture range.

Attribute/Limitation level	**Suitability subclasses for various crops**							
Soil physical condition (ps, pm, pa)	**Peanut**	**Navybean, Lucerne**	**Veges, Cruciferae, Cucurbits, Maize, Sorghum (forage), Sweet corn, Pineapple, Asparagus, Beans**	**Potato, Sweet potato**	**Sugar cane**	**Soybean**	**Avocado, Macadamias, Citrus, Stone fruits, Mango, Lychee, Grapes, *Pinus***	**Pastures**
No restrictions Code: 0	1	1	1	1	1	1	1	1
Surface soil condition								
Hardsetting massive soils with sandy loam to clay loam surface textures with dry moderately firm consistency Code: ps 1	2	2	1	2	1	2	1	2
Hardsetting massive soils with fine sandy loam to clay loam fine sandy surface textures with dry very firm consistency Code: ps 2	3	3	2	3	2	3	1	3
Crusting clays Code: ps 3	2	2	2	2	1	3	1	2
Large Aggregate size >20 mm Code: ps 4	4	4	3	2	2	4	1	3
Moisture range								
Moderate moisture range Code: pm 1	2	2	2	2	2	2	1	1
Narrow moisture range Code: pm 2	3	3	3	3	3	3	1	2
Soil adhesiveness								
Slightly adhesive soils Code: pa 1	2	1	1	1	1	1	1	1
Moderately adhesive soils Code: pa 2	3	1	1	2	1	1	1	1
Strongly adhesive soils Code: pa 3	4	1	1	3	1	1	1	1

SECONDARY SALINISATION (ss)

Effect
Deep drainage losses from permeable soils, usually higher in the landscape, may cause secondary salinisation downslope.

Assessment
Soil permeability (McDonald *et al.* 1990) and position in the landscape are used to determine areas of high recharge potential, and the effect that deep drainage may have on watertables downslope. The development of shallow groundwater (and subsequent surface expression in discharge areas) may occur on footslopes/lower slopes where drainage is restricted (eg. heavy textured, slowly permeable soils, lack of incised drainage etc.). Drainage class, permeability (see wetness) and position in the landscape determine the likelihood of salinisation.

Limitation class determination
Drainage class, soil permeability and position in the landscape. Soil hydraulic conductivity, groundwater level and salinity measurements are required for a wide range of soils and landscapes. Any UMA with existing salinity is class 5.

Attribute/Limitation level	**Suitability subclasses for all crops**					
Soil drainage/permeability at 1 m (see Wetness limitation)	**Landscape position**					
	Upper slopes (U)	**Lower slope (L)**		**Drainage depressions (D)+↑**	**Level plains**	
	All crops	***Pinus* (rainfed)**	**Other crops**	**All crops**	***Pinus* (rainfed)**	**Other crops**
6H	0 *	0	0	-	1	1
5H	0	0	0	-	1	1
5M	0	0	0	-	1	1
4H	0	1	2	-	1	1
4M	0	1	2	-	1	1
4S	0	1	3	-	1	2
4V	0	2	3	-	1	2
3H	0	1	2	5	1	1
3M	0	2	3	5	1	2
3S	0	3	4	5	2	3
3V	0	4	5	5	3	3
2H	0	2	3	5	1	2
2M	0	3	4	5	2	3
2S	0	4	5	5	3	4
2V	0	5	5	5	4	4
1H	-	3	4	5	2	3
1M	-	3	4	5	2	3
1S	-	3	4	5	2	3
1V	-	3	4	5	2	3
existing salinisation	5	5	5	5	5	5

* 0 - intake areas
\+ Drainage depression — level to gently inclined, long, narrow, shallow open depression with smoothly concave cross-section, rising to inclined side slopes.

EROSION (e)

Effect

Land degradation and long term productivity decline will occur on unprotected arable land due to excessive soil erosion.

Assessment

Soil loss will depend on soil erodibility and land slope for a particular crop and surface management system. For each soil type there is a maximum slope above which soil loss cannot be reduced to acceptable levels by erosion control measures or surface management practices.

Limitation class determination

Slope limits are determined in consultation with soil conservation extension and research personnel, and extension and research agronomists. The implications of the classes are:

e1	surveyed row direction only required
e2	conventional parallel structures required or some surface management practices[1]
e3	e2 measures and some surface management practices
e4 or e5	non-arable land

[1] Surface management practices: A range of options aimed at minimum soil disturbance, combined with the retention of harvest residue material as a surface cover.

Attribute/Limitation level		Suitability subclasses for various crops					
Slope %		**Avocado, Macadamia, Citrus, Mango, Stone fruit, Lychee, Grapes, Pastures, *Pinus***	**Sugar cane (spray) Lucerne**	**Maize, Sorghum, Veges, Cruciferae, Cucurbits, Asparagus, Sweet corn, Pineapple, Sweet potato**	**Navybean, Peanuts, Potato, Soybean, Beans**	**Furrow irrigated Sugarcane**	**Furrow irrigated other crops**
Very stable soils: Ferrosols							
	Code:						
0	E0	1	1	1	1	1	2
0–2	E1	1	1	1	1	2	3
2–5	E2	1	2	2	3	3	4
5–8	E3	1	2	3	4	4	5
8–12	E4	2	3	4	5	5	5
12–15	E5	2	4	5	5	5	5
15–20	E6	3	5	5	5	5	5
20–30	E7	4	5	5	5	5	5
>30	E8	5	5	5	5	5	5
Stable soils: Vertosols, clayey surfaced Dermosols, coarse surfaced well drained Dermosols, Chromosols, Rudosols and Kandosols							
	Code:						
0	A0	1	1	1	1	1	2
0–2	A1	1	1	2	2	2	3
2–5	A2	1	2	3	3	3	4
5–8	A3	2	3	4	4	5	5
8–12	A4	3	4	5	5	5	5
12–15	A5	3	5	5	5	5	5
15–20	A6	4	5	5	5	5	5
>20	A7	5	5	5	5	5	5
Unstable soils: Sodosols, Hydrosols, Podosols, Kurosols, loamy surfaced Dermosols and Tenosols							
	Code:						
0	B0	1	1	1	1	2	3
0–1	B1	1	1	2	3	2	3
1–3	B2	1	2	3	4	3	4
3–5	B3	2	3	4	5	4	5
5–8	B4	3	4	5	5	5	5
8–12	B5	4	5	5	5	5	5
>12	B6	5	5	5	5	5	5

FURROW INFILTRATION (Deep drainage) (if)

Effect

The amount of water applied and the rate of application with furrow irrigation must match the permeability of the soil to minimise deep drainage and to determine suitable furrow length. Additional management requirements are associated with short furrows, while waterlogging in the upper end of the furrow occurs where lengths are too long. The most suitable furrow lengths for flood irrigation on different soils need to be determined.

Deep drainage in recharge areas or undulating landscapes can contribute significantly to watertables in lower landscape positions. The effect of deep drainage on groundwater levels can be managed on:

- very slowly to moderately permeable soils within areas where groundwater is used for irrigation ; and
- level plains with very slowly to slowly permeable soils where there is minimal contribution to groundwater levels from the surrounding landscape.

Assessment

Subsoil permeability (see Wetness limitation) and landscape position are used to assess this limitation. Indicator attributes for soil permeability include texture, grade and type of structure, sodicity, pH and the presence or absence of a salt bulge.

Limitation class determination

Consultation.

Limitation classes relate directly to soil permeability, landscape position and whether the site is located within a recognised groundwater area. Hydraulic conductivity (permeability) measurements are required.

Attribute/Limitation level	**Suitability subclasses for various landscapes**		
Subsoil permeability to 1m (see Wetness limitation)	**Undulating landscape**	**Level plains**	**Areas within a groundwater area**
	All crops	**All crops**	**All crops**
V - very slowly permeable	0*	0	0
S - slowly permeable	4	0	0
M - moderately permeable	5	4	3
H - highly permeable	5	5	4

* 0 – suitable, but insufficient information to separate into classes 1, 2 or 3

SOIL PROFILE RECHARGE (ir)

Effect

The amount of water applied and rate of application must match the infiltration characteristics of the soil to ensure the soil profile wets up (recharge) with minimal runoff.

Assessment

Soil surface physical conditions (see Soil Physical Condition (p) limitation), surface infiltration characteristics and soil permeability (see Wetness (w) limitation) are assessed. Indicator attributes of surface infiltration and permeability include texture, grade and type of structure, sodicity, pH and the presence of absence of a salt bulge.

Limitation class determination

Consultation.

Surface infiltration and soil permeability are considered in relation to the rate of soil profile recharge (i.e. how slow) and any additional management requirements. Surface infiltration (disc permeameter) and hydraulic conductivity (permeability) measurements are required.

Soil/land attribute/limitation level	Suitability subclasses for all land uses
Surface condition (Codes: see p limitation)	
Slow surface infiltration - hardsetting massive soils with surface textures of fine sandy loam to clay loam fine sandy and very firm consistency when dry. Code: S2	2
Other soils. Codes: S1, S3, S4	1
Soil permeability to 0.5 m (Codes: see w limitation)	
Very slowly permeable Code: V	2
Slowly permeable Code: S	2
Moderately permeable Code: M	1
Highly permeable Code: H	1
Surface condition and soil permeability Combined	
Hardsetting massive soils with surface textures of fine sandy loam to clay loam fine sandy (Code: S2) and slow to very slow subsoil permeability at 0.5 m (Code: V or S)	3